Morphological and chemical characteristics of arable Vertisol from the Sofia soil province (Bulgaria)

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Abstract - *The morphological and chemical characteristics quickly reflect the changes in the soil matrix and are indicative of anthropogenic impacts. In our study we are discussing these for arable area developed as a result of intensive cultivation of soils for almost a century. The structural status of studied soils is also typical of Vertisols – lumpy-granular structure in the ploughing horizons and columnar-prismatic in the underlying horizons. Humus subhorizons are moderately humus (3.1-5%) and only the ploughing horizons might be estimated as highly humus (> 5% humus).*

Chemical parameters pH and sorption capacity show that as a result of the combined effects of the naturally occurring process of soil leaching and agricultural practices, the acid degradation of A-horizons of the moderately leached Smolnitsa from the land of Bankya city take place. The degradation processes cause the destruction of clay minerals and reduce their sorption capacity in contrast to the AC and C horizons where clays are unaffected by these processes.

Key words: exchange capacity, morphological characteristics, pH, humus, Vertisol

1. INTRODUCTION

Soil morphology as a science for organization provides basic information about origin and development of soils. It, however, should not be regarded as a static "stagnant" pattern, but as an only one stage in the series of consistent soil reorganizations [6]. Different neo-formations such as carbonate and iron-manganese concretions, phytolites and biolites are these highly informative indicators that show a concrete phase of the soil evolution. These components are relatively stable over time and preserve in their structure data on the surrounding ecological environment. Soil morphology combined with a thorough and accurate interpretation of soil chemical properties serves for determining the soil-forming processes and the soil place on a taxonomic level [7].

Chemical analysis also provides information on the soil degradation as a consequence of different natural and anthropogenic factors [18]. The most preferable and informative indicators for assessment of chemical status of soils are parameters pH and cation exchange capacity [9,17]. The exchange capacity, in particular, the cation exchange is one of the most important parameters in soil chemistry. It shows the quantity of the cations in the soil solid matrix that are capable of being exchanged with an equivalent amount of other cations occurring in the liquid and gaseous phases of soils. It is expressed by the total amount of ions that can be hold via exchange path under certain regularity [2]. Ion exchange, as it is well-known, occurs at the surface of colloidal structures that are saturated with negative charges as a result of non-equivalent isomorphic substitutions in the layered lattice of clay minerals, and from the acid ionization of the functional groups of humic substances. These negative charges are compensated by the positive charges of the cations adsorbed on the colloidal surfaces [11, 19]. The quantitative and qualitative characteristics of exchangeable ions and soil colloids are currently used in Bulgaria as an important sign of mineralogy, chemical reactivity and acid degradation of soils. An example of soils with high colloidal pedons are Vertisols. This soil type is widespread in the valleys of Southern Bulgaria, particularly in the Southwestern Bulgaria (Sofia, Radomir, Breznik, etc.). They occupy the total area of about 600 thousand hectares (5.45%) of the country's territory [13]. The cultivated are 530 thousand ha. This fact also determines the scientific interest of studying the characteristics of Vertisols in view of their sustainable management and fertility increase.

This study is aimed to reveal the morphological and chemical characteristics of arable Vertisols developed as a result of intensive cultivation of soils for almost a century. These characteristics quickly reflect the changes in the soil matrix and are indicative of anthropogenic impacts.

Materials and methods

In order to assess the extent of anthropogenic impacts on arable Vertisols, two soil profiles have been located in the previously studied areas (Figures 1-4).

Profile 1: Moderately leached Vertisol, deep, moderately clayey. WRB classification: Pellic Vertisol (Aric, Hypereutric, Humic, Amphygleyic).

The profile is positioned in the "Poleta" locality on the land of Bankya city, on 30 m Northeast from the railway Sofia-Bankya, in the lower part of a slightly pronounced Southern slope. The field is planted with barley (Figures 1 and 2).

Profile 2: Moderately leached Vertisol, deep, slightly clayey. WRB classification: Pellic Vertisol (Aric, Hypereutric, Humic, Amphygleyic).

The profile is located in the land of the village “Filipovtsi”, in the overflowing Kakach river terrace, on 15 m Southeast from “Shose Bankya” street, in a flat terrain with a very slight slope to the Southeast (Figures 3 and 4).

The following methods of analysis are applied:

1. Pretreatment of soil samples for physicochemical analysis - according to BDS ISO 11464.

2. pH (H_2O) determination - potentiometrically according to ISO 10390.

