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Microbiome status and determinants in soils from the region of Maritsa-Iztok coal mine (Bulgaria). II. Spolic Technosols

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Abstract

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Soil microbial community plays important role in maintaining the soil sustainability and is integrally related to soil fertility since provides the accessibility and cycling of nutrients in organic niches. Different parameters, characterizing the structure and activity of soil microbiome usually serve as indicators for reclamation effectiveness. Among them, the basal soil respiration, microbial biomass carbon content, microbial density and diversity are widely used all over the world as a measure of the progress of bio-transforming processes and the turnover of soil into a functioning ecosystem. Based on these parameters this paper aimed to establish the microbiome status and determinants in natural and reclaimed soils affected by pyrogenic carbon emissions in the area of Maritsa-Iztok lignite basin and particularly to reveal the response of microorganisms to such anthropogenic influence. Pyrogenic carbon (PyC) is a climate-warming agent and its influence on biological and chemical processes in soils is of paramount importance nowadays in view of the amplification of climate changes. In this part of the study, data on three reclaimed soils (Spolic Technosols) located close to Maritsa-Iztok industrial complex are presented.

The results obtained show that the basic feature of studied Tecnosols is the different depth of the humus horizon formed by reclamation and this together with their proximity to the main source of pyrogenic carbon ("Maritsa-Iiztok 2" Thermal Power Plant) determines the observed differences in the activity, density and behavior of different microbial groups. The general hallmark of studied microbial populations was the strong density decrease in sub-horizons, active participation in the biochemical transformations of organic matter, including the stable fraction of PyC and low need of endogenous available nitrogen. Likewise the natural soils oligotrophic, heterotrophic and ologonitrophilic bacteria prevailed in Technosols but mainly oligotrophs and ologonitrophils showed asynergetic behavior in respect of other microorganisms and were capable to utilize the exogenous nutrients equally well. Due to the extremely high spatial variation of oligonitrophils density this group could be used as bioindicator of soil anthropogenization especially of pyrogenic carbon (PyC) accumulation. Only organic carbon, PyC (with small exceptions) and available potassium determined the microbial growth and density in studied Technosols while pH, humic acids, available nitrogen and clay contents were not significant factors. Availablity of phosphorus positively influenced microbiome status only in Technosols occupied by perennial crops (profiles 2 and 3) with exception of asynergetic groups. In low content of organic carbon and prevailing mineralization processes carbonates become important determinant of microbiome activity.

Keywords: Spolic Technosols; microbial biomass; microbial density; pyrogenic carbon; soil nutrients

Introduction

In order to reach the productive layers, huge masses of geological materials overlying the coal are removed, transported and heaped on surrounding land during the opencast coal-mining. These piles are considered mining wastes and are usually called spoils. Humus layers of fertile soils destroyed by mining are traditionally used for reclamation of mine spoils in Bulgaria – they are placed onto the mined substrate (geological materials) to provide favourable conditions for plant growth (Ordinance 26; Sheoran, 2010). Soils formed as a result of mining activities are classified Technosols according to the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015) and this name will be used in the present paper simulteniously with the Bulgarian name, reclaimed soils. These soils often have low pH and organic matter content, disadvantageous texture and water retention capacity, and are devoid of vegetation and nutrients (Banov, 1989; Marinkina, 1999; Baldrian et al, 2008). Therefore, reclaimed soils usually present uncultivated and severe media for plant and microbial growth. Nowadays, it is well known that geological materials are not sterile, thereby the soil microbial community in the deeper soil strata also determines soil properties and success of reclamation (Ivanov et al., 2007; Tsolova et al., 2014).

Soil microbial community plays important role in maintaining the sustainability of soils and is integrally related to soil fertility. Microbiome is also responsible for successful ecosystem restoration in reclaimed lands since it provides the accessibility and cycling of nutrients in organic niches (Rana et al., 2007; Quadros et al., 2016). It starts the prelude to the transformation of soil turnover into a functioning ecosystem and generally prepares soil for plants. Therefore, the microbiological status of natural soils is used as a reference in assessment of distribution of microbial populations in mine spoils, their activity and interlinks with other soil ingredients.

