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FRACTIONAL COMPOSITION OF HUMUS COMPOUNDS OF SOILS ON RECLAIMED EXTERNAL DUMPING GROUND OF A SULPHUR MINE

Maria Flis-Bujak[*], Tadeusz Węgorek[**], Grażyna Żukowska[*]

[*] Institute of Soil Science and Environmental Management,
[**] Faculty of Melioration and Agricultural Construction, University of Life Sciences in Lublin
Leszczyńskiego str. 7, 20-069 Lublin, grazyna.zukowska@up.lublin.pl, tadeusz.wegorek@up.lublin.pl

Summary. After 41 years of forest reclamation the content and fractional composition of humus compounds of soils formed of loams (down to a depth of 25 cm) were studied on an external dumping ground of the sulphur mine at Piaseczno. Notable accumulation of $C_{org.}$ was observed – from 7–10 $g \cdot kg^{-1}$ in the layer of 20–25 cm to 23–30 $g \cdot kg^{-1}$ in the layer of 0–5 cm. The accumulated material was mainly humus substances that do not undergo extraction (humins). The share in the fractional composition of humus was 70–80% $C_{org.}$ Among the humus acids, fulvic acids dominated over humic acids and their prevalence increased with the depth into the profile.

Key words: forest reclamation, organic carbon, fractional composition of humus, humic acids, fulvic acids

INTRODUCTION

During ground (parent rock) reclamation the processes of humification lead to the accumulation of humus. The amount of humus accumulated in the forming soil is used as an indicator of the effectiveness of reclamation, whereas in the estimation of the soil-formation factors and soil processes it is highly important to acquire knowledge on the quality of humus compounds. In the literature of the subject there are only a few studies [Pietrzykowski and Krzaklewski 2007] concerning the quality of humus compounds in soils formed through forest reclamation in Poland.

The objective of the study reported here was qualitative and quantitative analysis of humus compounds accumulated in soils formed of loams on external dumping grounds of the sulphur mine in Piaseczno, after 41 years of forest reclamation.

MATERIAL AND METHOD

The study was conducted on the crest of the dumping ground, on permanent test plots [Węgorek 2003] (covered with 41-year old tree stands) designated with the following numbers:

27 – one-floor stand of silver birch with 20% cover, the undergrowth covering 60% of the area (lime, oak, locusts (*Robinia*), dogwoods, birch, hazel), ground cover 70% (sedges, goldenrods, blackberry, horsetail, self-sown trees and bushes), mosses 20%;

44 – two-floor tree stand, upper floor formed by silver birch (20% of area coverage), and lower floor by lime and beech (90%), the undergrowth, ground cover and mosses attaining area coverage below 10%;

45 – two-floor tree stand, with upper floor of silver birch (50%), and lower floor of lime, oak and locusts (20%), the undergrowth (40%) and ground cover (80%) have species composition as those in area 27, mosses cover 20% of the area.

The soils forming under the tree stands are anthropogenic industrial soils with undeveloped profile, acc. to the Classification of Forest Soils of Poland [2000]: Ol-Ainan-Can. In all the plots the soil material consists of loams from the particle size composition groups of light loam, medium loam and heavy loam – in the profiles they appear in layers, in various arrangements [Węgorek and Flis-Bujak 2009].

Soil samples were taken in the test plots from the depths of 0–5, 5–10 and 20–25 cm (as averaged samples from 4 profiles in each test plot). Determinations performed included the content of $C_{org.}$ (oxidised) with the Tiurin method, and humus composition acc. to the method of Kononowa and Bieliczkowa [Kononowa 1968].

RESULTS AND DISCUSSION

The content of $C_{org.}$ in the soils decreased with increasing depth (Tab. 1). In the layer of 0–5 cm the highest content of $C_{org.}$ (30.4 $g \cdot kg^{-1}$) was noted in profile 44 under dense two-floor tree stand in which the lower floor (lime and beech) dominates in terms of area coverage. The lowest content of $C_{org.}$ in the 0–5 cm layer (22.6 $g \cdot kg^{-1}$) was found in profile 45, where the dominant species is birch which forms the upper floor. Whereas, in profile 27, under a negative birch tree stand (20% coverage) the content of $C_{org.}$ was only under 3 $g \cdot kg^{-1}$ lower than in plot 44, but 5 $g \cdot kg^{-1}$ higher than in plot 45. At the depth of 5–10 cm the content of $C_{org.}$ was similar in all the profiles (14–15 $g \cdot kg^{-1}$). Notable in the distribution of $C_{org.}$ content in the profiles is the high level of that component (10 $g \cdot kg^{-1}$) at the depth of 20–25 cm in plots 27 and 45 (Tab. 1).

