Physico-Chemical Properties of Regosols in Bulgaria

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Abstract

The paper deals with physico-chemical properties of Regosols in Bulgaria. Ten soil profiles are studied in North and South part of the country. These soils are spread mainly on unconsolidated rocks (regolith), slopes and eroded terrains in semi-arid areas. Sediments in these areas are manly alkaline with good sorption capacity. Regosols are moderately acidic to slightly alkaline soils. Exchangeable Ca^{2+} is almost equal to the soil cation exchange capacity. The amount of exchangeable Ca^{2+} is between 8 to 26 mequ/100g. Regosols have high base saturation from 75 to 100 %.

Key words: Regosols, Soil pH, CEC, Base Saturation

Introduction

In Bulgaria weak developed soils such as Regosols are formed mainly on unconsolidated rocks (Regoliths), slopes and eroded terrains usually in semi-arid areas. They are characterized with a weak process of soil formation, shallow profile with primary AC structure, as well as no diagnostic horizons. Regosols development is totally influenced by the properties of parent material. Sediments in these areas are manly alkaline with good sorption capacity. The main component that determine the soil reaction in these soils are carbonates (Hristov, 2014). The soil profiles contain high amounts of calcium carbonate, which increase in depth due to alkaline parent material. Carbonate minerals, such as calcite ($CaCO_3$), aragonite, and dolomite ($CaMg(CO_3)_2$), are considered to be the main sources for alkaline reaction of soils. Calcium and magnesium ions predominate in studied soils and respectively in their cation exchange capacity (CEC). Organic matter in Regosols is low (under 1 %) and CEC depends mainly from clay minerals content and composition. Well known fact is that CEC is the soil's ability to hold positively charged ions. This important soil property impacts soil reaction, soil structure stability, nutrient availability, and the soil's reaction to fertilizers and other ameliorants (Hazleton and Murphy 2007). Cations from the soil surface can be quite easily exchangeable with the cations from the solution (Tomašić et al.2013).In Bulgaria Regosols are slightly alkaline to medium acidic soils with pH form 8.2 to 5.2.

Many methods have been proposed for measuring CEC and exchangeable cations (ISO 11260, ISO 11464; Gillman, G. P. 1979; Sparks et al. 1996; Sumner et al. 1996). The most frequently used methods are based on soil cation exchange with solution of known concentrations of salts which contain cations that are not present in soil. In this study we use the method of Ganev et al. (1980), in which exchangeable ions were determined, titrimetrically and complexometrically, respectively, after saturation of the soil sample with buffer solution (Na-acetate and K-maleate, pH(H_2O) 8.2).

The aim of this paper is to determine the cation exchange capacity, as well as the content of exchangeable cations (Ca^{2+}, Mg^2+, Al^{3+} and $H_{8.2}^{+}$), soil pH and base saturation of Bulgarian Regosols and the relationships between them.

Foto 1. *Typical hilly relief in North Bulgaria.*

Material and Methods

Ten soil profiles were studied. Three of them are form South Bulgaria (profile 1,2 and 501) the rest of them are form northern part of the country.

According to WRB2014 classification and location soil profiles are: Profile 1, Calcaric Regosol (Loamic Ohric) in v. Vinogradi, (Teoharov, 2009); Profile 2, Calcaric Regosol (Loamic Ohric) in v. Melnik, (Teoharov, 2009); Profile 501, Calcaric Regosol (Loamic Ohric) in v. Sklave, (Teoharov, 2009); Profile 4, Eutric Regosol (Loamic), in v. Yakimovo; Profile 5, Eutric Regosol (Loamic) in v, Yakimovo; Profile 11, Calcaric Regosol (Siltic, Ohric) in v. Musalievo; Profile 14, Calcaric Regosols (Siltic, Ohric) in v. Milkovitza; Profile 15, Calcaric Regosol (Siltic, Ohric) in v. Milkovitza; Profile 16, Eutric Regosol (Arenic, Ohric) in v. Milkovitza; Profile 18, Calcaric Regosol (Loamic, Ohric) v. Opanetz.

