

THE DYNAMICS OF COLLOIDAL SYSTEM IN LOESS SOILS

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A b s t r a c t. In horizons of brown soils - arable and forest, developed from loess - basic characteristics were determined and the mineral content of fractions $<2\mu\text{m}$. Mobility of fractions $<2\mu\text{m}$ was found when determining the coagulation factor - K, stabilisation factor - St, and mobility factor - R. In model experiments the influence of CaCO_3 on the behaviour of soil colloids at humus level was defined. When calculating the relationship between the amount of colloids isolated in three centrifugations by water and the amount of colloids isolated by 0.2 % solution of Li_2CO_3 , the eluviation factor of the fraction $<2\mu\text{m}$ was determined.

It was established that in arable soil the eluviation factor of the fraction $<2\mu\text{m}$ is the highest at horizon A, whereas in forest brown soil the factor achieves its highest value at the browning horizon. The addition of calcium carbonate to forest brown soil lowered the value of the eluviation factor to a considerable extent. The coagulation, stabilisation and mobility factors changed distinctly.

Almost a linear relationship exists between the reaction of soil and the value of eluviation factor. The factor calculated from fraction $<2\mu\text{m}$ allows determining at which pH values of soil solution the mobilization and leaching of soil colloids begins. It seems that such research will enable us to learn mechanisms of soil degradation under the influence of acidification, and define the methods of prevention.

Key words: loess soil, dynamic of colloids

INTRODUCTION

The course and intensity of the eluvial process in soils depends upon their composition and characteristics and land use category. In this process different phenomena like dissolving, washing out and moving of high-dispersion

molecules take place, which cause a degradation of sorptive complex in the soil, as well as an eutrophication of waters [2-10].

One of the most important factors influencing the mobility of soil colloids is the soil reaction. This is why the aim of this work was to analyse in laboratory conditions the dynamics of soil colloids (fractions $<2\mu\text{m}$) in brown soils developed from loess and to determine the influence of calcium carbonate on their stabilisation.

METHODS

Two kinds of brown soils produced from loess, with similar profile construction but differently used were the subject of research (Table 1). In samples taken from genetic horizon of the soils under study, basic characteristics were examined in the laboratory with the help of procedures widely used in soil science.

The mineral composition of fraction $<2\mu\text{m}$ was determined with X-ray diffractometer and by the thermal analysis method. Mobility of the fraction $<2\mu\text{m}$ was defined by the method described by Blümel *et al.* [1], when determining the coagulation factor - K, stabilisation factor - St, and mobility factor - R. In order to find the quantitative changes in the mobility of soil colloids under the influence of calcium carbonate, it was added to the soil in different amounts, and then the quantity of fractions $<2\mu\text{m}$ washed out

Table 1. Localization and more important morphological features of the soils under study

Name of soil, land use category, relief	Symbol of horizon	Depth of the horizon (cm)	Special features of the horizon
Profile 1 Biały Kościół brown soil arable field, slight slope	A	0-30	silty dust , dark grey, granular structure, loose system, gradual changes
	Bbr	30-70	silty dust , granular-prismatic structure, slightly compact system, gradual changes
	C	70-150	silty dust , yellow, loose, few CaCO ₃ concretions
Profile 2 brown soil deciduous forest (beeches 60 years)	O	0-3	duff at a medium grade of decay
	A	3-18	silty dust , dark grey, granular structure, loose system, gradual changes
	Bbr	18-60	silty dust , granular-prismatic structure, loose system, gradual changes
	C	60-150	silty dust , yellow, loose with CaCO ₃ concretions

by water and by lithium carbonate in three successive centrifugations was defined. The obtained results are presented in Tables 1-4 and Fig. 1.

RESULTS AND DISCUSSION

The differences in the granulometric composition, especially in the content of clay fractions in particular levels within a profile, as well as among the analysed profiles - is first of all the result of soil processes taking place in them (Table 2). The lower content of silt and clay parts and colloidal clay fractions in the brown soil humus horizon of the profile 1 is probably connected with the visible eluvial process.