3. Cation exchange capacity – method of Ganev and Arsova (1980) [12]. This method determines the contribution of both the permenent, preferential charges (on basal surfaces, T_{CA}) and variation charges (basically pH dependent exchange including the lateral surfaces, T_A) of soil colloids to the cation exchange capacity by titration of soil extract (4 g of soil and several portions of 8 cm^3 of 1.0 n sodium acetate and 0.2 n potassium maleate with pH 8.25 to reach 100 cm^3) with 0.04 n sodium hydroxide solution in the presence of phenolphthalein to determine T_A and subsequent titration of the above eluate with 0.04 n complexon (after dilution up to 200 cm^3 with deionized water and addition of 10 cm^3 of triethanolamine and 2 cm^3 of 5.0 n potassium hydroxide solution-non-carbonate to achieve pH 12-13) in the presence of chromium-blue to determine T_{CA}.

4. Particle size distribution – method of Kachinsky [15]. This method differs from the method described in ISO 11277:2009 mostly in samples pretreatment (NaOH is used here as a dispersing agent) and sieves mesh sizes. The following size of major fractions are recognized by Kachinsky: Sand – this fraction involves particles with 1.00 - 0.05 mm equivalent spherical diameter; Silt fraction – from 0.05 to 0.001 mm equivalent diameter and Clay <0,001 mm.

5. Content of organic matter - the modified method of Turin was applied [10, 16]. It includes oxidation of the soil sample with 0.4 n $K_2Cr_2O_7$ and concentrated H_2SO_4 in a ratio 1:1 at 120 ^{0}C for 45 min. in the presence of Ag_2SO_4 followed by a titration with 0.2 n Mohr’s salt. Humus content is calculated by multiplication with the coefficient 1.724.

6. Content of carbonates (total amount) - method of Schiebler [1].

7. Soil sampling – according to BDS ISO 10381-2:2014.

8. Field study - BDS ISO 10381-4:2014.

Results and discussion

Studied soils are moderately leached Smolnitsa according to the Bulgarian soil classification [13] and might be described as: colloidal-rich soils developed on soil-forming materials with at least 30% clay content; saturated (up to 100 cm from the soil surface the degree of saturation with bases varies from 85.8 to 94.4%) with dark-colored (10 YR 2/1 to 10 YR 2/2, i.e., value below 4 and chroma below 3) humus-accumulative horizons, containing above 1.5% humus till 40 cm depth. Slight profile differentiation (texture coefficient of up to 1.04) and lack of churning soil material (the constant internal pedoturbation) are established in the Smolnitsa from the vicinity of Bankya city (profile 1). Oppositely there is a pedoturbation in profile 2, which affect the morphological, physical and chemical properties of ACck-horizon (Table 2). In both soils there is a firm (slightly sticky) moist horizon starting from the 30 cm of the soil surface and ≥ 20 cm thick with highest clay content, neutral pH and very dark grey color (10 YR 3/1 according to the Munsell soil color book) which was observed during the previous study [8]. The compaction between 45 and 55 cm of both pedons established in the present study resemble plough pan in low permeability and dark reddish-brown mottles and therefore could be considered a sign of anthropogenic alteration of soils.

The structural status of studied soils is also typical of Vertisols – lumpy-granular structure in the ploughing horizons and columnar-prismatic in the underlying horizons.

Table 1: Basic classification characteristics in profile 1

Soil horizon, depth (cm)	pH H_2O	Humus (%)	Carbo-nates (%)	Percentage distribution of mechanical elements by fractions (mm)				
				1-0.25	0.25-0.05	0.05-0.01	<0.001	Sum <0.01
Ap 0-30	5,5	4,00	-	4,0	10,7	13,4	48,9	71,9
A_2 30-50	7,0	1,79	0,76	2,5	3,4	15,7	56,1	78,4
A_3 50-110	6,1	1,58	-	2,9	10,7	11,1	54,6	75,3
ACcк 110-165	7,2	1,52	5,34	3,2	11,5	10,3	52,7	75,0
Cск 165-200	7,6	0,37	6,42	9,4	20,3	12,8	36,6	57,5

Humus subhorizons of studied soils are moderately humus (3.1-5%) and only the ploughing horizons might be estimated as highly humus (> 5% humus) according to the classification of Gurov and Artinova [13].

