4 SOILS FORMING ON BUILDINGS IN TORUŃ

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Introduction

Human activity in urbanized areas involves permanent changes in various components of the environment. Land preparation for building development usually leads to removal of the natural vegetation and soil cover. Covering the soil surface (soil sealing) contributes to inhibition of the soil-forming processes. A construction site becomes a new land and, as in the natural environment, is affected by external, climatic or biological factors (Woodell 1979; Duchoslav 2002; Lisci et al. 2003) – Fig. 1. Consequently, weathering of bricks, concrete and similar materials takes place. The development of crevices and cracking filled with residual deposits allows the succession of vegetation and initiation of the initial soil-forming process. Obviously, the presence of plants is followed by some adverse effects, including further destruction of the surface of brick and stone walls (biological weathering), e.g. through secretion of organic acids affecting the decomposition of carbonates, and mechanical delamination of materials as a result of the root growth (Jasieńko et al. 2011).

In favourable environmental conditions, particularly in humid climate, such processes may result in relatively fast soil cover development on buildings (unless prevented by man). Invasion of ruderal and woody vegetation may result in the total concealment of a construction.

Properties of soils forming on buildings are also largely determined by the inflow of matter from outside, e.g. as a result of transport by wind and water, birds and other animals living there. In this respect, gutters and recesses of roofs provide specific conditions conducive to accumulation of the allochthonous matter. According to Achkasov et al. (2006), the sedimentation rate of wind-transported material in transportation areas can vary significantly. In Moscow, it ranges from 0.1 to 3 g·m^2 per day. It should be expected that accumulation of deposits on buildings occurs at a reduced rate.

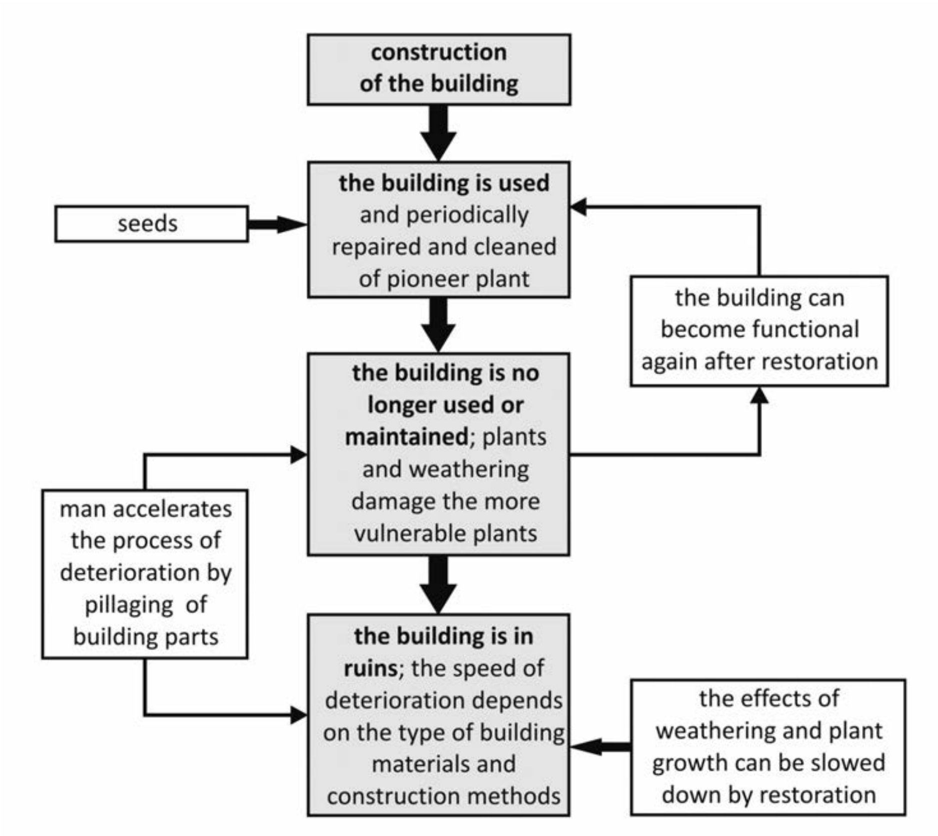


Fig. 1. Block diagram presenting the building's fate in relation to human and environmental intervention (Lisci et al. 2003, modified)

Although soils of urbanized areas become increasingly popular among professionals from different fields, so far the described soils have not attracted much attention of researchers. This study is a continuation of pioneer research undertaken in Poland by Charzyński et al. (2011). The results of the research conducted in Toruń were used in the description of soils forming on buildings. Furthermore, particular attention was paid to issues related to genesis and classification of these soils.

