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Classification of technogenic soils according to WRB system in the light of Polish experiences

Abstract: Technosols are relatively young soil group in WRB soil system, and there is still a lot of to do to better understand processes taking place in these soils and to classify them in a proper way. The objectives of this paper were to (1) evaluate Technosol and 'technogenic' qualifiers for other Reference Soil Groups, and (2) propose new solutions which would improve the classification of technogenic soils in WRB. New qualifiers – Edific, Nekric, Misceric, Artefactic, Radioactivic and new specifier – Technic – are proposed to be added to keys to Technosols. Moreover, Salic and Sodic qualifiers should be also available for Technosols. Furthermore, the supplementation of definitions of *thionic* horizon and *sulphidic* material with reference to Technosols is also suggested.

Key words: soil classification, Word Reference Base for Soil Resources, Technosols, technogenic soils

INTRODUCTION

In spite of the fact that over a hundred years have passed since the beginning of modern soil science, neither in the world nor in Poland the issue of scientific soil classification has been dealt satisfactorily (Prusinkiewicz 1985; Dudal 1990). The reasons for such a situation are numerous. The most important ones included highly diversified soil genesis, as well as their physical, chemical and mineralogical variability. A specific feature of soil classification is the fact that soil forms a continuum the properties of which change constantly. This does not make delimitation of soil individuals easy (Prusinkiewicz 1985; Deckers et al. 2002). Moreover, the definition of every taxon (type or soil group) is mostly an intellectual act and it results from the scientist's thinking the issue over. Delimitation of soil units is, in most cases, a difficult matter, which cannot be decided upon fully satisfactorily. The reason for this situation is the fact that taxonomy of soil types is complicated by the existence of numerous transition stages, as well as deviations from standards (Strzemski 1971, 1975). Due to that the borders between individual systematic units have to be settled arbitrarily (Dudal 2003). All those remarks refers to natural soils but apply perfectly to technogenic soils as well. Furthermore scientific interest in those soils started practically in 1970s, although some pioneer researches dates back several decades earlier (in Poland e.g. Skawina 1958). In 1990s the knowledge on urban soils shifts away from studies restricted to soil pollution (Lehmann and Stahr 2007). The first national soil classification that included unit for technogenic soils was the one for England and Wales (Avery 1980). At the highest level, the major group of man-made soils was defined. In next decades many other national soil classification systems was supplemented with such, e.g. The Czech Taxonomic Soil Classification System (Němeček et al. 2001), German Soil Classification System (Blume and Runge 1978; Mitt. DBG 1998; AG Boden 2005); Russian Soil Classification System (Shishov et al. 2001). Although number of important proposals exist, they were not entirely introduced into official soil taxonomies (e.g. Czerwiński and Pracz 1990; Burghardt 1996; Hiller and Meuser 1998; Sobocká 2004, 2011; Greinert 2003; Greinert et al. 2013a, 2013b; Charzyński et al. 2011a, 2011b). As a culmination of this process could be considered the introduction of the Technosols to the international soil classification system WRB in 2006 (IUSS Working Group WRB 2007).

Classification is a basic requirement of all science and needs to be revised periodically as knowledge

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increases (Isbell 1996). In case of technogenic soils it is particularly important since the history of their classification is much shorter than natural ones.

While the second edition of the WRB was prepared in 2006, number of papers with proposals was published, which aimed to evaluate usefulness of the system for classification of Polish soils (Charzyński et al. 2005; Charzyński 2006). Together with suggestions of changes in criteria of designation of soil horizons, materials and properties also new qualifiers were proposed:

- Deluvic to indicate that soil was developed in the position of lower part of the slopes as an effect of developing thick A horizon caused by rain water denudation in hilly regions; such need was documented not only in Poland but also in Lithuania by Bauziene (2002);
- Murshic to indicate Histosols which are permanently drained;
- Sideric to indicate Arenosols which have cambic-like horizon developed in consequence of *'in situ'* weathering.

Suggestions supplemented with examples of profiles, were also sent to the Secretary of the IUSS Working Group WRB. Those ideas can be found in second edition of WRB (IUSS Working Group WRB 2007). However, proposed names of qualifiers Deluvic, Murshic and Sideric were not used, and the terminology coming from the English (Colluvic, Brunic and Drainic respectively) was introduced instead. Unfortunately, the Polish contribution to the development of second edition of the WRB was not so apparent (noticeable) in the nomenclature.