Different parameters, characterizing the structure and activity of soil microbiome usually serve as indicators for reclamation effectiveness (Dimitrova et al., 2008; Sun et al., 2019). Hanney et al. (2008) compared microbial properties of native and reclaimed soils with moderately alkaline reaction and concluded that basal soil respiration (BR) and microbial biomass carbon (Cmic) were good indicators of capability of soils to sustain plant growth. Nowadays the basal soil respiration, microbial biomass carbon content, microbial density and diversity are widely used all over the world as a measure of the progress of bio-transforming processes and the transformation of soil into a functioning ecosystem (Nannipieri et al., 1990; Alef, 1995; Ingram et al., 2005; Ingram et al., 2003; Ingram et al., 2005). Based on these parameters this paper aimed to establish the microbiome status and determinants in natural and reclaimed soils affected by pyrogenic carbon emissions in the area of Maritsa-Iztok lignite basin and particularly to reveal the response of microorganisms to such anthropogenic influence. Pyrogenic carbon (PyC) is a climate-warming agent and its influence on biological and chemical processes in soils is of paramount importance in view of the amplification of climate changes.

In this part of the study, data on three reclaimed soils (Spolic Technosols) located close to Maritsa-Iztok industrial complex are presented.

Materials and Methods

Description of studied sites

Reclaimed soils are located in “Staroselets” heap (all of them inside the ellipsoid shown on Figure 1) and belong to the agricultural fund. General information about the construction of “Staroselets” heap is given below.

• Base layer – formed by mixing of clays (located beneath, between and above coal strata of the deposit) and cinder-ash (cinder, slag, bottom ash from caldrons and fly ash from coal incineration, all produced in “Maritsa-Iiztok 2” Thermal Power Plant) in a clays/cinder-ash ratio 80% – 85% / 15% – 20%. Later, a three-component mixture of cinder-ash, gypsum (representing solid waste from the desulphurisation of waste gases from coal burning) and clays had been used in a ratio: 15-20 % (cinder-ash mixture): 15-20 % (gypsum): 60-70 % (clays).

• Isolating layer – since 2007 a gradual reclamation of heap had begun by placing suitable clays (not very clayey or skeletal and non-toxic) occurring in the above coal complex (fine-grained silty and silty-sand clays with yellow-brown, light gray and blue-green colors) over the base layer. This reclamation layer was 2-3 m deep and represented the main soil-forming substrate that determined the properties and pedogenesis of reclaimed soils.

• Topsoil layer – formed by piling on 35-40 cm a mixture of humus horizons of destroyed soils (collected from the top soil before mining activities) over the isolating stratum.

The studied soils were located at different distance from the PyC sources (Figure 1) – the Maritsa-iztok mine (in the left ellipsoid edge) and “Maritsa-Iztok 2” Thermal Power Plant (in the right). The first reclaimed soil (Spolic Technosol 1) was located 4 km away from Thermal Power Plant (near the Maritsa-Iztok mine and Kovachevo village) at 175 m altitude and 42°13.58’ N; 26°05.316’ E. It was an arable soil under wheat at the time of sampling. Soil was classified as Reclaimed soil, black, calcareous, deep, according to the Bulgarian classification (Yolevski & Hadzhiyanakiev, 1976), and as Spolic Technosol (Transporto-tonguimollic, Epicambic, Endogleyic, Hypereutric, Clayic) according to the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015).

The Spolic Technosol 2 was located in the northernmost part of "Staroselets" heap in a flat terrain at 182 m altitude and 42°14'49.45" N, 26°6'22.76" E. It was remote on 1.5 km from the "Maritsa-Iztok 2" Thermal Power Plant (TPP) in the South-west direction and was sown with alfalfa (*Medicago sativa)*. The soil was classified as Reclaimed soil, bright olive, calcareous, shallow according to the national classification (Yolevski & Hadzhiyanakiev, 1976) which corresponded to WRB (2015) nomenclature Spolic Technosol (Bathyochric, Stangnic, Hypereutric, Clayic).

The third profile (Spolic Technosol 3) was situated 700 m south-southwest of profile 4 in a crest of oblique slop slightly oriented to the South. It was geographically positioned at 42°14'26.97"N; 26° 6'34.46"E and 164 m altitude. This was a Reclaimed soil, dark gray, calcareous, deep or Spolic Technosol (Transporto-Chernic, Bathyhumic, Hypereutric, Clayic) occupied by shrubby and grass vegetation.