The study area and soil site documentation

This chapter presents the results of the research on soils developed on buildings in the city of Toruń (5 sites) – Fig. 2. Some of the data presented (site 1 and 4) come from the study by Charzyński et al. (2011).

The first three study sites were located in the Old Town (founded in 1233) with an area of 34 ha. Site 1 was located in Podmurna street on a Gothic city wall from the first half of the 13th century. The two other sites were located within a group of buildings from the end of the 19th century (Ciasna street): on a roof (site 2) and in a gutter (site 3).

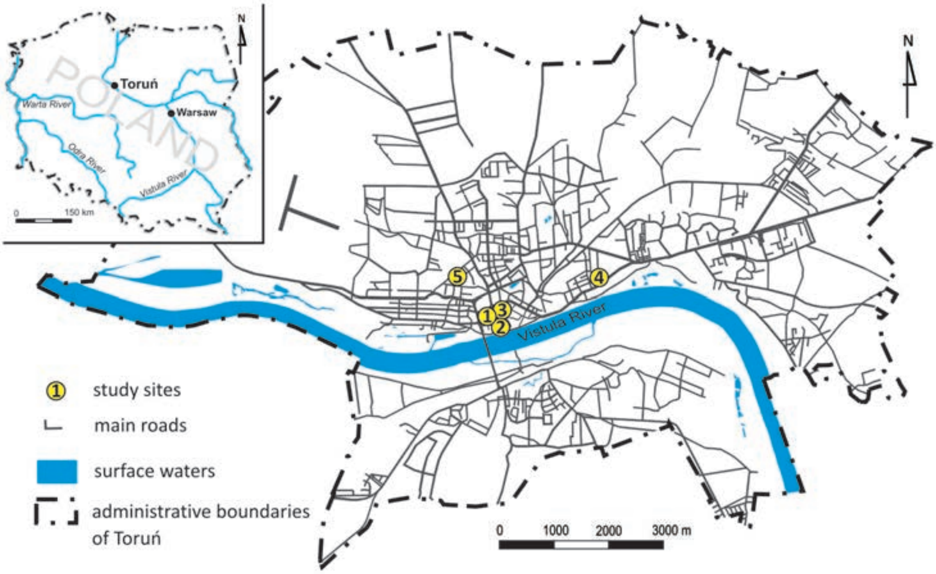


Fig. 2. Location of the study sites

Site 4 was located on a wall surrounding the ruins of a former slaughterhouse (Tormięs, Lubicka street) in the district of Jakubskie Przedmieście. Construction of the slaughterhouse began in 1883–84 and it operated until 1999. Apart from the residential-industrial buildings mostly from the 20th century, several wattle and daub buildings with the so-called timber framing have been preserved in the district since the 19th century.

The last sample (site 5) was collected from a gutter in the complex of garages built in the 1970s in Bema street, within the district of Chełmińskie Przedmieście. This district is mostly covered with multi-family housing development, which includes new, modern buildings, but also old buildings from the communist People's Republic of Poland, the interwar period, and even the 19th century buildings with a timber framing.

The analysis of soil material collected from buildings was performed according to international standards (van Reeuwijk 2006). The content of lead, zinc, copper and cadmium was determined by atomic adsorption spectroscopy after mineralization of samples in the mixture of acids HF and $HClO_3$. Organic samples were previously predigested in H_2O_2 to destroy organic matter. The phosphorus content (P_{ca}) was determined in 1% citric acid solution (van Reeuwijk 2006).

Site 1

Location:
Podmurna St., medieval city wall,
at a height of 3 m,
Toruń, Northern Poland
Coordinates:
53° 00' 42.64'' N
18° 36' 19.47'' E
Vegetation:
Achillea millefolium L.,
Taraxacum officinale F.H. Wigg,
Poaceae sp.
Soil classification (WRB 2007):
Linic Technosol
(Paracalcaric, Paraarenic)

AuCu – 0–3 cm: soil material accumulated in gaps and cracks between bricks, loamy sand, light grey, fresh, clear boundary, high content of carbonates, artefacts (pieces of bricks, mortar; 20%).

