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Comparative characteristics of soil organic matter in Technosols built with different geological materials and agricultural land use

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Abstract

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Present paper presents a comparative characteristic of soil organic matter in reclaimed Technosols with agricultural land use, differing in their geographical location and type of geological materials. Based on published data, non-humus reclaimed mine spoils were selected from the two largest coal-mining regions in Bulgaria – Maritsa-Iztok (mine spoil Iztok, mine spoil Ovcharitsa and experimental site Galabovo) and town of Pernik (Moshino site). Data for four soil profiles with different post-reclamation period and different crops were compared.

As a result of the comparative characteristic, it is supported the hypothesis for influence of agricultural land use on the fractional composition of soil organic matter in Technosols, which is observed in natural arable soils. It is confirmed the creation of favourable conditions for soil organic matter accumulation in studied Technosols in association with clay mechanical composition and alkaline pH. The correlation in the fractional composition of soil organic matter between Maritsa-Iztok profiles and the difference to Moshino site is probably due to the peculiar conditions under the influence of the type of geological materials and specific climate.

Keywords: Technosols; soil organic matter; agricultural usage
Abbreviations: SOM – soil organic matter, HA – humic acids, FA – fulvic acids

Introduction

Mining is related with disturbance of large land areas, which are subsequently reclaimed in order to restore their fertility and productivity (Zhivkova et al., 2003). Characteristic feature of mine spoils from geological materials is that after their construction, the processes of soil formation still do not influence them (Banov, 1989). With increasing of post-reclamation period, a number of scientists carried out various studies on mine spoils from different regions, built with different geological materials and land use, etc., aimed at studying of ongoing soil formation processes or different soil properties and characteristics (Petrova & Gencheva, 1991; Filcheva et al., 2000; Hristova & Hristov, 2003; Tsolova, 2005; Ivanov, 2007; Tsolova et al., 2014; Hristov et al., 2015; Petkova et al., 2017; etc.).

Humus formation and humus accumulation are some of the main processes determining soil fertility. In this respect, the content of soil organic matter (SOM) is an important indicator influencing different soil properties and functions (Koynov et al., 1980; Filcheva, 2007; Tsolova & Banov, 2011; Tsolova et al., 2018). This is particularly important in reclaimed soils, especially when the spoils from geological materials could be used in agriculture.

Present paper aim is to present a comparative characteristic of the SOM between reclaimed Technosols with agricultural land use, differing in geographical location and type of geological materials.

Materials and Methods

Object of the study are reclaimed mine soils from the two largest coal-mining areas of Bulgaria – Maritsa-Iztok and Pernik Coal Basins. Studied soil profiles are four. They are located on the territory of different mine spoils and differ in the post-reclamation period of development. The brief description of studied sites is based on published data (Banov, 1989; Ivanov, 2007).

Three of the profiles are located in Maritsa-Iztok region – profile 1 (mine spoil Iztok), profile 2 (mine spoil Ovcharitsa), and profile 3 (experimental site Galabovo) (Banov, 1989). The fourth profile is located on the Moshino site in Pernik Coal Basin (Ivanov, 2007).

According to the data, the post reclamation period of development of soil profiles (during the soil surveys) is as follows: profile 1 – 5 years, profile 2 – 10 years, profile 3 – 20 years, profile 4 – 15 years. The vegetation that is grown is represented by Wheat (*Triticum aestivum, L.*) – profiles 1 and 4, Barley (*Hordeum vulgare, L.*) – profiles 2 and 3.

The discussed data is result of soil sample analyzes for determination of SOM content by the modified method of Tyurin (Kononova, 1963), and composition of SOM by the accelerated method of Kononova-Belchikova (Kononova, 1963).

Results and Discussion

The geological materials that compose the studied reclaimed soils are represented by heterogeneous mixture of yellow and green Pliocene clays in Maritsa-Iztok region (Banov, 1989) and marls in Moshino site (Ivanov, 2007). These are the basic materials, which build the mine spoils in researched sites (Treykyashki, 1972; Garbuchev et al., 1975; Lichev et al., 1973; Gushevilov, 1977)., The compared reclaimed soils are classified as *Spolic Technosols* according to the World Reference Base for Soil Resources – WRB (IUSS Working Group WRB, 2014).

Before discussion of indicators for SOM of studied soil profiles, we will look at their morphological characteristics. This will allow clear and precise discussion of the analytical data.

Characteristic of the chosen soil profiles is their non-humus reclamation method. This excludes the possibility of presence of organic matter to be caused by spreading of natural soil layer (Banov, 1989; Ivanov, 2007).