Field study and laboratory assays

All methods of analysis, sampling time and data processing followed procedures described in the first part of the study. Since studied Technosols are slightly calcareous (calcium carbonate content < 3%) the basal respiration (BR) rates was also determined by measuring CO_2 efflux from soil (Alef, 1995). Respiration rates are shown in mg CO_2/100 g dry soil/h and represent the total microbial activity in soils (Nannipieri et al., 1990).

Monitoring samples from the surface horizons near Spolic Technosols 1 and 3 were taken as described for the natural Vertisol 2, vulnerable to PyC inputs (Figure1, in a parallel line of the TPP starting from a monitoring point in the vicinity of profile), while the location of three of the samples near Technosol 2 was compliant with the proximity to Thermal Power Plant.

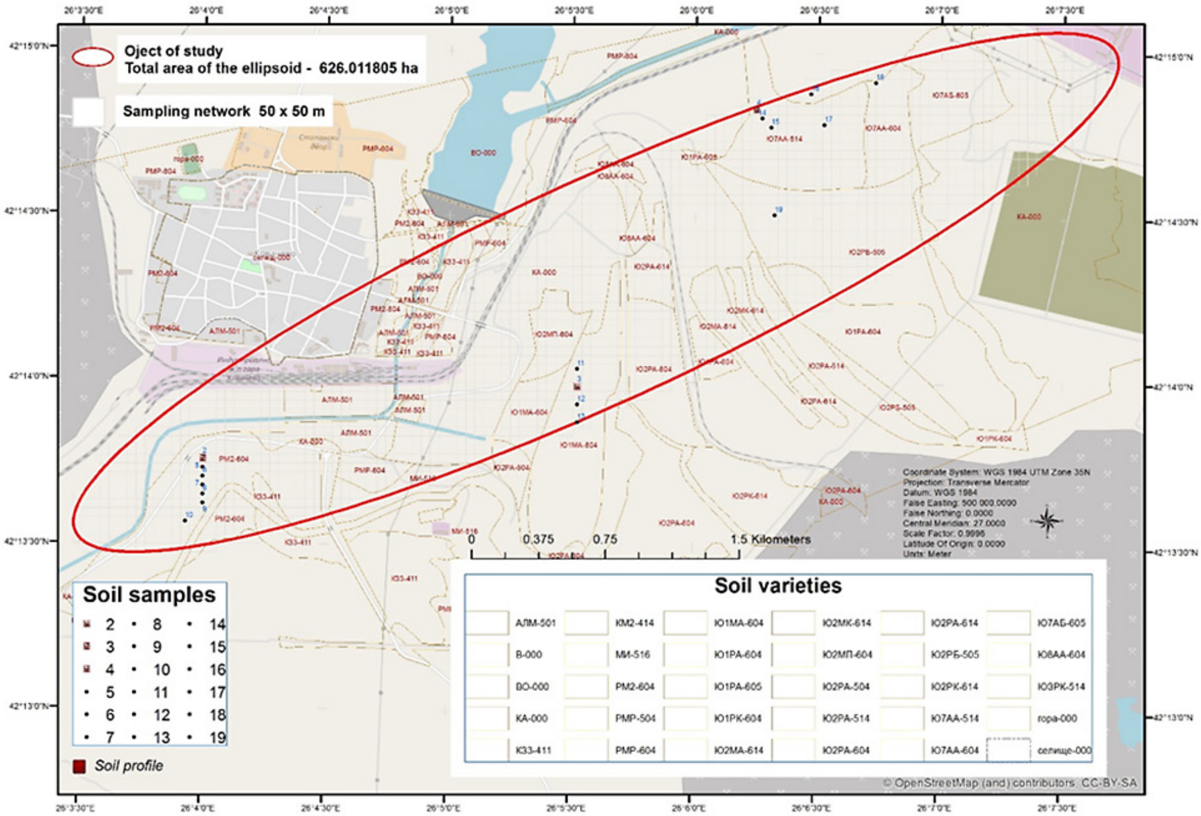

Fig. 1. Location of soil profiles and sampling points in the region of Maritsa-Iztok lignite mine

Results and Discussion

Basic soil characteristics supporting functioning, distribution and density of soil microbiota are shown on Figure 2 – a, b, c and d. All Technosols are distinguished for very slightly alkaline soil reaction (pH 7.1 – 7.7), clay loam to clay texture, low to medium levels of available N (6.3-42.0 mg/kg), very low to very good levels of available P (1.9-32.80 g/100 g) and medium to very good availability of K (15.0-71.80 g/100 g).