After publishing the second version of WRB, the system has been further evaluated by Polish researches and between 2006 and 2013 numerous proposals of modification was given. Most of them concerned various technogenic soils from e.g. traffic, urban and mining areas (Charzyński et al. 2013; Charzyński and Hulisz 2013; Jankowski and Sewerniak 2013; Uzarowicz and Skiba 2011; Greinert and Drab 2013) and some of these ideas was also thoroughly discussed during field sessions of SUITMA 7 conference in Toruń (September 2013).

Technogenic soils are extremely heterogeneous. The list of qualifiers for Technosols is one of the longest one of all RSGs defined in 2006 edition of WRB (IUSS Working Group WRB 2007). In author's opinion it is still insufficient and do not allow for precise classification of pedons, which underwent transformations related to construction, industry, transportation, mining and military human activities. Therefore, the aim of this paper is to evaluate WRB Technosols and 'technogenic' qualifiers for other Reference Soil Groups (RSGs) considering the possibilities of classification of different technogenic soils and suggest the modifications of the *World Reference Base for Soil Resources* (IUSS Working Group WRB 2006).

PROPOSALS TO IMPROVE THE CLASSIFICATION OF TECHNOGENIC SOILS IN WRB 2014

The following are proposals for changes in Technosol RSG and "technogenic" qualifiers that have been discussed in Polish literature in recent years. There are both the definitions of the new (proposed) qualifiers and some modifications to existing criteria.

Edific qualifier

Such qualifier should be designed for very specific type of urban soils developed on the different elements of buildings (e.g. walls, roofs, rain gutters) or building ruins. Their properties are primarily dependent on the characteristics of construction materials, as well as local environment conditions under which the soil substratum is deposited and transformed by living organisms. Therefore, those soils can be defined as seminatural or semitechnogenic (Charzyński et al. 2011a; Charzyński and Hulisz 2013). The authors propose the following definition of that qualifier.

Edific (ef) – from Latin *aedificium*, building
Developing spontaneously, without intentional human activity from technic hard rock on the buildings as a result of weathering of technogenic materials *in situ*, and with supply of mineral particles and organic matter carried by wind, rainwater or animals (in *Technosols* only).

Nekric qualifier

Land use as cemeteries leads to development of specific soils, which could be named Nekrosols. Soils of graveyards are occurring throughout the world. They develop due to deep mechanical transformation leading to disturbances in natural horizons sequence and to the formation of alternating technogenic and of anthropogenic layers artificially enriched with organic matter, with the addition of material from the overlying layers and horizons and with the presence of artefacts originating from older tombstones, coffin remains, funeral clothing etc.

Lack of possibility of emphasis of specific properties of cemetery soils, was noted by Charzyński et al. (2011b) and Majgier and Rahmonov (2012, 2013). The definition of Nekric qualifier is proposed below. That qualifier should be allowed in most of RSGs.

Nekric (ne) – from Greek *nekrós*, dead

Having layer between 100 and 200 cm from surface artificially enriched with organic matter with presence of large quantities of artefacts i.e. bones, textiles, wood, metals and raised amount of phosphorus in comparison with background values as a result of carcasses decomposition.

Misceric qualifier

Many human activities connected with the construction of buildings is associated with a significant transformation of the soil in the form of the mixing and destruction of soil horizons sequence. Such disturbances occur, very often without transporting material outside the immediate vicinity, so Transportic qualifier doesn't apply. These changes, however, are significant enough, that in the WRB system should be created possibility of marking them in the name of soil unit. The definition of this qualifier should be as follows:

Misceric (ds) – from Latin *miscere*, to mix

Having a layer 30 cm or more thick containing material disturbed and/or mixed by activity connected with construction, showing visible features of primary, natural horizons within 100 cm from soil surface.

Similar qualifier was proposed also by Jankowski and Sewerniak (2013) under a name Disturbic.