In the soil under study a movement of cations of base character down in the soil profile (Table 3) takes place. In concerns especially calcium carbonate existing within the soil profile, where in forest brown soil it occurs deeper than in arable brown soil. The content of organic carbon is higher in profile 1 (Table 3). The soils under study are very different in respect of reaction. The arable brown soil at humic level has a slightly acid reaction, whereas the forest brown soil at level A has a strongly acid reaction. The parent-rock of the soil under study has a base reaction.

On the basis of diffractometrical analysis and thermal analysis it was found that the mineral

Table 2. The granulometric and mineralogical composition of fractions <2 μm of the soils under study

Soil profile	Depth of sampling (cm)	Horizon	Content of fractions (%)									Mineralogical composition of fractions <2 μm
			1.05	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.006	0.006-0.002	<0.002	<0.02	
1	5-15	A	2	2	4	11	39	21	6	15	42	(I-S) ₂ , I ₂ , S ₃ , K ₃ , Q ₄
	40-50	Bbr	1	2	4	9	40	16	7	21	44	(I-S) ₂ , I ₂ , S ₃ , K ₃ , H ₄ , Q ₄
	140-150	C	-	-	2	10	41	20	6	19	45	I ₂ , S ₂ , K ₃ , (I-S) ₃ , H ₄ , Q ₄
2	5-15	A	1	1	1	12	35	25	5	20	50	(I-S) ₂ , I ₂ , S ₃ , K ₃ , Q ₄
	40-50	Bbr	-	1	1	13	40	19	4	22	45	(I-S) ₂ , I ₂ , S ₃ , K ₃ , Q ₄
	140-150	C	2	2	4	20	36	20	4	12	36	I ₂ , S ₂ , (I-S) ₃ , K ₃ , H ₄ , Q ₄

Explanations: I-minerals from illite group, S-minerals from smectite group, K-minerals from kaolinite group, I-S-minerals of mixed structures, H-hydrobiotite, Q-quartz, quantitative content: 2 - 25-40 %, 3 - 10-25 %, 4 - < 10 %.

Table 3. Some chemical features of the soils under study

Soil profile	Sampling depth (cm)	Horizon	CaCO ₃ (%)	C _{org} (%)	pH		Hh (mmol H ⁺ /100 g)	S (mmol(+)/100 g)	T (mmol(+)/100 g)	V (%)
					H ₂ O	KCl				
1	5- 15	A	0.0	1.74	6.3	2.4	2.4	9.3	11.7	79
	40- 50	B1br	0.0	0.25	6.8	2.1	2.1	11.8	13.9	84
	60- 70	B2br	0.0	-	6.8	1.8	1.8	12.0	13.8	87
	100-110	C1	1.0	-	7.6	1.1	1.1	12.1	13.2	91
	140-150	C2	4.0	-	7.8	1.0	1.0	14.1	15.1	93
2	5- 15	A	0.0	1.17	4.5	5.4	5.4	8.6	14.0	61
	40- 50	Bbr	0.0	0.29	4.5	3.1	3.1	9.3	12.1	74
	90-100	C1	0.0	-	4.3	1.5	1.5	12.4	13.9	88
	140-150	C2	8.6	-	7.9	0.8	0.8	20.2	21.0	96

composition of fractions <2 μm of the soils under study is very similar. The main minerals of colloidal fraction as illite, smectite, and mineral of mixed-packet illite-smectite structure. The accompanying minerals are: kaolinite, hydrobiotite and high-dispersion quartz. Hydrobiotite does not occur at accumulation horizons and it would suggest a stronger weathering degree of these horizons in comparison with parent rock [3,5].

In Table 2 a quantitative mineralogical characteristics of the particular horizons is presented, on the basis of the intensity of diffraction from crystal planes 001 in a four-grade scale.