Analysis of the relation between the content of $C_{org.}$ in the soil profiles and the structure of the vegetation cover showed that the species composition and degree of area coverage by the plants – under the conditions of the study – determi-

Table 1. Content of $C_{org.}$ and fractional composition of humus compounds

Profile	Depth cm	$C_{org.}$ $g \cdot kg^{-1}$	Compounds extracted with a mixture of 0.1 mol $Na_4P_2O_7$ + 0.1 mol NaOH				Compounds extracted with		Humus complexes bound with Ca $g \cdot kg^{-1}$ % $C_{org.}$	Humins $g \cdot kg^{-1}$ % $C_{org.}$
			C $g \cdot kg^{-1}$ % $C_{org.}$	Ckh $g \cdot kg^{-1}$ % $C_{org.}$	Ckf $g \cdot kg^{-1}$ % $C_{org.}$	Ckh : Ckf	0.1 mol NaOH	0.05 mol H_2SO_4		
							$g \cdot kg^{-1}$ % $C_{org.}$			
27	0–5	27.60	5.67 20.87	2.28 8.26	3.48 12.61	0.66	2.88 10.43	0.78 2.83	2.88 10.44	21.84 79.13
	5–10	13.80	1.92 13.91	0.60 4.35	1.32 9.56	0.45	0.96 6.96	0.30 2.17	0.96 6.96	11.88 86.09
	20–25	10.20	1.68 16.47	0.48 4.71	1.20 11.76	0.40	0.39 3.82	0.18 1.76	1.29 12.65	8.52 83.53
44	0–5	30.41	8.76 28.81	3.60 11.84	5.16 16.97	0.70	3.15 10.36	0.72 2.37	5.61 18.45	21.64 71.19
	5–10	14.85	4.44 29.90	1.32 8.89	3.12 21.01	0.42	1.62 10.91	0.60 4.04	2.82 18.99	10.41 70.10
	20–25	6.75	2.16 32.00	0.72 10.76	1.44 21.33	0.50	0.66 9.87	0.36 5.33	1.50 22.22	4.59 68.00
45	0–5	22.65	7.68 33.91	3.00 13.25	4.68 20.66	0.64	2.67 11.92	0.96 4.24	5.01 22.12	14.97 66.09
	5–10	15.00	4.56 30.40	1.56 10.40	3.00 20.00	0.52	1.08 7.20	0.66 4.40	3.48 23.20	10.44 69.60
	20–25	10.05	4.68 46.57	1.08 10.75	3.60 35.82	0.30	0.87 8.66	0.42 4.18	3.81 37.91	5.37 53.43

ned the amount of accumulated organic carbon. Birch gives a small falloff of organic matter that is hard to decompose [Bublinec 1984], therefore under tree stands with its domination in the species composition (plot 45) the level of $C_{org.}$ in the surface horizon of the soil was the lowest (the sparse supply of falloff from the trees could not be compensated for by falloff from the undergrowth). In the other tree stands birch covers only 20% of the area: in plot 44 beneath its canopy there is a dense (90%) lower floor, in which the dominant species is lime that gives abundant and easily decomposing falloff; in plot 27 there is a well developed (60% coverage) multi-species undergrowth that includes lime, hazel and locusts, among others. Those species determine the high quality of duff and, consequently, accumulation of $C_{org.}$ in the soil.

Analysis of the composition of humus compounds indicates that in the process of humification there formed and accumulated mainly fractions that do not undergo extraction (humins). Their share in the composition of humus constituted, as a rule, 70–80% $C_{org.}$ (Tab. 1). By the same token only a slight content of humus compounds related with silicate-less forms of R_2O_3 and Ca was observed (Tab. 1). Their lowest level was recorded in plot 27 – in the layer of 0–5 cm less than 21% $C_{org.}$ I, and in 5–10 cm under 14% $C_{org.}$. In profile 44, throughout the depth of the profile humus complexes with silicate-less forms of R_2O_3 and Ca constituted ca. 30% of C_{org}. In profile 45, the complexes in question accounted for over 30% of $C_{org.}$ in the layers of 0–5 and 5–10 cm, up to nearly 47% $C_{org.}$ at the depth of 20–25 cm.

