Bulgarian Journal of Agricultural Science, 28 (No 6) 2022, 985–988

Technosols and organic carbon in the World Reference Base for Soil Resources – WRB

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Abstract

Ivanov, P. & Banov, M. (2022). Technosols and organic carbon in the World Reference Base for Soil Resources – WRB. Bulg. J. Agric. Sci., 28 (6), 985–988

The paper reviews the development of Technosols classification in the World Reference Base for Soil Resources (WRB) in terms of organic carbon content. Typical Technosols from industrial activities with high carbon content and its sources are analysed. Some of the possible qualifiers needed to indicate the organic carbon are briefly reviewed. All editions of the WRB from the introduction of Technosols (IUSS Working Group WRB, 2006) to the fourth edition of the classification (IUSS Working Group WRB, 2022) are included in the study. Newly introduced qualifiers ensuring the differentiation of organic carbon in relation to its origin have been indicated. Recent updates of the discussed qualifiers and their possible applications are highlighted.

Keywords: Technosols; organic carbon; WRB

Introduction

A widely applied principle in soil classification is connected with development of soil studies related to morphology, composition, physical, chemical and physicochemical properties and characteristics of soils, which expand the possibilities for development of detailed soil classifications, refinement of taxonomic units and inclusion of new soil types (Penkov et al., 1992). Similar soil classification is the World Reference Base for Soil Resources (WRB), which, besides introduction of new reference soil groups (RSGs) (IUSS Working Group WRB, 2006), enriches the list of diagnostic horizons and improves various definitions (IUSS Working Group WRB, 2014). Clear example of this development are the Technosols, which, after introduction in WRB (IUSS Working Group WRB, 2006), expand the possibilities for their detailed classification (IUSS Working Group WRB, 2014, 2015, 2022).

One of the diagnostic indicators of different soil horizons, properties and materials in WRB is the content of organic carbon. In addition to natural soils, this soil characteristic is also part of Technosols that are built with various materials, included in the soil profile (IUSS Working Group WRB, 2006, 2007, 2014, 2015, 2022). Therefore, it is important the classification of Technosols to be able to indicate not only the presence of organic carbon in them, but also its source from the point of view of the origin of materials that built their soil profile.

The paper aims to present short review for development of Technosols classification in relation to their organic carbon content.

Materials and Methods

Achieving the aim necessitated the analysis of the classification indicators in WRB related to organic carbon content in Technosols after their introduction as an RSG (IUSS Working Group WRB, 2006). Establishment of the various changes and additions was carried out by studying of the definitions of relevant diagnostic materials and qualifiers.

The clarification of organic carbon sources in Technosols is realized by further analyzing of the qualifiers related to the materials considered as artefacts in WRB (IUSS Working Group WRB, 2006, 2007, 2014, 2015, 2022) and the results of various soil science studies.

Results and Discussions

Behind Technosols introduction

Organic carbon is part of the diagnostic characteristics of various horizons, properties and materials in WRB. Regarding Technosols, it finds a place in the definitions of several prefix qualifiers (*Folic* (as diagnostic criterion of organic material), *Histic*, *Mollic* and *Umbric* horizons, *Vitric* properties and *Fluvic* materials), as well as *Humic* qualifier, which is considered as suffix. Thus, organic carbon is presented in the specified prefixes as part of various organic materials, organic matter, etc., described in the diagnostic criteria of the respective soil units (qualifiers) (IUSS Working Group WRB, 2006). On the other hand the definition of *Humic* qualifier, which is retained in the update of the second edition of WRB, is aimed solely at different organic carbon content in the fine earth fraction of the individual RSG's. This places Technosols among the soils, which can contain ≥1% organic carbon at depth of 50 cm from the mineral soil (according to the definition of the Humic qualifier) (IUSS Working Group WRB, 2007).