It is easy to observe, when analysing the content of minerals at the particular horizons that the top horizons contain more minerals of mixed-packet illite-smectite structure. On the basis of glycerin test it was found that at the parent rock far more smectite occurs than at surface levels. Kaolinite, which content in the soils under study was established at 10-25 %, occurs more frequently at horizons A than at horizons C. The mineral content of colloidal fraction of soils under study is not dependent upon the way of using them [5].

The results of analysis of the soils under study (Table 4) prove that the accumulation horizons show a high mobility of molecules <2 μm. The mobility factor R reaches its top value at the browned horizon of forest soil. It can be explained by the low pH and the oxidic conditions. The parent-rock of both soils under study has the lowest value of mobility factor, which is

connected with the high pH and the presence of CaCO₃. The values of coagulation factor - K and the stabilisation factor - St of fractions <2 μm are arranged inversely. These factors take their lowest values at A horizons, with the exception of the browned horizon in profile 2, where both the coagulation factor and the stabilisation factor are the lowest ones.

The obtained results allow determining the extent to which fraction <2 μm is prone to move under the influence of water or 0.2 % solution of lithium carbonate. When calculating the proportion of amount of colloids washed out in three centrifugations in water W_i and the amount of colloids washed out in three successive centrifugations in 0.2 % solution of lithium carbonate Li_i we can determine the mobility of fractions <2 μm. The amount defined in this way was conventionally called in this work the factor of eluviation (movement, washing out) of fractions <2 μm and given the symbol E1.

$$E1 = \frac{\sum_{i=1}^3 W_i}{\sum_{i=1}^3 Li_i} \cdot 100$$

where 1, 2, 3 successive centrifugations in water and lithium carbonate solution. The calculated eluviation factors (in %) for particular soil horizons under study (Table 4) are the resultant and factors influencing the coagulation,

Table 4. Results of analysis of the mobility and stability of fractions < 2µm of the soils under study

Profile No.	Level	Sampling depth (cm)	Colloidal fraction (cm ³)										K*	St	R	EI	
			Centrifuging with water (W)					Centrifuging with 0.2% Li ₂ CO ₃ (Li) solution									
			1	2	3	2+3	1+2+3	1	2	3	2+3	1+2+3					
1	A	5-15	1.6	2.1	2.1	4.2	5.8	3.7	3.7	2.8	6.5	10.2	2.37	1.5	0.26	56.0	
	5 g A+0.05 g CaCO ₃		0.1	0.2	1.4	1.6	1.6	9.4	6.6	3.3	9.9	19.3	100	6.2	0.01	8.3	
	5 g A+0.1 g CaCO ₃		0.1	0.2	1.3	1.5	1.5	9.2	6.5	3.3	9.8	19.0	100	6.5	0.01	7.6	
	5 g A+0.25 g CaCO ₃		0.1	0.2	1.6	1.8	1.8	10.2	6.4	3.6	10.0	20.2	100	5.5	0.01	8.9	
	5 g A+0.5 g CaCO ₃		0.1	0.2	1.2	1.4	1.4	10.5	6.2	3.6	9.8	20.3	100	7.0	0.01	6.9	
	Bbr	40-50	0.9	3.0	3.9	6.9	7.8	8.7	6.6	4.6	11.2	19.9	9.66	1.6	0.09	39.0	
	C1	100-110	0.4	2.1	3.1	5.2	5.6	5.2	3.8	2.7	6.5	17.7	13.0	1.2	0.07	31.0	
	C2	135-145	0.1	0.2	1.8	2.0	2.1	7.6	5.7	3.5	9.2	16.8	76.0	4.6	0.01	12.5	
	2	A	5-15	3.0	2.8	2.3	5.1	8.1	9.3	4.7	2.6	7.3	16.8	3.10	1.4	0.22	48.0
		Bbr	40-50	4.3	4.3	3.2	7.5	11.8	9.8	6.1	3.7	9.8	19.6	2.28	1.3	0.28	60.0
C1		90-100	0.8	2.4	1.8	4.2	5.0	7.0	6.7	3.4	10.1	17.1	8.75	2.1	0.09	29.0	
C2		140-150	0.6	0.6	1.1	1.7	2.3	7.0	4.0	3.7	7.7	14.7	11.6	4.5	0.06	15.6	