Foto 2. *Profile 1, over Pliocene sediments, village of Vinogradi, South Bulgaria*

The main diagnostic soil characteristics were obtained using the following methods: Soil pH was measured in water suspension 1:2.5. The exchangeable Al^{3+} was determined titrimetrically after displacement of Al^{3+} ions by 1N CaCl2. The total exchangeable hydrogen exch. $H_{8.2}^{+}$ (total acidity) and exchangeable bases (Ca^{2+} and Mg^{2+}) were determined, titrimetrically and complexometrically, respectively, after saturation of the soil sample with buffer solution (Na-acetate and K-maleate, $pH_{(H2O)}$ 8.2). The cation exchange capacity (CEC) was calculated by the sum of $H_{8.2}^{+}$ and exchangeable bases in mequ/100g method of Ganev et al. (1980). Base saturation is the percentage of CEC that is saturated with base exchangeable cations (Ca2+ and Mg2+), V%=Σsum of base exchangeable cations/CEC*100. For statistical analyses and graphics was used Microsoft Excel 2010 software.

Foto 3. *Profile 18, over quaternary loess, village of Opanetz North Bulgaria*

Results and Discussion

According to analyzed soil samples in Table 1, Regosols are moderately acidic to slightly alkaline soils with $pH_{(H2O)}$ form 5.2 to 8.2, with mean value 7.18 and median 7.6 (table 2) . These soils could have lower pH in mountains regions especially under conifer vegetation. Our soil profiles are spread manly over calcareous sediments with alkaline reactions but in some high steeply places carbonates are washed by rainfalls and consequently the pH is lower such as in profile 16. Statistical correlation matrix (table 3) shows that soil pH correlate mostly with base saturation (0.95) and it has strong correlation with exchangeable Ca^{2+} (0.63).

Table1. *Soil pH (H2O), CEC, Exchangeable Ca^{2+}, Mg^{2+} , $H_{8.2}^{+}$, Al^{3+} , Base Saturation*

Horizon / Depth (cm)	pH/ H_2O	CEC	Ex. $H_{8.2}^{+}$	Ex. Al^{3+}	Ex. Ca^{2+}	Ex. Mg^{2+}	Base Saturation %
		mequ/100g					
		Profile 1. Calcaric Regosol (Loamic Ohric), (Teoharov, 2009)					
A_k 0 – 17	7.5	24.49	0.0	0.0	23.14	1.35	**100**
AC_k 17 – 30	8.0	25.48	0.0	0.0	24.98	0.50	**100**
C_k 30 – 50	8.3	19.04	0.0	0.0	18.30	0.74	**100**
		Profile 2. Calcaric Regosol (Loamic Ohric), (Teoharov, 2009)					
A_1 0 – 17	6.7	15.46	2.11	0.0	9.40	3.95	**86.35**
C_1 17 – 30	7.7	16.94	0.0	0.0	14.84	2.10	**100**
		Profile 501. Calcartic Regosol (Loamic Ohric), (Teoharov, 2009)					
A_k 0 – 20	8.0	22.00	0.80	0.0	17.60	3.60	**96.40**
C_k 20 – 47	8.2	15.70	0.50	0.0	12.20	3.20	**96.80**
		Profile 4. Eutric Regosol (Loamic)					
A_h 0 – 14	6.0	22.0	4.5	0.0	15.0	2.3	**79.55**
$C_к$ 14 - 30	5.8	20.8	5.0	0.5	13.2	2.5	**75.96**
		Profile 5. Eutric Regosol (Loamic)					
A_k 0 - 20	5.8	21.0	4.8	0.4	13.0	2.8	**77.14**
C_k 20 – 40	5.2	20.1	5.2	0.9	12.4	2.6	**74.13**
		Profile 11. Calcaric Regosol (Siltic, Ohric)					
A_k 0 – 18	7.9	24.8	0.0	0.0	21.5	3.3	**100**
C_k 18 – 35	8.3	24.7	0.0	0.0	21.2	3.5	**100**
		Profile 14. Calcaric Regosols (Siltic, Ohric)					
A_k 0 – 10	7.6	29.0	0.0	0.0	26.0	3.0	**100**
AC_k 10 – 32	7.8	25.4	0.0	0.0	22.0	3.4	**100**
		Profile 15 Calcaric Regosol (Siltic, Ohric)					
A_h 0 – 16	6.4	23.9	3.5	0.0	17.5	3.0	**85**
C_k 16 –35	7.4	20.0	0.0	0.0	16.8	3.0	**100**
		Profile 16. Eutric Regosol (Arenic, Ohric)					
A_h 0 – 15	5.5	15.0	3.2	0.5	10.5	1.2	**78.67**
C_1 15 – 30	6.5	9.9	0.8	0.0	8.0	1.0	**91.92**
		Profile 18. Calcaric Regosol (Loamic, Ohric)					
A_k 0 – 14	8.1	25.9	0.0	0.0	22.6	3.3	**100**
C_k 14 – 30	**8.0**	**21.9**	**0.0**	**0.0**	**18.5**	**3.4**	**100**

Studied soils have average cation exchange capacity (Mean=21 mequ/100g) with values between 9.9 to 29 mequ/100g. The fact is that profiles 16 with lowest CEC and profile 14 with highest are spread over loess in North Bulgaria, but profile has sandy (arenic, WRB 2014) texture with low clay content (Hristov, 2014).