Humic acids are one of the most important fractions in the composition of humus compounds. Among the humus acids extracted in the soils fulvic acids dominate over humic acids (Tab. 1). The index of quality of humus compounds, i.e. the ratio of Ckh : Ckf, assumed values of 0.64–0.70 in the layers of 0–5 cm. In the layers of 5–10 cm and 20–25 cm the domination of fulvic acids over humic acids intensified, and the ratio Ckh : Ckf varied within the range of 0.30–0.52.

In the soil profiles under analysis the share of free humus complexes and those bound with silicate-less forms of R_2O_3 (extracted with 0.1 mol NaOH) was varied. In profile 44 their content in relation to the content of $C_{org.}$ was similar at all depths and amounted to ca. 10%. In profiles 27 and 45 the level of those complexes decreased with increasing depth, from about 10 to ca. 4 and from approximately 12 to about 9% $C_{org.}$, respectively.

Among the analysed fractions a significant share was constituted by humus complexes bound with Ca, which may be related with the presence of carbonates and neutral reaction in the profiles [Węgorek 2003]. The highest level of those compounds was noted in profiles 44 and 45, at 18–22 and 22–37% $C_{org.}$, respectively (Tab. 1).

The content of humus compounds extracted with 0.05 mol H_2SO_4 varied from about 2% (profile 27) to approx. 5% $C_{org.}$ (profile 44) – Table 1.

A study by Pietrzykowski and Krzaklewski [2007], conducted in the area of a sand quarry in Szczakowa, under reclamation through afforestation (objects after 17–25 years of reclamation), revealed in the Ain horizon (pH $_{H2O}$ 5.2–5.4)

a notable variation in the values of the ratio of Ckh : Ckf (0.7–1.6); the share of humic acids (% $C_{org.}$) was distinctly higher than in the soils analysed in the study presented herein. Gilewska [1998] reports that the resources and quality of humus compounds formed in the process of 20-year agricultural reclamation and utilisation of post-mining lands (dumping grounds of overlay of a lignite deposit) were similar to those of a comparable arable soil. It should be noted that the fractional composition of the humus compounds in the soils studied cannot be related with the variation in the vegetation structure (species composition and density of three stands and undergrowth). The presented results of analyses of fractional composition indicate a different course of the process of humification in the reclaimed grounds as compared to natural soils studied by Flis-Bujak [1978], Turski [1988, 1996] or Drozd *at al*. [1993]. This generalisation, however, requires to be supported in further studies on dumping grounds, under different tree stands and on sandy soils. It should be emphasised that the soils studied are at the initial stage of development, and the vegetation assemblages are juvenile in character and therefore are characterised by a different fractional composition of humus compounds.

CONCLUSIONS

1. During 41-year forest reclamation there took placer accumulation of $C_{org.}$ in the amount of about 6–9 $g \cdot kg^{-1}$ at the depth of 0–5 cm, with simultaneous rapid drop in its content with depth (as a rule down to ca. 2 $g \cdot kg^{-1}$ at the depth of 20–25 cm).

2. In the process of humification, it was mainly humus substances which do not undergo extraction (humins) that were accumulated in the soils of the dumping grounds.

3. In the composition of humus acids fulvic acids dominate, and their domination increases down the soil profiles (down to 25 cm).

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SKŁAD FRAKCYJNY ZWIĄZKÓW PRÓCHNICZNYCH GLEB NA REKULTYWOWANYM ZWAŁOWISKU ZEWNĘTRZNYM KOPALNI SIARKI

Streszczenie. Po 41 latach leśnej rekultywacji wykonano badania zawartości i składu frakcyjnego związków próchnicznych gleb powstających z glin (do głębokości 25 cm) na zwałowisku zewnętrznym kopani siarki w Piasecznie. Stwierdzono znaczną akumulację $C_{org.}$ – od 7–10 $g \cdot kg^{-1}$ w warstwie 20–25 cm do 23–30 $g \cdot kg^{-1}$ w warstwie 0–5 cm. Zakumulowane są głównie substancje próchnicowe, nieulegające ekstrakcji (huminy). Udział ich w składzie frakcyjnym próchnicy stanowił 70–80% $C_{org.}$ W obrębie kwasów humusowych dominowały kwasy fulwowe nad kwasami huminowymi i przewaga ich pogłębiała się wraz ze wzrostem głębokości profilu.

Słowa kluczowe: rekultywacja leśna, węgiel organiczny, skład frakcyjny próchnicy, kwasy huminowe, kwasy fulwowe