The morphological characteristics show that the soil profiles have surface horizon with thickness of 20 – 25 cm because of agricultural usage of reclaimed soils. This horizon has crumbly structure, and roots from weeds and crop vegetation. The boundary between surface horizon and underlying soil layers is sharp in all soil profiles. The observed peculiarities of surface horizons distinguish them to some extent from the general structure of reclaimed soil profiles (Banov, 1989; Ivanov, 2007).

Similar is the state of SOM in the compared reclaimed soils. The data show that total carbon content in cultivated layer (~ 0–22 cm) exceeds the depth values, despite the wide ranges across the soil profiles (Table 1). Approximately 20–23% of carbon is in extracted organic form (Figure 1).

According to the classification of Artinova et al. (0000) for humus state of soils in Bulgaria (Filcheva, 2007), two profiles (1 and 2) have low SOM content in cultivated horizon. This can be explained by the fact that the mine spoils are reclaimed without spreading of humus horizon from natural soil and the short period of development of Technosols has not yet led to significant influence from the processes of SOM formation and accumulation (Banov, 1989; Marinkina, 1999; Ivanov, 2007). On the other hand, the agricultural usage of reclaimed areas is related to frequent cultivation and plan harvesting of crops (Ivanov, 2007), which prevents development of the typical for grasslands sod horizon. It can be assumed that these processes would be more active in grassed mine spoils where the plant debris will lead to more intense microbiological activity and related processes of decomposition of organic residues. Ivanov (2007) observes such a compliance in a study about the distribution of organic carbon in surface horizons of naturally grassed and afforested reclaimed mine soils.

The other two soil profiles (3 and 4) are characterized by higher values of total carbon and, respectively, higher SOM content (Table 1). Often, similar high carbon quantities are associated with the presence of coal impurities in reclaimed mine soils (Banov, 1989; Petrova & Gencheva, 1991; Marinkina, 1999; Ivanov, 2007; Hristova, 2013; etc.). In turn, this leads to very high content and random distribution of organic matter (Tsolova et al., 2011). Moreover, coal fine ash particles could affect the humus and its quantity in other adjoining soils (Hristov et al., 2013). However, the observed decline of carbon in depth of the profiles hints at its accumulative distribution (Banov, 1989; Ivanov, 2007). Therefore, for a clearer comparative characteristic we will look at the results from the analyses for determination of fractional composition of SOM.

The data from laboratory studies show that the humic acids (HA) fraction prevails over the fulvic acids (FA) in organic carbon composition in cultivated layer of reclaimed soil profiles (Figure 2). A distinctive feature of HA is that they adsorb on the surface of clay minerals and form

Table 1. pH, content and composition of SOM in compared soil profiles

Depth, cm	pH (H_2O)	Total C, %	Organic carbon, %					Unext. org. C, %	Ext. C in 0.1 N H_2SO_4
			Extracted with 0.1M $Na_4P_2O_7$ + 0.1M NaOH			Humic acids			
			Total	Humic acids	Fulvic acids	Free and bound with R_2O_3	Bound with Ca		
Profile № 1 – Mine spoil Iztok, ~ 5 years, Wheat (*Triticum aestivum* L.) (Banov, 1989)									
0–5	7.4	0.91	0.20[a] 21.98[b]	0.16 17.58	0.04 4.40	0.05 31.25[c]	0.11 68.75	0.71 78.02	0.02 2.20
5–22	7.5	0.87	0.17 19.54	0.13 14.94	0.04 4.60	0.00	100.00	0.70 80.46	0.02 2.30
22–40	7.7	0.15	0.03 20.00	0.00	0.03 20.00	0.00	0.00	0.12 80.00	0.00
Profile № 2 – Mine spoil Ovcharitsa, ~ 10 years, Barley (*Hordeum vulgare* L.) (Banov, 1989)									
0–5	7.1	0.83	0.16 19.28	0.09 10.84	0.07 8.43	0.00	100.00	0.67 80.72	0.02 2.41
5–20	7.3	0.58	0.13 22.41	0.09 15.52	0.04 6.90	0.00	100.00	0.45 77.59	0.00
20–40	7.6	0.22	0.04 18.18	0.00	0.04 18.18	0.00	0.00	0.18 81.82	0.00
Profile № 3 – Experimental site Galabovo, ~ 20 years, Barley (*Hordeum vulgare* L.) (Banov, 1989)									
0–5	5.8	2.12	0.48 22.64	0.48 22.64	0.00	0.08 18.18	0.36 81.82	1.64 77.36	0.02 0.94
5–25	6.1	1.92	0.48 25.00	0.37 19.27	0.11 5.73	0.00	100.00	1.44 75.00	0.02 1.04
25–40	7.2	0.20	0.05 25.00	0.00	0.05 25.00	0.00	0.00	0.15 75.00	0.02 10.00
Profile № 4 – Moshino site, ~ 15 years, Wheat (*Triticum aestivum* L.) (Ivanov, 2007)									
0–22	7.90	2.38	0.54 22.69	0.28 11.76	0.26 10.93	0.00	100.00	1.84 77.31	0.00
22–42	7.90	1.63	0.11 6.75	0.07 4.29	0.04 2.46	0.00	100.00	1.52 93.25	0.00
42–54	8.00	1.28	0.09 7.03	0.07 5.47	0.02 1.56	0.00	100.00	1.19 92.97	0.00
54–85	8.00	0.80	0.11 13.75	0.00	0.11 13.75	0.00	0.00	0.69 86.25	0.02 2.50