Large group of Technosols is represented by mine spoils (IUSS Working Group WRB, 2006), which are built in the process of coal mining for energetics. Their common feature is the presence of coal impurities, which directly affect the carbon content in spread geological materials (Hristov & Pencheva, 1995; Tsolova et al., 2011). Another part of Technosols includes soils containing slag and coal ash with character of technical waste products (IUSS Working Group WRB, 2006, 2007). These products are collected in landfills known as slag heaps or coal ash ponds built up as a result of the combustion of coal in thermal power plants (TPP) (Gyurov & Artinova, 2015) and are characterized by high carbon content (Garbuchev et al., 1975; Dimitrov et al., 2010; Hristov et al., 2015).

Geological materials from coal mining, as well as industrial waste in coal ash ponds, fully meet the criteria of *artefacts* in WRB (IUSS Working Group WRB, 2006). This shows that organic carbon, as classification indicator, may be related to soil formation processes, but it may also be result of industrial activity. On the other hand, while the organic carbon content can be explained with prefixes by the presence of certain materials and occurrence of pedogenetic processes, *Humic* qualifier still does not allow clearer interpretation of the origin of organic carbon in Technosols in the update of the second edition of WRB (IUSS Working Group WRB, 2007). All of this necessitated the development of several additions in the third WRB edition, which will be discussed below.

Further development

We will first consider soil organic carbon, which was newly introduced as diagnostic material in WRB, precisely to distinguish organic carbon meeting the artefacts requirements from that accumulated in soils as a result of pedogenesis (IUSS Working Group WRB, 2014). This new diagnostic material is included in definitions of multiple soil horizons, properties and materials in order to be applicable in soil classification. The requirements for usage of Humic qualifier have been clarified by clear specifying the presence of soil organic carbon. Likewise, some of supplementary Technosols qualifiers in WRB include in their definitions the newly introduced soil organic carbon. Another one (Pretic horizon), also introduced in WRB 2014, refers to addition of charcoal in the soils, and is characteristic of several RSG's, including Technosols (IUSS Working Group WRB, 2014).

The presence of soil organic carbon in Technosols may be inherited when a mine spoil has been reclaimed by spreading natural humus layer on the surface, whereas in non humus reclamation, the weak accumulation of organic carbon is result of vegetation influence and initial soil formation processes leading to formation of low-thick humus-mineral horizon with low organic matter accumulation (Hristova, 2013). Under these conditions, the origin of organic carbon in Technosols reminds for established criteria defining newly introduced soil organic carbon *(*as diagnostic material in WRB) (IUSS Working Group WRB, 2014) and enables the use of Humic qualifier, but only if its quantitative and morphological requirements are met (IUSS Working Group WRB, 2015). This requirement is important because organic carbon contained in coal impurities and coal dust is not result of the processes of natural decomposition of plant residues (Kachova, 2021). Therefore, Petrova et al. (2003) apply procedure that makes possible determination of not only the total amount of organic carbon, but also the coal carbon and humic carbon in soils containing coal impurities.

Thus, the question of how to highlight the high content of organic carbon in Technosols as a result of various industrial activities arises, which is answered by another newly introduced in WRB 2014 Carbonic qualifier. According to the definition, typical for Technosols only, Carbonic refers to the presence of 20% or more organic carbon qualifying as artefacts in ≥10 cm layer within 100 cm of the soil surface. Artefacts, as diagnostic materials, retain their basic definitions, which have been improved (IUSS Working Group WRB, 2014, 2015). Thus, the classification of a soil in WRB as Spolic Technosol (Carbonic) indicates both its morphological composition (from mine spoil or coal ash pond – Spolic) and the origin of organic carbon in it (Carbonic). Here the second question arises, about the differentiation of mine spoils, in which organic carbon may result from presence of coal impurities in geological materials (Hristov & Pencheva, 1995; Tsolova et al., 2011), from ash ponds, where the carbon is contained not in deposited geological substrates, but in waste materials (slag, coal ash) (Dimitrov et al., 2010; Hristov et al., 2015). In this case, the WRB is probably answered by the newly introduced Immissic qualifier (for Technosols only), which describes ≥ 10 cm surface layer with 20% recently deposited dust, soot, or ash that meets the criteria of artefact (IUSS Working Group WRB, 2014). Later, IUSS Working Group WRB (2015) supplemented the definition of this qualifier by explaining the possible subqualifiers that could be used.