Morphological study revealed that Spolic Technosol 2 has contrasting morphogenesis and different properties comparing to Spolic Technosols 1 and 3 due to the lack of humus topsoil. The surface horizon was slightly transformed by hypergenic processes, plant roots and residues are few and the humification process has not yet started (humic acids were not extracted) – mineralization of organic matter was dominant but also slightly running process. The humus horizon in the rest of soils, although not formed *in situ*, consisted of well humificated, Mull type humus wherein humic acids were strongly condensed polymers (E4/E6 varied from 3.02 to 3.74) with high stability and maturity. Pyrogenic carbon formed between 16% and 48% of organic carbon and the highest value was found at the closest to TPP monitoring point (Figure 2c).

Nevertheless, the basal respiration (BR) rates and microbial biomass carbon (Cmic) were not low in Spolic Technosol 2 and exceeded the values in Spolic Technosol 1 (Table 1). In fact, the last (Spolic Technosol 1) had similar Cmic content to the control soil (natural Vertisol 1) and this was most likely related to the time of reclamation – this part of the "Staroselets" heap was reclaimed first. Likewise in natural soil located in the vulnerable region (Vertisol 2), this indicator significantly varied along the monitoring network.

The younger reclaimed soils show typical of them rapid population with microorganisms (Marinkina, 1999; Ivanov, 2007), which is evident in the present study through the values of main indicators – total microbial activity (basal respiration rates) and microbial biomass carbon.

Due to the lack of humus horizon Technosol 2 showed detail of the processes of initial colonization of mineral hori-