**a* – % of soil sample; *b* – % of total carbon content; *c* – % of humic acids content

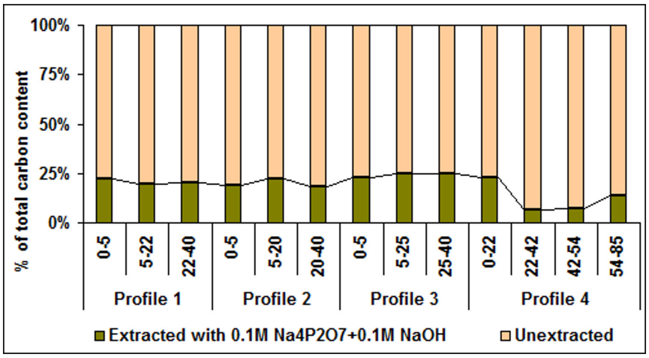

Fig. 1. Organic carbon forms in soil profiles

insoluble humates, where the humus can be preserved for a long (Koynov et al., 1980). This can be considered as favorable circumstance regarding Maritsa-Iztok mine spoils built with yellow-green Pliocene clays (Banov, 1989), as well as the cultivated horizon of Technosol from Moshino site with physical clay content (mechanical fraction < 0.01 mm (Kachinski, 1965) = 79.80% (Ivanov, 2007). It should be noted here that the unextracted carbon in studied technogenic soil profiles is greater than the total extracted carbon (Table 1). Therefore, some authors (Banov et al., 1989; Pencheva & Hristov, 1998) expressed that this is due to the formation of stable to laboratory extraction organo-mineral complexes.

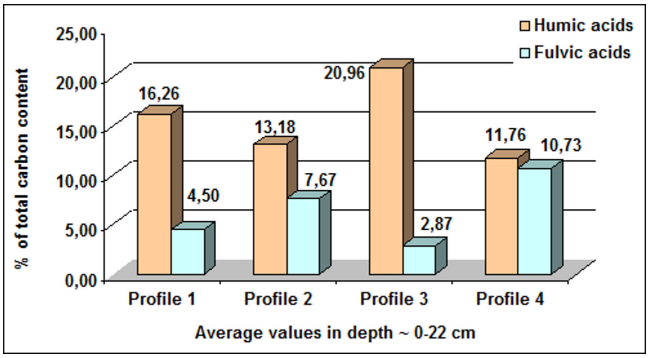

Fig. 2. Extracted organic carbon fractions in cultivated layer

Significant part of HA in cultivated layer (~ 0–22 cm) of studied profiles are Ca complexed. The content of aggressive faction of FA (Filcheva et al., 2018) present small part of SOM or is missing (Table 1). Higher value characterizes only the subsurface layer (25–40 cm) of profile 3. An increase of Ca complexed HA and decrease of aggressive fraction of FA in plough horizon is described by Filcheva (2007) in a study for changes in humus state of Brown forest soils under arable conditions. This leads us to support the hypothesis (Ivanov, 2007) that the specific anthropogenic soil formation factor (Effland & Pouyat, 1997; Dudal, 2004) probably influence also on the SOM composition in compared Technosols. However, it is necessary to remind the changes in soils under arable conditions associated with reduction of the humus content (Filcheva, 2007).