Table 2: Basic classification characteristics in profile 2

Soil horizon, depth (cm)	pH H_2O	Humus (%)	Carbo-nates (%)	Percentage distribution of mechanical elements by fractions (mm)				
				1-0.25	0.25-0.05	0.05-0.01	<0.001	Sum <0.01
Ap 0-30	6,2	3,40	-	5,2	16,5	17,1	38,4	61,2
A_2 30-100	6,5	1,66	-	3,7	8,9	7,6	47,6	79,8
ACск 100-150	7,0	0,71	0,4	3,7	25,3	13,6	36,2	57,4
Cск 150-170	7,7	0,19	3,83	6,0	37,5	13,8	25,3	42,7

Along chemical properties the difference between pH of ploughing horizon and A-subhorizons in the profile 1 strongly impresses, but typifies the effect of agriculture systems applied over the years. The strong heterogeneity of A-horizons in terms of pH suggests that the necessary agro-ameliorative practices have been carried out to improve the soil conditions - liming, manuring or fertilization. These activities, along with the recommended subsoiling tillage lead to observed changes in the chemical status of leached Smolnitsa from Bankya (profile 1). Data available in ISSAPP "N. Pushkarov" shows that changes in pH values of this soils have ensued after 1967 [8] - initially soils had pH (KCl), which gradually increased in depth: 4,6 → 4,9 → 5,3 → 7,0 → 7,2 while the distribution now has a non-linear character till 110 cm from the soil surface: 4,9 → 6,5 → 5,2 → 6,7 → 7,0.

Data in the table 3 reveal that the process of acidification affects the mineral adsorbent of soils. Physico-chemical quantities, shown in table 3 are used to characterize the chemical properties of soil adsorbent.

Table 3. Main exchangeable features of the studied soils

Horizon, depth (cm)	pH H_2O	$T_{8,2}$ (CEC)	T_{CA}	T_A	exch. $H_{8,2}$	exch. Al	exch. Ca	exch. Mg	V (%)
		cmol/kg							
Profile 1. Pellic Vertisol (Bankya city)									
Ap 0-30	5,5	49,30	42,80	6,50	7,00	0,30	35,80	6,50	85.80
A_2 30-50	7,0	51,50	47,50	4,00	3,00	0,00	42,10	6,80	94.40
A_3 50-110	6,1	49,30	43,20	6,10	5,40	0,00	37,10	6,60	89.10
ACск 110-165	7,2	54,00	50,20	3,80	0,50	0,00	47,60	6,30	99.10
Cск 165-200	7,6	50,90	0,0	0,0	0,00	0,00	45,50	5,40	100.00
Profile 2. Pellic Vertisol (Filipovtsi village)									
Ap 0-30	6,2	44,70	37,50	7,20	5,50	0,00	33,00	6,20	87.70
A_2 30-100	6,5	48,00	41,00	7,00	5,00	0,00	37,00	6,20	89.60
ACск 50-110	7,0	47,50	43,40	4,10	3,00	0,00	38,20	6,40	93.70
Cск 150-170	7,7	44,60	0,0	0,0	0,00	0,00	38,50	6,10	100.00

The parameter $T_{8.2}$ describes both the cation exchange capacity and the colloidal status of soils and is a measure of their physico-chemical reactivity. According to the physicochemical classification of Ganev (1990) [11], both Vertisols are highly colloidal soils ($T_{8,2}$ 45-65 cmol/kg) along the entire depth. In general, the cation exchange capacity varies slightly across soil depth. This is a consequence of homogeneous distribution of the soil adsorbent main component here - clay minerals. Further the dominant presence of montmorillonite clays can be expected due to the extremely high proportion of strongly acidic positions (T_{CA}). However, assuming the physicochemical classification of Ganev [11], Pellic Vertisol in the Bankya city can be defined as degraded-illuvial soil because of the ratios: $T_{8,2}$ in Ap / $T_{8,2}$ in Cck < 1 and $T_{8,2}$ in ACck / $T_{8.2}$ in Cк > 1. The degradation in Ap horizon, which is accounted by the first ratio, shows that besides the leaching process, a weak acidification also takes place and causes the degradation of colloidal structures. The acid degradation of Vertisols is associated with the formation of mobile humic acids. This process is facilitated by the heavily clayey composition of A-horizon and associated phenomena of surface over-wetting and anaerobic transformation of plant debris. As we have already mentioned, another factor that can significantly lower pH and cause an acid destruction of colloids, is the systemic use of ammonium fertilizers - they have well-known acidifying effect. A similar low ratio found in the A_3 horizon ($T_{8,2}$ in A_3 / $T_{8,2}$ in Cck <1) suggests a deep disruption of the colloidal structure in the humus horizon and high mobility of organic matter.

Figures 5 and 6 show the relative share (in percent of CEC) of each exchangeable cation in the formation of the cation exchange capacity, which is also indicative of functioning of soil colloids.