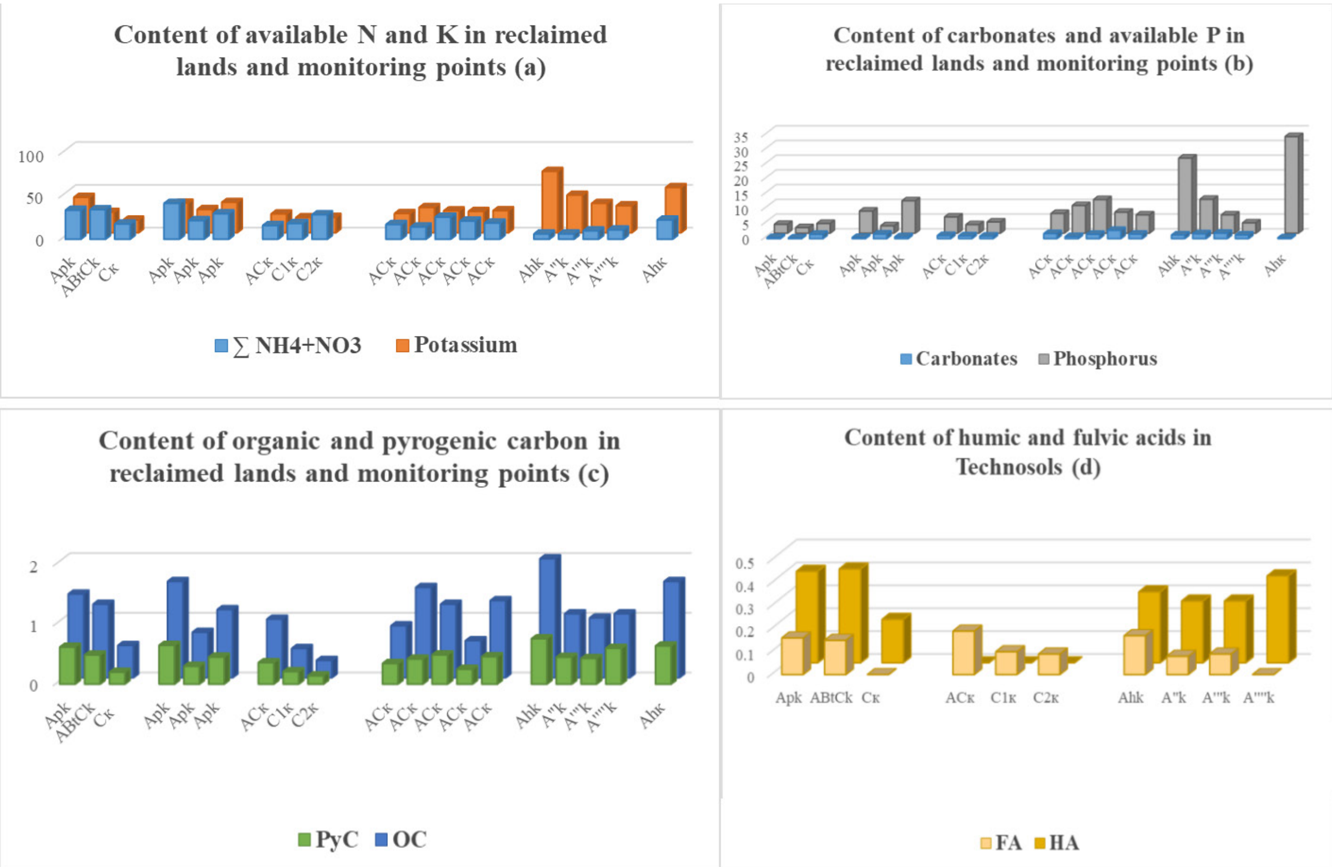

Fig. 2. Content of basic nutritious ingredients in studied Technosols

Table 1. Basal respiration and microbial biomass carbon in studied Technosols

Soil horizons and depth, cm		Basal respiration, mg CO_2/100 g/h	Cmic, mg C/100 g
Spolic Technosol 1 (black, calcareous, deep soil; humus reclamation)			
A_{pk}	0-30	0.296 a	17.43 a
AB_tC_k	30-55	0.229 b	12.10 b
C_k	55-120	0.238 b	5.70 c
Monitoring points near Spolic Technosol 1			
I – A_{pk}	0-20	0.550 c	56.34 a
II – A_{pk}	0-20	0.779 a	32.36 b
III – A_{pk}	0-20	0.715 b	30.76 c
Spolic Technosol 2 (bright olive, slightly humic, shallow soil; non-humus reclamation)			
AC_k	0-18	0.452 a	20.09 a
$C1_k$	18-53	0.416 b	3.57 b
$C2_k$	53-100	0.339 c	3.57 b
Monitoring points near Spolic Technosol 2			
IV- AC_k	0-20	0.587 b	29.16 e
V – AC_k	0-20	0.498 d	36.09 c
VI – AC_k	0-20	0.642 a	45.15 a
VII – AC_k	0-20	0.437 e	38.22 b
VIII – AC_k	0-20	0.553 c	32.36 d
Spolic Technosol 3 (dark gray, calcareous, deep; humus reclamation)			
A_{hk}	0-20	0.596 a	25.96 a
A''_k	20-40	0.367 b	17.96 b
A'''_k	40-60	0.321 c	13.16 c
A''''_k	60-80	0.321 c	16.36 b
Monitoring point near Spolic Technosol 3			
IX – A_{hk}	0-20	0.642 a	18.50 b

zons with microorganisms in modern conditions. Microscopic fungi and cellulolytic microorganisms were less common in the deep horizons of Technosol 2, until the undemanding oligonitrophilic and oligotrophic bacteria occupied this not rich nutritional niche (Table 2). The maximal value of oligonitrophils density established here as well as the extremely strong variation in their number (V = 127 %) cannot be related to the predominant influence of any of the studied soil factors (Table 3) except with the proximity of the samples to the main source of pyrogenic carbon – "Maritsa-Iiztok 2" Thermal Power Plant. This allowed us to assume that PyC allocation in soils could increase topsoil temperature and thus to facilitate the adaptability of oligonitrophils, among which nitrogen-fixing species were presumably very active if we take into consideration the crop grown (alfalfa) and possible symbiosis between them. It is also reasonable to assume that the variation coefficient with values above 120% could be used as an indicator of soil anthropogenization especially of pyrogenic carbon (PyC) accumulation.

Spolic Technosol 3 had a very deep humus horizon (due to the erosion and landslide processes after reclamation) characterized with the highest microbial density and thus strongly contrasted to Technosol 2. This was a result of the biological nature of humus horizon and microorganisms already inhabited there, that further catalyzed biogenic transformations.