Artefactic qualifier

Such qualifier should replace qualifier Technic, because this name is not indicating type of technogenic influence on soil. Also Technic does not appear on the list of qualifiers for Technosols. However, it should be noted that there are Technosols that do not meet the criteria for the artefacts, but because of the presence of other features (technic hard rock or geomembrane) may be classified to that RSG. On the other hand, it is true that Technic Technosol would sound strange. Furthermore, criteria of this qualifier seems too strict in author's opinion, not allowing to highlight in the name substantial amounts of artefacts, but not reaching totally 10% in upper 100 cm of soil. Authors suggest the following definition of that qualifiers:

Artefactic (at)

Having a layer, ≥30 cm thick within ≤100 cm of the soil surface, with ≥10 percent (by volume, by weighted average) *artefacts*.

Moreover, there is a problem in the case of aqueous solutions (e.g. brines), it seems unclear whether the contents of liquid artefacts should be calculated for the solution or the soil volume.

Radioactivic qualifier

Radioactive elements (e.g. U and Th) are rare components of soils. The worldwide mean of the U content of soils ranged from 0.8 to 11 $mg \cdot kg^{-1}$, and for Th, it ranged from 3.4 to 10.5 $mg \cdot kg^{-1}$ (Kabata-Pendias and Pendias 2001). However, there are soils in which contents of both elements are higher. Such soils can be found, for example, (1) on mine spoils of uranium mines, (2) on dumps built of wastes originated in lignite and bituminous coal mines, and (3) on landfills where combustion wastes (e.g. fly ash and slag) from lignite and bituminous coal power plants are deposited (Table). Soil containing high amounts of such elements like, for example, U and Th, can be radioactive. Taking this into consideration, it seems to be justified to incorporate a suitable qualifier (suffix) into WRB soil system. The name of such qualifier should be Radioactivic. The definition of this qualifier should be as follows:

Radioactivic (rv)

Exhibiting high radioactivity exceeding the geochemical background for given area.

Further investigations in this matter should focus on determination of limits of radioactivity which, if exceeded, should allow to use Radioactivic qualifier.

TABLE. Contents of uranium and thorium in selected technogenic soils from Poland (ranges in $mg \cdot kg^{-1}$)

Description and location of soils	U	Th
Soils developed from mine wastes originated in the abandoned pyrite and uranium mine in Rudki (Holy Cross Mts.) *	3.2–23.2	0.8–15.9
Soils developed from mine wastes originated in the abandoned "Siersza" hard coal mine in Trzebinia (Silesian Upland) *	1.5–5.4	6.3–14.2
Soils developed from lignite combustion wastes originated in Pątnów and Konin power plants (Great Poland Lowland) **	0.4–6.9	0.3–15.8
Soils developed from bituminous coal combustion wastes originated in Łaziska power plant (Silesian Upland) **	3.3–10.2	9.3–25.7

Explanations: * according to Uzarowicz (2011), ** according to Uzarowicz (not published).

Radioactivic qualifier should be, first of all, assigned to the key to the Technosols, as the data concerning radioactivity and contents of radioactive elements in other soil groups are still limited (e.g. Elless and Lee 2002; Taylor 2007; Jabbar et al. 2010). However, as the database in this matter increases in the future, the Radioactivic qualifier can be also added to the keys to other soils groups in the next editions of WRB.

Radioactivic qualifier would be unique and required. One might say that Toxic qualifier should be used in case of soils containing radioactive elements. Indeed, it should be. However, it has to be stressed that the hazard connected with the occurrence of radioactive elements in soils is double. First of all, they can be toxic (like other trace elements, e.g. Cd, Pb or As) when taken by plants or ingested by animal or human (Rosik-Dulewska and Dulewski 1989). Secondly, unlike most of harmful trace elements, radioactive elements are also dangerous due to radiation released during their spontaneous decay. Therefore, Radioactivic qualifier will inform about the occurrence of contaminants (e.g. U and Th) harmful both from the toxicological and radiological point of view.