Thus formulated, updated and newly introduced diagnostic horizons, materials and qualifiers in WRB differentiate organic carbon in Technosols depending on industrial activity or natural pedogenetic factors (IUSS Working Group WRB, 2014, 2015). However, the definitions of qualifiers continue to be refined to provide more possibilities for their use in soil classification.

Current state

Recently, the soil science community had the opportunity to get acquainted with the fourth edition of WRB, in which new morphological definitions and qualifiers were introduced, various corrections and additions were made (IUSS Working Group WRB, 2022). Below we will review the changes in diagnostic horizons, materials and qualifiers that are relevant to those discussed so far in this paper:

– Spolic qualifier does not change the criteria for its usage in classification, but already provides an additional definition with higher minimum required thickness of technogenic layer (≥ 50 cm) and the amount of artefacts of industrial products.

– Carbonic qualifier, which is no longer specific for Technosols only, is updated by reducing the required minimum amount of organic carbon (related to artefacts) from 20% to 5%.

– Immissic qualifier has not been changed and is still specific for Technosols only.

– Artefacts retain the diagnostic criteria and their supplemented examples including black carbon are attached in the Field Guide, which is new Annex in WRB.

– Soil organic carbon also does not change its diagnostic criteria.

– Humic, as supplementary qualifier, retains its partial revision from the updated second edition of the WRB (IUSS Working Group WRB, 2015), related to the content of soil organic carbon ≥ 1% in the respective RSG’s.

– Pretic horizon is characterized by an update in its general description regarding charcoal as a result of human activity, where the newly introduced black carbon is indicated. In this regard, in part of the diagnostic criteria, the so far necessary artefacts and charcoal have been changed to black carbon with an explanation of its necessary amount and ratio compared to total carbon content. Another change is related to lower minimum required percentage of organic carbon, which must now meet the definition of soil organic carbon, without artefacts. Here, IUSS Working Group WRB (2022) clarifies that black carbon is assumed to be artefact if it is purposefully manufactured by humans, and if it is not, it is treated as natural.

Changes of Carbonic qualifier requirements for organic carbon content (IUSS Working Group WRB, 2022) expand the possibilities for its usage in Technosols classification. An example of this is laboratory research of substrates from yellow and green Pliocene clays for reclamation of lands from Maritsa-iztok Mines, Bulgaria, which reported that content of carbon in coal ash from TPP, used as an additive to substrates, represents 5.7% (Garbuchev et al., 1975). Another study of waste materials from TPP indicates close values of organic carbon in coal ash (4%), which is unavailable for plants (Dimitrov et al., 2010). Similarly, in two soil profiles of reclaimed mine spoils with coal impurities in the region of Pernik, Bulgaria, Kachova, (2021) found more than 5% organic carbon in soil layers at depth exceeding the minimum required for the criteria of Carbonic qualifier (IUSS Working Group WRB, 2022).

Conclusions

The discussed development of Technosols classification in WRB in relation to content of organic carbon makes it possible to formulate the following conclusions:

The additional definition of Spolic qualifier allows its more precise usage in Technosols classification. Updated Humic and introduced in 2014 Carbonic qualifiers clarify the origin of organic carbon in soils. Immissic qualifier implies the possibility for differentiation of Technosols depending on the different types of materials (substrates) that built them. The revised diagnostic criteria of Pretic horizon allow the possibility for presence of black carbon and soil organic carbon. The update in the definition of Carbonic qualifier expands the possibilities for its usage in Technosols classification.

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Received: August**, 14, 2022**; *Accepted***: August, 26, 2022**; *Published*: **December, 2022**