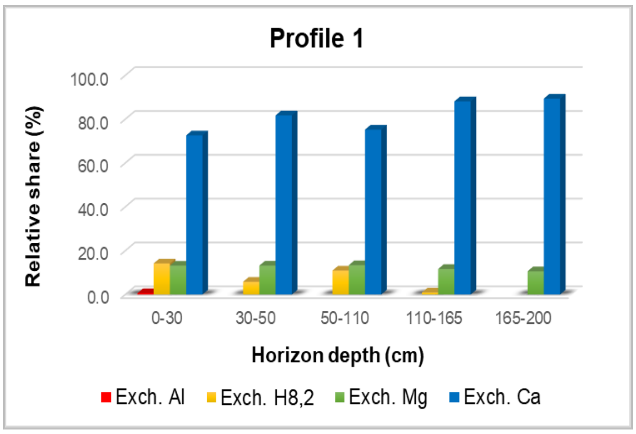

Fig.5. Relative share of basic exchangeable cations in profile 1

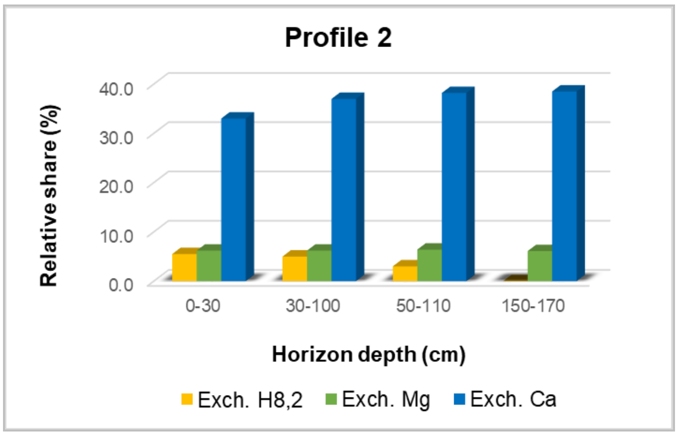

Fig.6. Relative share of basic exchangeable cations in profile 2

Soil colloids form a hydrolytic-acidic adsorption salt in the ploughing horizon of profile 1 composed of slightly basic aluminum cations and highly acidic anion surface of the soil adsorbent - T_{CA}. This reactive system further sustains the aggressive and toxic soil environment. The slightly acid soil reaction (pH 6.2) in the surface horizon of profile 2, is entirely due to hydrolytic acidity (exchangeable $H_{8.2}$) which occupies slightly acidic positions of the soil adsorbent - T_A. According to the Ganev's physicochemical theory, if the adsorption of hydrogen ions (exch. $H_{8.2}$) takes place only on the slightly acidic positions of the soil adsorbent (these are the lateral and defective surfaces of the clay minerals) could not cause acid destruction – this is established in soils neighboring the Filipovtsi village. The degree of saturation with bases (V, Table 3) varies from 87.7 to 100%, and classifies this soils as saturated (Hypereutric). The adsorption of hydrogen ions onto the strongly acidic positions (T_{CA}, Table 3) is found in the leached Smolnitsa from the land of Bankya city to causes the destruction of colloids and formation of exchangeable acidity (exch. Al). As we mentioned above it is a result of the combined effect of naturally and anthropogenicaly catalyzed acidification of the humus horizon, and causes a slight degradation of its physicochemical properties. Even in this horizon the degree of saturation with bases remains above 85% (Table 3), which determines the soils as saturated along the entire depth.

CONCLUSIONS

Studied Pellic Vertisols (Aric, Hypereutric, Humic, Amphygleyic) from the Sofia soil province are rich colloidal and saturated soils with moderate humus content and deep humus horizons. The major morphological hallmarks of the soils are stable and unchanged during their long-lasting cultivation but compaction established between 45 and 55 cm of both pedons could be considered a sign of modern anthropogenic alteration of soils. Among chemical parameters pH and sorption capacity are also an effective "barometer" of soil alteration and can be used as indicators of the degree of anthropogenic impact. They show that as a result of the combined effects of the naturally occurring process of soil leaching and agricultural practices, the acid degradation of A-horizons of the moderately leached Smolnitsa from the land of Bankya city take place. The degradation processes cause the destruction of clay minerals and reduce their sorption capacity in contrast to the AC and C horizons where clays are unaffected by these processes. The large depth of the humus horizon reduce the possibilities for performing fast actions to limit chemical degradation. Still, these data are concrete example and a basis for revision of the agricultural practices applied on Vertisols.

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