The maximum density of actinomycetes, hetero- and oligotrophs was established here, and this could not be entirely associated with the amount of nutrients or dense grass cover – the horizon morpho-physical characteristics were also beneficial – clay loam, structured, dark in color horizon, providing favorable thermal, air and water conditions.

Still, the general hallmark of all studied Technosols was the strong decrease of microbial density in sub-horizons (from 1.5 to 240 times) and predominantly statistically insignificant differences beneath them. This distribution of microorganisms coincided with the distribution in the natural soil, accepted as a standard (Vertisol 1), revealing that the number and viability of microorganisms was a very dynamic parameter, which was rather influenced by the species diversity and soil management than the time for soil formation.

The calculated correlations provided a deeper insight into the complex interactions between mineral and organic components in soils (Table 3). They showed that:

There is a strong synergetic interlinks between all microbial groups in Technosol 1, similar to that in the control soil (Vertisol 1). All groups participated in the biochemical transformations of organic matter, including the stable fraction of PyC and depended on their content. All of them also determined the microbial activity and amount of microbial biomass. Available potassium was the other main determinant of microbiome density while available nitrogen, humic and fulvic acids were vital regulator only of cellulolytic microorganisms. Since all nutritious substances are concentrated in the silt fraction it is also important for microbiome functioning.

➢ Oligotrophs unbalanced the microbiome synergy in Technosol 2 because were not allied to any of the studied microbial groups. The calculated correlations suggested that these bacteria mainly utilized exogenous nutrient sources but were interlinked and depended on the content of SOC and carbonates. In fact, carbonates (although distributed as nuts) were among the factors determining the activity of all other microorganisms along with the basic nutrients except available N. Obviously, all microbial groups can use carbonates

Table 2. Population density of different microbial groups in Spolic Technosols (CFU/g.10^4)

Soil horizons and depth, cm		Hetero-trophic bacteria	Oligotrophic bacteria	Oligonitrophilic bacteria	Actinomycetes	. Fungi	Cellulolytic microorg
Spolic Technosol 1 (humus reclamation)							
A_{pk}	0-30	30.40 a	29.00 a	4.40 a	3.87 a	0.060 a	0.053 a
AB_tC_k	30-55	2.68 b	5.27 b	0.19 b	0.60 b	0.005 b	0.027 b
C_k	55-120	1.29 b	3.10 b	0.51 b	0.25 b	0.001 b	0.004 c
Monitoring points near Spolic Technosol 1							
I – A_{pk}	0-20	15.00 c	138.00 b	36.27 c	5.33 a	0.027 a	0.088 a
II – A_{pk}	0-20	25.93 a	205.33 a	43.73 b	6.20 a	0.012 b	0.047 b
III – A_{pk}	0-20	20.07 b	194.00 a	49.67 a	2.40 b	0.007 b	0.091 a
Spolic Technosol 2 (non-humus reclamation)							
AC_k	0-18	47.33 a	39.73 a	22.87 a	4.53 a	0.240a	0.062 a
$C1_k$	18-53	12.13 b	46.20 b	4.18 b	1.22 b	0.001 b	0
$C2_k$	53-100	2.81 b	18.13 c	2.97 b	0.58 b	0	0.001 b
Monitoring points near Spolic Technosol 2							
AC_k	0-20	96.67 b	248.00 a	199.33 b	23.20 a	0.66 c	4.77 c
AC_k	0-20	116.00 a	208.67 b	87.33 c	12.67 c	1.44 a	5.77 c
AC_k	0-20	32.00 c	94.67 d	34.00 d	10.40 c	0.84 b	5.67 c
AC_k	0-20	30.67 c	150.67 c	24.67 d	16.27 b	0.21 d	1.60 a
AC_k	0-20	20.00 c	88.00 d	597.33 a	5.73 d	0.01e	0.97 b
Spolic Technosol 3 (humus reclamation)							
Ah_k	0-20	333.33 a	300.0 a	118.67 b	28.0 a	0.26 a	0.045 b
A''_k	20-40	87.33 b	118.0 b	162.67 a	20.0 ab	0.17 b	0.011 c
A‴k	40-60	62.67 b	90.0 b	63.33 c	13.3 b	0.051 c	0.008 c
A''_k	60-80	98.67 b	106.0 b	63.33 c	22.67 ab	0.007 d	0.0067 c
Monitoring points near Spolic Technosol 3							
Ah_k	0-20	16.00 c	104.67 b	18.67 d	15.87 b	0.026 c	2.733 a

as a carbon source when organic carbon content is low and to develop a strong carbon-fixing ability. Such an assumption made Sun et al. (2019) for microorganisms occurring in poor of organic carbon mine spoils subjected to acid mine drainage. Sand and silt fractions played the well-known role of nutrients domain and had a great importance to microbiome.