Similar CEC have Calcic Chernozems in North Bulgaria spread also over loess between 29 to 20 mequ/100g (Ganev et al. 1990) . Higher CEC in Bulgaria have Vertisols, Haplic Chernozem, Phaeozems and other caly rich soils (Ganev et al., 1990; Nikova et al., 2011; Hristova et al., 2002). Sandy and shallow soils such as Cambisols, Arenosols and Leptosols have lower CEC and base saturation (Andreeva, 2014; Kirilov et al., 2015).

Accodring Malinova (2016) Regosols in Central Balkan mountain have CEC between (47 – 4, cmol(+).kg^{-1}). In this mountain area CEC depends also form parent rock. The soils developed on weathering materials of gneiss and granite have higer CEC and Base Saturation than and those developed on white gneiss and schist.CECs correlate totally and only with exchangeable calcium (0.90) because in most of the soil profiles exch. Ca^{2+} is almost equal to the soil CEC, and all other cations are in low quantities (Figure 1). Calcium is the most plentiful cation occupying 75% or more of the sites on the cation exchange complex of soil that is neutral to slightly acidic. Calcium is adsorbed strongly as compared with other exchangeable cations.(Ganev, 1990, Sposito, 1989, Benkova et al., 2003)

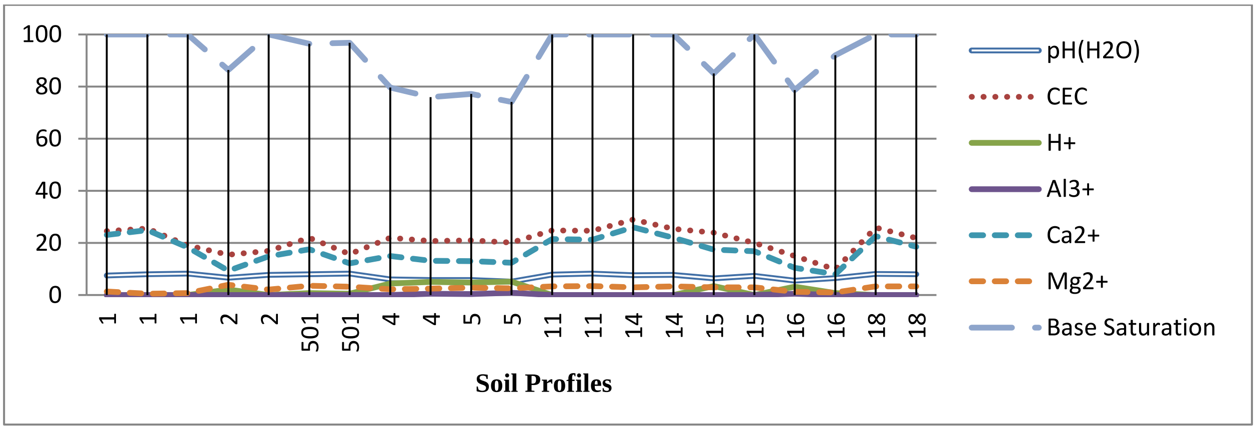

Figure 1. *Graphical distribution - soil pH, CEC, Exchangeable Ca^{2+}, Mg^{2+}, H^{+}, Al^{3+}, Base Saturation*

Calcium is also found in the silt particle size fraction. That is why soils with more clay adsorb more calcium. This is particularly the case in loess and quaternary sediments (Hristov et al., 2010). As it was mentioned above carbonate minerals, such as calcite ($CaCO_3$), aragonite, and dolomite ($CaMg(CO_3)_2$), are considered to be the main sources for exch. Ca^{2+} in soil. The amount of exch. Ca^{2+} varies from 8 to 26 mequ/100g . Correlation matrix (Table 3) shows that exchangeable calcium correlates well with other data. In addition to strong correlation between CEC and soil pH, there is also good relation with base saturation (0.66).

Other exchangeable basic cation such as Mg^{2+} also could be found in sediments and carbonate minerals like dolomite. The behavior of magnesium in soil is similar to calcium. Regosols and other soils often contain less magnesium relative to calcium. This is because a magnesium ion is not adsorbed as tightly by clay particles and organic colloids (Rytwo et al. 1996). In general, the source of magnesium in regolith is less than that for calcium. As an exchangeable cation in neutral to slightly acidic soil, magnesium is commonly second in abundance to calcium. In studied profiles the amount of exchangeable Mg^{2+} is between 0.5 to 3.95 mequ/100g.