Site 2

Location:
Ciasna St., roof of the 19th c outbuilding, at a height of 4.5 m, Toruń, Northern Poland

Coordinates:
53° 00' 32.65''N
18° 36' 29.43'' E

Vegetation:
Galinsoga parviflora Cav.,
Stellaria media (L.) Vill.

Soil classification (WRB 2007):
Linic Technosol

AuCu – 0–5 cm: soil material accumulated on the roof surface covered with roofing felt, sand, artefacts (bird feathers, pieces of mortar; 30%).

Site 3

Location:
Ciasna St., gutter of the 19th c outbuilding, at a height of 4.5 m, Toruń, Northern Poland
Coordinates:
53° 00’ 32.78’’N
18° 36’ 29.87 E
Vegetation:
Galinsoga parviflora Cav.,
Epilobium adnatum Griseb.
Soil classification (WRB 2007):
Protofolic Linic Technosol

Ou – 0–5 cm: organic soil material accumulated in a galvanized steel gutter, very few artefacts (bird feathers, pieces of mortar; 2%).

Site 4

Location:
Lubicka St., top of the wall constructed in the 19th c surrounding the meat processing factory Tormięs, at a height of 3 m, Toruń, Northern Poland

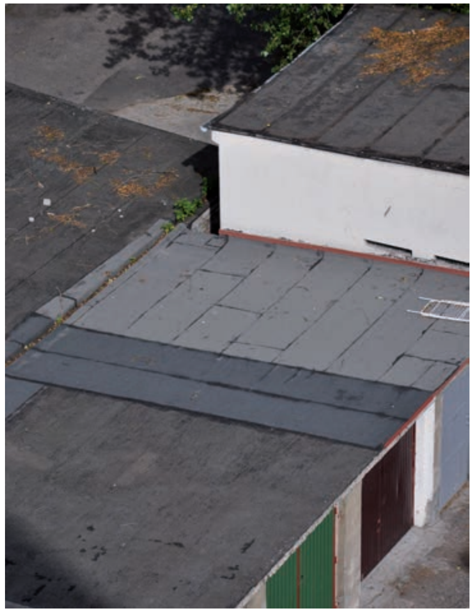
Coordinates:
53° 01' 01.75'' N
18° 38' 11.13'' E

Vegetation:
Taraxacum officinale F.H. Wigg, *Plantago media* L., *Achillea pannonica* Scheele

Soil classification (WRB 2007):
Linic Technosol (Paraarenic)

Au – 0–3 cm: humus horizon, loamy sand, very dark brown, sharp boundary, artefacts (pieces of bricks, mortar; 30%).
Cu – 3–9 cm: parent material, sand, very pale brown, weathered mortar, high content of carbonates.

Site 5



Location:
Bema St., gutter of garages constructed in the 1970s, at a height of 3 m, Toruń, Northern Poland

Coordinates:
53° 01' 12.52'' N
18° 35' 46.86'' E

Vegetation:
Acer negundo L.

Soil classification (WRB 2007):
Protofolic Linic Technosol

Ou – 0–6 cm: organic soil material accumulated in a gutter lined with roofing felt, very few artefacts (pieces of mortar; 3%).

Table 1. Selected soil properties

SITE No.		1	2	3	4		5
BUILDING TYPE		wall	roof	gutter	wall		gutter
HORIZON		AuCu	AuCu	Ou	Au	Cu	Ou
DEPTH [cm]		0–3	0–5	0–3	0–3	3–9	0–6
PARTICLE SIZE DISTRIBUTION [%]							
>2 mm		18	13	–	11	3	–
2 mm–50 μm		86	99	–	87	94	–
50–2 μm		11	1	–	12	2	–
<2 μm		3	0	–	1	4	–
TEXTURE CLASS (USDA)		loamy sand	sand	–	loamy sand	sand	–
SOIL MATRIX COLOUR	dry	10YR 7/1	–	–	7.5YR 2.5/2	10YR 8/3	–
	moist	10YR 6/1	–	–	7.5YR 2.5/1	10YR 8/1	–
OC [%]		3.95	3.87	15.8	6.99	1.00	27.0
N_t [%]		0.292	0.400	0.949	0.347	0.071	1.72
C:N		14	10	17	20	14	16
pH	in H_2O	7.9	7.1	6.9	7.5	8.2	6.4
	in 1M KCl	7.6	7.0	6.6	7.2	7.7	6.0
$CaCO_3$ [%]		5.1	2.1	1.3	1.1	3.7	trace
P_{ca} [mg·kg^{-1}]		245	3920	1050	240	163	1090