➢ Microbial interlinks in Technosol 3 were disturbed by oligonitrophilic bacteria, which are related only with microscopic fungi. They had specific behavior here – did not depend on any of the studied factors, do not participate in the formation of microbial mass and do not determine bacterial activity. The great variety of species that this group can include largely explained their asynergetic behavior and the lack of interlink with studied soil parameters. Since this soil can be identified as an oligonitrophilic medium (the mineral nitrogen content is extremely low – 6.3 to 10.9 mg/kg in the deepest horizon), the diversity of oligonitrophilic species is of great interest. In this profile, the clay and partly the sand fraction also determined the density of microorganisms by hosting the main sources of nutrients – SOC, PyC, FA, P and K. The last were the main determinants of microbial density with exception of actinomycetes, for which FA were not a source of energy.

Conclusion

The studied reclaimed soils had a different morphological organization, which together with the short period of post-reclamation genesis determined the observed microbiological differences.

Soils with a profile corresponding to the reclamation design (Spolic Technosol 1) had similar microbiological characteristics to natural soils located in the remote soil area (control soil). Here, like in the natural soils, hetero- and oligotrophic bacteria prevailed and the number of all microbial groups sharply decreased in depth. There is a strong synergy between microorganisms in Technosol 1 mostly because they all participated in the biochemical transformations of organic matter, including the stable fraction of PyC. With

Table 3. Correlation coefficients (r) between studied microbial and soil parameters

Parameters	Hetero-trophs	Oligotrophs	Oligonitrophils	Actino-mycetes	Fungi	Cellulol. microorg.
Spolic Technosol 1						
Heterotrophic bac.	1.00					
Oligotrophic bac.	1.00	1.00				
Oligonitrophilic bac.	0.99	0.99	1.00			
Actinomycetes	1.00	1.00	0.99	1.00		
Fungi	1.00	1.00	0.99	1.00	1.00	
Cellulolytic microorg.	0.90	0.92	0.85	0.92	0.91	1.00
BR (CO_2)	0.99	0.98	1.00	0.98	0.98	0.82
Cmic	0.86	0.88	0.80	0.88	0.87	1.00
PyC	0.77	0.79	0.69	0.79	0.78	0.97
SOC	0.90	0.92	0.85	0.92	0.91	1.00
Humic acids	0.50	0.53	0.40	0.54	0.52	0.83
Fulvic acids	0.58	0.61	0.49	0.62	0.60	0.88
pH	-0.78	-0.80	-0.71	-0.81	-0.79	-0.97
Available N	0.51	0.54	0.41	0.55	0.53	0.83
Available P_2O_5	0.27	0.24	0.38	0.23	0.26	-0.17
Available K_2O	0.96	0.97	0.92	0.97	0.96	0.99
$CaCO_3$	-0.45	-0.48	-0.35	-0.49	-0.47	-0.79
Sand (1.0-0.063 mm)	-0.19	-0.23	-0.08	-0.24	-0.21	-0.60
Silt (0.063-0.002 mm)	0.95	0.96	0.91	0.96	0.95	0.99
Clay (<0.002 mm)	-0.98	-0.98	-1.00	-0.98	-0.98	-0.81
Spolic Technosol 2						
Heterotrophic bac.	1.00					
Oligotrophic bac.	0.48	1.00				
Oligonitrophilic bac.	0.99	0.35	1.00			
Actinomycetes	1.00	0.44	1.00	1.00		
Fungi	0.98	0.30	1.00	0.99	1.00	
Cellulolytic microorg.	0.98	0.28	1.00	0.99	1.00	1.00
BR (CO_2)	0.86	0.86	0.78	0.84	0.75	0.74
Cmic	0.98	0.30	1.00	0.99	1.00	1.00
PyC	0.99	0.58	0.97	0.99	0.95	0.95
SOC	0.96	0.69	0.92	0.95	0.89	0.89
Fulvic acids	0.99	0.38	1.00	1.00	1.00	0.99
pH	-0.20	-0.95	-0.05	-0.15	0.00	0.01
Available N	-0.78	-0.92	-0.68	-0.75	-0.64	-0.63
Available P_2O_5	0.85	-0.05	0.92	0.88	0.94	0.94
Available K_2O	0.97	0.24	0.99	0.98	1.00	1.00
$CaCO_3$	0.94	0.75	0.88	0.92	0.85	0.84
Sand (1.0-0.063 mm)	0.84	-0.07	0.91	0.87	0.93	0.94
Silt (0.063-0.002 mm)	0.98	0.64	0.94	0.97	0.93	0.92
Clay (<0.002 mm)	-1.00	-0.41	-1.00	-1.00	-0.99	-0.99
Spolic Technosol 3						
Heterotrophic bac.	1.00					
Oligotrophic bac.	1.00	1.00				
Oligonitrophilic bac.	0.25	0.32	1.00			
Actinomycetes	0.83	0.81	0.33	1.00		