In depth, under the cultivated horizon, a connection between the Technosols from Maritsa-Iztok region is established regarding absence of HA. The same trend is not observed in the soil profile from Moshino site, where the HA are established in the subsurface layer also (Figure 3). In this profile, below 54 cm, the FA are the main organic carbon fraction (Table 1). This makes us pay attention to the pH value in soil profiles, as it creates the conditions for chemical interactions between the mineral and organic colloids (Filcheva, 2004; 2007). From the data in Table 1, we can not bind the absence of HA in the subsurface soil layers with pH, which is slight alkaline, as for the three profiles from Maritsa-Iztok region as well as for the profile from Moshino site. We consider that such a correlation is difficult to be established because in a study of humus content in cultivated layer of natural soils, Filcheva (2004) summarizes that the alkaline pH creates conditions for connections between Ca ions and SOM, as well as between clay minerals and SOM. Here we may assume that the association of pH with SOM and HA fraction can also be observed in the subsurface layers of Maritsa-Iztok profiles, which, however, is not established. In this regard we will note that the similarity between soil profiles 1, 2 and 3, related to the absence of HA in the subsurface layer (Figure 3), coincides with the humus state of afforested mine spoil in the region of Maritsa-Iztok (Zheleva & Bozhinova, 2011). As a reason for this specific feature of reclaimed soils, the authors point to the greater mobility of the FA.

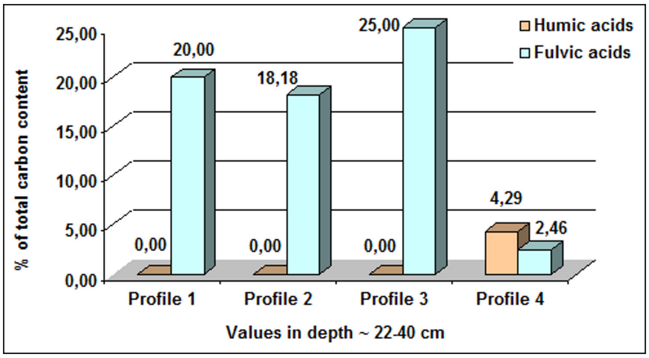

Fig. 3. Extracted organic carbon fractions in subsurface layer

One of the assumptions for such a differentiation of spoils from compared coalmine regions regarding composition of SOM in subsurface layer of the soil profiles is the type of geological materials. This probability could be supported more strongly in the presence of more than one soil profile of arable land in Moshino site for comparison. However, the lack of additional data suggests that this may be an isolated case or to have specific soil formation conditions in individual mine regions because of a stronger influence of some factor. In this regard, we will point out that in a profile in afforested area from Moshino site, the FA are the main organic fraction at greater depth – below 35 cm (Ivanov, 2007). This can somewhat support the assumption that the observed compliance in the composition of SOM in soil profiles from Maritsa-Iztok region and the difference from Moshino site is due to the specific conditions of humus formation under the influence of geological materials.

Here, we will add that the processes of soil formation and humus accumulation in soils are also related to climate conditions (Koynov et al., 1980). This implies their specific impact on reclaimed soils from both coal-mining regions, which are located in different climate subareas of the European continental climate area – moderately continental for Pernik Coal Basin and transitional continental for Maritsa-Iztok region (Hydrometeorology Department, 1960). In another study of mine spoils, Filcheva et al. (2000) also summarize that the accumulation of organic carbon depends on climate too.

The ratio between HA and total carbon content shows that the compared soil profiles are characterized by average to high humification of SOM in cultivated layer according to the classification of Artinova et al. (0000)for humus state of Bulgarian soils (Filcheva, 2007). Banov & Hristov (1998) also report high degree of humification in a study of reclaimed spoils with Pliocene clays and different land use. The type of SOM between the compared four soil profiles ranges from humic to fulvic-humic according to the classification of Grishina and Orlov (Orlov, 1985). These results confirm that there are conditions for the formation of more stable forms of organic matter, mentioned in other studies (Ivanov et al., 2007), although the profiles are not influenced by the grass vegetation. This is important, considering the typical higher degree of mineralization of humus in arable soils, mostly combined with mineral nitrogen fertilization (Koynov et al., 1980), as a part of agro-technical activities. On the other hand, the stable forms of SOM create prerequisites for better water-physical properties of reclaimed soils, which in combination with frequent tillage affect the distribution of organic matter (Ivanov, 2007). In depth, the lack of HA is the reason for the very low humification degree of SOM in studied soil profiles.

Conclusions

The clay mechanical composition and alkaline pH confirm for creation of favourable conditions for SOM accumulation in compared Technosols from both coalmine regions. It is supported the hypothesis for influence of the specific anthropogenic factor of soil formation on the fractional composition of SOM in surface layer of some of the compared soil profiles, which is observed in arable soils. Conformity in the composition of SOM in soil profiles from Maritsa-Iztok region and the difference from Moshino site is probably due to the specific conditions for SOM formation because of the type of geological materials and specific climate.

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