Properties of soils forming on buildings

The analysed soils are very shallow, which can be attributed to their specific origin, developed from both mineral (site 1, 2 and 4) and organic sediments (site 3 and 5). The maximum thickness of the soil material was 9 cm. The mineral material was dominated by sands and loamy sands (Table 1), which resulted from the nature of substratum. In most cases, it was masonry mortar containing considerable amounts of sand. The content of fractions finer than sand at sites 1 and 4 (wall) may have resulted from aeolian transportation or alluviation of particles washed down by rainwater from higher parts of the building. A high content of skeleton parts in some soils (i.e. fragments of bricks and slightly weathered mortar) is also worth noting.

The content of organic carbon significantly varied in the studied soils (Table 1). The lowest content of OC was recorded at site 4 (wall, Cu horizon – 1.0%), and the highest content – at site 5 (gutter, Ou horizon) in the soil developed from the organic material (27.0%). The total content of nitrogen (Nt) closely correlated with the OC content and ranged from 0.071 to 1.72%. The C:N ratio in most of the studied soils was narrow and did not exceed the value of 20, which could indicate a regular inflow of fresh organic matter.

The pH values in the studied soils measured in mineral horizons (site 1, 2 and 4) were high and ranged from 7.1 to 8.2 in H_2O and from 7.0 to 7.7 in KCl (Table 1). Neutral and alkaline reaction of the samples was probably caused by the presence of binder – a parent substance of masonry mortar. Soils occurring on roofs (site 3 and 5) were characterised by slightly lower pH values (6.4–6.9 in H_2O and 6.0–6.6 in KCl), which can be attributed to a high content of organic matter.

The content of $CaCO_3$ in the analysed soils varied and ranged from trace amounts in the gutter (site 5) to 5.1% on the wall (site 1). The content of carbonates was affected mainly by a binder contained in the masonry mortar. Whereas accumulation of $CaCO_3$ on the roofs of buildings occurred in places with many cavities facilitating the accumulation of construction debris from damaged facades of buildings, weathering in situ. The soil material present in gutters was characterised by the lowest carbon content. The reason for this was probably much smaller deposition of mortar and the presence of large amounts of organic matter washed off the roof or derived from the decomposition of litterfall (leaves, flowers, small twigs) carried by the wind from trees growing nearby.

The content of phosphorus soluble in 1% citric acid (P_{ca}) ranged from 163 $mg \cdot kg^{-1}$ (site 4) to 3920 $mg \cdot kg^{-1}$ (site 2) – Table 1. Determination of the geochemical background is not possible for the analysed soils because of the allochthonous material of unknown origin. The activity of animals should also be accounted for (Crowther 1997). Bird droppings, which are a significant source of phosphorus, can accumulate in gutters and on the roofs of buildings. This was evidenced by the presence of artefacts of avian origin (feathers) in some soils.

The content of heavy metals in the studied soils should be attributed mainly to the input of construction materials, such as plates or wires and the impact of pollutants from the atmosphere instead of the natural environmental conditions in the study area of Toruń. High pH values resulting in immobilization of some metals is an additional factor responsible for their accumulation (Brümmer, Herms 1983). The lead content in the analysed soils ranged from less than 16 $mg \cdot kg^{-1}$ to 214 $mg \cdot kg^{-1}$ (Table 2). The distance between the study sites and the main traffic routes may be the differentiating factor. Despite the downward trend in recent years, the concentration of this element in the air was relatively high, which is confirmed by the environmental monitoring data (Hildebrandt et al. 2010). And probably therefore, a relatively high content of Pb (131 $mg \cdot kg^{-1}$) was recorded at site 4 located at a busy two-lane street connecting the city centre with the largest Toruń outskirts. The copper content ranged from 11 to 110 $mg \cdot kg^{-1}$. The elevated values may suggest that this pollutant originates mainly from corrosion of copper wiring or roof elements in the vicinity of the research sites. The zinc content in the analysed samples was the highest among all the identified heavy metals and ranged from 72 to 654 $mg \cdot kg^{-1}$. The main source of Zn is the widespread use of zinc carbonate coated steel, i.e. galvanized steel, especially in gutter construction. As in the case of zinc, the highest content of cadmium was found in soils occurring in gutters (sites 4 and 5), i.e. 30 and 41 $mg \cdot kg^{-1}$, respectively.