Salic and Sodic qualifiers (for Technosols)

The properties of the technogenic soils affected by salinization and sodification are often similar to the naturally salt-affected soils. However, sometimes they may have a significantly higher salt and exchangeable sodium content (Hulisz 2007; Hulisz and Piernik 2013). The main sources of salinity in the technogenic landscapes are industrial wastes, brines, mine waters and salts using in the chemical technology of ice removal from streets. Hulisz et al. (2010) have pointed out that the list of qualifiers for Technosols does not include formative elements, allowing to express the soil salinity and sodicity features. Therefore it should be considered to add already defined and commonly used qualifiers, i.e. Salic and Sodic for that RSG in the next WRB edition.

The supplementation of definitions of *thionic* horizon and *sulphidic* material with reference to Technosols

Certain suggestions concerning supplementation the *thionic* (WRB) and *sulfuric* (Soil Taxonomy, Soil Survey Staff 1999) horizon definitions, as well as the definition of *sulphidic* (sulfidic) materials were presented by Uzarowicz and Skiba (2011). It was suggested to add the Thionic suffix qualifier to the key to the Technosols within the WRB classification, as technogenic soils in which horizons fulfilling the definition of *thionic* horizon were documented (Uzarowicz and Skiba 2011). Such soils occur, for example, on mine dumps in the vicinity of sulphide ore mines, as well as lignite and bituminous coal mines (e.g. Krzaklewski et al. 1997; Hüttl 1998; Neumann 1999; Greinert et al. 2009; Horbaczewski 2010; Uzarowicz and Skiba 2013), where sulphides are common minerals.

Sulphidic material is currently defined as waterlogged deposit containing sulphides, most commonly occurring in coastal regions (IUSS Working Group WRB 2007). However, parent technogenic materials (e.g. mine spoils, sludge) containing high amounts of sulphides – mainly pyrite and marcasite, immediately after deposition on land surface can be considered as sulphidic material as well. In author's opinion, any unweathered ("fresh") deposit containing sulphides and occurring on land surface can be considered as *sulphidic* material, which can evolve into a soil with *thionic* horizon. Therefore, it is suggested that the definition of *sulphidic* material should be rearranged into the following: *sulphidic* material is a waterlogged deposit or other material, both natural and anthropogenic origin, which contains sulphides and other oxidizable sulphur compounds as primary constituents.

Technic specifier

In author's opinion there should be also considered to add the specifier which would enable to emphasize technogenic origin of certain soil properties. Some features can be an effect of both natural and man influenced processes (Hulisz et al. 2010). Only the introduction of Technic specifier will allow to distinguish the origin of these features, e.g. in the case of Solonchaks or Salic, Sodic, Thionic and Calcaric qualifiers.

SUMMARY

Preparations to publish the next edition of the *World Reference Base for Soil Resources* are in its final stage. The above suggestions for amendments in this system hopefully should be introduced. As a result, system will become more precise in describing the variety of extremely heterogeneous group of soils of urban, industrial, traffic, mining and military areas. It seems that intense studies of various Technosols, which have been carrying out currently all over the world, will constitute a background for better understanding and classification of these soils.

Authors also hope that next edition of the *Polish Soils Classification* (Commission V on Genesis, Classification and Cartography of Soils PSSS 2011) will have broader group of technogenic soils enabling better classification of those soils.

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Klasyfikacja gleb technogenicznych według WRB w świetle polskich doświadczeń

Streszczenie: Technolose są młodą jednostką glebową w klasyfikacji WRB. Konieczne są dalsze badania naukowe, ukierunkowane na zrozumienie procesów zachodzących w tych glebach oraz na prawidłową ich klasyfikację. Celem artykułu jest (1) ocena kwalifikatorów używanych w stosunku do technosoli oraz związanych z technogeniczną naturą gleb, jak również (2) zaproponowanie nowych rozwiązań, które ulepszyłyby WRB w kontekście klasyfikacji gleb Technosols. Proponuje się wprowadzenie nowych kwalifikatorów (Edific, Nekric, Misceric, Artefactic, Radioactivic) oraz przedrostka uściślającego Technic do klucza dla grupy Technosols. Proponuje się również dodanie do tego klucza kwalifikatorów Salic i Sodic. Ponadto potrzebne jest uzupełnienie definicji poziomu thionic i materiału sulphidic oraz dopuszczenie stosowania kwalifikatora thionic w Technosolach.

Słowa kluczowe: klasyfikacja gleb, World Reference Base for Soil Resources, Technosols, gleby technogeniczne