Table 3. Continued

Fungi	0.83	0.86	0.75	0.80	1.00	
Cellulolytic microorg.	0.99	1.00	0.32	0.76	0.85	1.00
BR (CO_2)	0.98	1.00	0.39	0.78	0.89	1.00
Cmic	0.96	0.97	0.48	0.90	0.94	0.95
PyC	0.82	0.77	-0.08	0.91	0.55	0.72
SOC	0.99	0.99	0.28	0.90	0.85	0.97
Humic acids	0.12	0.04	-0.48	0.49	-0.13	-0.03
Fulvic acids	0.75	0.80	0.42	0.33	0.71	0.84
pH	-0.44	-0.43	-0.54	-0.84	-0.67	-0.36
Available N	-0.56	-0.63	-0.91	-0.44	-0.89	-0.64
Available P_2O_5	0.93	0.96	0.53	0.70	0.92	0.97
Available K_2O	0.95	0.97	0.50	0.74	0.92	0.98
$CaCO_3$	-0.64	-0.59	0.02	-0.91	-0.48	-0.52
Sand (1.0-0.063 mm)	0.78	0.80	0.10	0.31	0.54	0.85
Silt (0.063-0.002 mm)	-0.56	-0.60	-0.14	-0.02	-0.40	-0.67
Clay (<0.002 mm)	0.99	0.99	0.23	0.77	0.80	1.00

regard to the mineral nutrients, there are different trends in Technosol 1 from those found in natural soils, which were a result of the very low number of microbial communities in the sub-horizons and therefore the low need of endogenous mineral resources.

Soils that were deprived of reclamation humus horizon (Spolic Technosol 2) had rapidly populated with microorganisms and respectively have a higher microbial activity and density of all groups of microorganisms compared to Technosol 1. Their numbers in sub-horizons were greatly reduced too, until the populations of fungi and cellulolytic microorganisms were completely suppressed. Monitoring data showed a strong adaptability of studied groups to the existing conditions and their ability to use both the endo- and the exogenous nutrient sources equally well. Due to the extremely high spatial variation of oligonitrophilic bacteria density (V > 120 %) this group could be used as bioindicator of soil anthropogenization especially of pyrogenic carbon (PyC) accumulation.

Soils with extremely deep humus horizon (also not coinciding with the reclamation plan) were an excellent environment for microbial growth, and many of the studied groups had maximum density here – actinomycetes, hetero- and oligotrophic bacteria. Ologonitrophils were also present in large amount in the low-nitrogen environment of Technosol 3 but showed asynergetic behavior and were not interlinked with studied soil parameters.

Only organic carbon, PyC (with small exceptions) and available potassium determined the microbial growth and density in studied Technosols while pH, humic acids, available nitrogen and clay contents were not significant factors. Availablity of phosphorus positively influenced microbiome status only in Technosols occupied by perennial crops (profiles 2 and 3) with exception of asynergetic groups. In low content of organic carbon and prevailing mineralization processes carbonates become important determinant of microbiome activity.

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