Table 2. Content of some heavy metals soluble in a mixture of acids HF and $HClO_3$

Site No.		1	2	3	4		5
Building Type		wall	roof	gutter	wall		gutter
Horizon		AuCu	AuCu	Ou	Au	Cu	Ou
Depth [cm]		0–3	0–5	0–5	0–3	3–9	0–6
Pb	**[$mg \cdot kg^{-1}$]**	<16	42	214	131	<16	96
Cu		26	11	30	110	14	41
Zn		211	136	654	402	72	448
Cd		<5	<5	17	<5	<5	18

Summary

Several attempts have been undertaken to define urban soils. According to Blume (1989), urban soil is a sealed natural soil with properties modified as a result of covering the soil surface with anthropogenic material and soil developing on anthropogenic material and occurring in urban agglomerations. Also Hollis described urban soils as any unconsolidated organic or mineral material on the Earth's surface with conditions suitable for the plant growth (Effland, Pouyat 1997). A slightly broader definition was provided by Burghardt (1994; 1996), who defined urban soil as a soil occurring in an urban ecosystem (Urbic Technosol) with elements resulting from human activity, including truncated horizons, deposition of natural and technogenic material, churning, intrusions of liquids and gases into the soil. Soils described in the present chapter fall into the aforementioned definitions. Their formation would have been impossible without a human factor, i.e. architectural objects providing a platform for their development and inflow of allochthonous soil material, both of technogenic (weathering mortar) and natural origin (parts of plants, bird droppings).

So far, other researchers have not been interested in these soils, except for Burghardt (1996) who, however, outlined only one of the possible scenarios for the development of soils on buildings, i.e. the development of aerosols as a result of aeolian accumulation of the material produced by vehicular traffic. The spontaneous development of the studied soils on the technogenic substratum was, however, not accounted for, e.g. mortar with mineral and organic matter brought by wind, rainwater or animals.

Soils develop on buildings in a very specific way – spontaneously, without intentional human activity, but the soil parent material is highly technogenic. Properties of these soils are primarily dependent on the characteristics of construction materials, as well as environmental conditions under which the soil substratum is deposited and transformed by living organisms. Therefore, in a sense, the soils may be defined as semi-natural or semitechnogenic, and their genesis – as natural (Charzyński et al. 2011). Furthermore, the analysed soils can also be considered as a technogenic analogue of natural initial soils.

Soils forming on buildings are usually ephemeral, which is associated with specific character of objects on which they developed. Some buildings, i.e. ruins of no historical value, might be demolished within a short time as they are a blot on city centres. Gutters with soils may break off under the load of deposited material or they may be cleaned. Buildings of historical importance (site 1), still used by man, are periodically cleaned of all the soil and vegetation. The presence of geomembrane in the floor, instead of the roof (Ekranosols), is an important distinguishing feature of the analysed soils. In this case, a shielding layer does not reduce the impact of the external environment on the soil development, but blocks the contact with natural or technogenic soils occurring on the Earth's surface.

The main factor determining the physical and chemical characteristics of the analysed soils is their location *sensu stricto*, i.e. roof, gutter, wall, etc.

Based on the performed analysis of soils developing on buildings, we propose a new taxonomic unit called **Edifisols** (Latin *aedificium* = building), which should be introduced to urban soil taxonomy.

It is also recommended to provide a possibility of precise classification of the described soils in the international classification of WRB, because they develop worldwide in places where man creates housing estates and carries out business activity. In the currently valid edition of WRB (IUSS Working Group WRB 2007), Edifisols may be classified as Linic Technosols, although this unit was created rather for soils intentionally placed on the top of buildings, the so-called "green roofs".

The above classification does not specify the nature of soils, i.e. their spontaneous development without intentional human activity, so the next edition of WRB should include the additional qualifier Edific.

The definition of this qualifier should account for the lack of contact with substratum (the presence of geomembrane), due to location on the buildings, and spontaneous development as a result of weathering of technogenic material *in situ*, and also the supply of mineral and organic matter carried by wind, rainwater or animals.

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