In contrast to other cations like K, Ca, and NH^{4+}, Mg is less mobile in soils. Whereas the ionic radius of Mg is smaller than that of Ca, K or Na, its hydrated radius is substantially larger (Shaul 2002; Gardner2003; Maguire et al. 2002). One consequence is that Mg is less strong bound to soil charges (CEC) leading to compared to other cations higher Mg concentrations in the soil solution (Gransee et al. 2013). That is one of the reasons why Mg^{2+} doesn't correlate with CEC, Ca^{2+}, ect.

Table 2. *Descriptive statistic - soil pH, CEC, Exchangeable Ca^{2+}, Mg^{2+}, $H_{8.2}^{+}$, Al^{3+}, Base Saturation*

	pH(H2O)	***CEC***	***$H_{8.2}^{+}$***	***Al^{3+}***	***Ca^{2+}***	***Mg^{2+}***	***Base Saturation***
Mean	7,18	21,12	1,45	0,11	17,08	2,56	92,47
Maximum	8,3	29	5,2	0,9	26	3,95	100
Minmum	5,2	9,9	0	0	8	0,5	74,13
St. Dev.	1,03	4,58	2,00	0,25	5,22	1,03	9,88
Median	7,6	21,9	0	0	17,5	3	100

Chemical index of total acidity of soils ($H_{8.2}^{+}$) is the sum of all exchangeable cations with acidic functions, adsorbed on strongly acid and weekly acid ion exchangers of the soil colloids (Ganev, 1989). Total acidity in studied soils is low, from 0 to 5.2 mequ/100g. The reason for that are carbonates with high pH in parent rocks as it was mentioned above. Thus, total acidity of the soils shows inverse correlation with soil pH, Base Saturation, exchangeable Ca^{2+} and it has positive correlation only with soil exchange acidity (exch. Al^{3+}).

Table 3. *Correlation matrix - soil pH, CEC, Exchangeable Ca^{2+}, Mg^{2+}, $H_{8.2}^{+}$, Al^{3+}, Base Saturation*

	pH(H2O)	***CEC***	***$H_{8.2}^{+}$***	***Al^{3+}***	***Ca^{2+}***	***Mg^{2+}***	***Base Saturation***
pH(H2O)	1,00						
CEC	0,35	1,00					
H^{+}	-0,91	-0,20	1,00				
Al^{3+}	-0,76	-0,19	0,75	1,00			
Ca^{2+}	0,63	0,90	-0,56	-0,43	1,00		
Mg^{2+}	0,15	0,28	0,00	-0,11	0,05	1,00	
Base Saturation	0,95	0,32	-0,98	-0,78	0,66	0,05	1.00

Soil exchange acidity (exch. Al^{3+}) is the acidity of the strongly acid positions of soil adsorbent (exchange aluminum, manganese, zinc etc., amphoteric cations and eventually hydrogen ions)(Ganev, 1989). In the studied soil profiles exch. acidity is too low almost zero and it has no influence on soil properties.

The sum of basic exchange cations expressed in per cent (%) of the value of total CEC is the degree of base saturation. Regosols have high base saturation between 75 – 100 % due to high amount of exch. Ca^{2+} and in addition exch. Mg^{2+}. According to correlation matrix base saturation has strong positive correlation with soil pH and exch. Ca^{2+}. Otherwise it has inverse correlation with soil total acidity ($H_{8.2}^{+}$) and exchange acidity (exch. Al^{3+}).

Conclusion

Regosols in Bulgaria are spread manly over calcareous sediments with alkaline reaction. They are moderately acidic to slightly alkaline soils with $pH_{(H2O)}$ form 5.2 to 8.2. Studied soils have cation exchange capacity with values between 9.9 to 29 mequ/100g. CEC correlate totally and only with exchangeable calcium (0.90), because in these soils exch. Ca^{2+} is almost equal to soil CEC. Loess and other quaternary sediments are considered to be the main sources for exch. Ca^{2+} of the soils. The amount of exch. Ca^{2+} vary from 8 to 26 mequ/100g . Regosols contain less magnesium relative to calcium because magnesium ion is not adsorbed as tightly by clay particles and organic colloids. In studied profiles the amount of exchangeable Mg^{2+} is between 0.5 to 3.95 mequ/100g . Total acidity and exchange acidity are in low quantities and the reason for that is high base saturation form 75 to 100 %.

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