*Explanations: K = Li₁/W₁; St = Li₂₊₃/W₂₊₃; R = 1/K + St; EI = $\sum_{i=1}^3 W_i / \sum_{i=1}^3 Li_i \cdot 100$.

stabilisation and mobility of fractions $<2 \mu\text{m}$. It can be assumed that the value of eluviation factor is proportional to the intensity of the eluviation process. In arable soil the eluviation factor is the highest at A horizon, whereas in forest soil the factor takes its highest value at the browned horizon. It proves that these levels are in the existing conditions within the reach of eluviation process.

In order to determine in what way the soil pH influences the value of eluviation factor, to the analysed 5 g sample of soil with natural humidity from the humus horizon of profile 1 in successive analyses respectively: 0.05g CaCO_3 , 0.1 g CaCO_3 , 0.25 g CaCO_3 and 0.5 g CaCO_3 were added.

Calcium carbonate, irrespectively of its amount added, clearly lowered the value of eluviation factor and radically changed the values of R, K and St (Table 4). It proves that activation and washing out of colloids in alkaline environment is practically stopped.

The relation between the value of eluviation factor and the exchange acidity of arable and forest brown soils is presented in Fig. 1.

On the basis of that diagram it can be proved that an almost linear relationship exists between the exchange acidity of a soil and the eluviation factor value. Only at horizons A and Bbr of forest brown soil, at the same value of pH in 1n KCl the value of E1 is higher for the browned horizon. Most probably this can be explained by the protective action of organic colloids occurring at the accumulation horizon of forest brown soil.

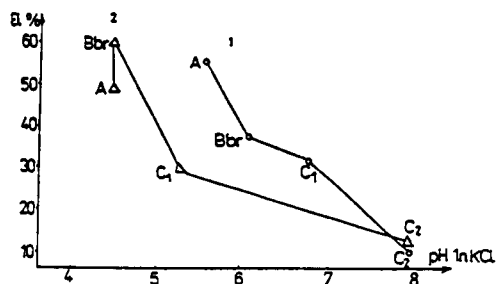


Fig. 1. Relationship between the eluviation factor and the pH value.

CONCLUSIONS

The introductory research carried out on dynamics of colloids (fractions $<2 \mu\text{m}$) in arable and forest brown soils showed that:

- mobility of colloids in the top horizons of the soils under study depends on the pH value;
- it is possible to determine empirically for particular soil, at what values of pH activation and movement of soil colloids starts;
- introductory research on the soil colloids dynamics presented here enables finding out about the mechanisms of soil degradation as a result of natural and anthropogenic causes.

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DYNAMIKA KOLOIDÓW W GLEBACH LESSOWYCH

W poziomach gleb brunatnych - omej i leśnej wytworzonych z lessu - oznaczono podstawowe właściwości oraz skład mineralny frakcji $<2 \mu\text{m}$. Ruchliwość frakcji $<2 \mu\text{m}$ oznaczono określając współczynnik koagulacji - K, współczynnik stabilizacji - St oraz współczynnik ruchliwości - R.

W doświadczeniach modelowych określono wpływ CaCO_3 na zachowanie się kolidów glebowych w poziomie próchnicznym. Obliczając stosunek ilości kolidów wyizolowanych

w trzech odwirowaniach przez wodę do ilości koloidów wyizolowanych przez 0.2% roztwór Li_2CO_3 określono wskaźnik eluwiacji frakcji $<2 \mu\text{m}$.

Stwierdzono, że w glebie brunatnej omiej wskaźnik eluwiacji frakcji $<2 \mu\text{m}$ jest najwyższy w poziomie A, natomiast w glebie brunatnej leśnej wskaźnik przyjmuje najwyższą wartość w poziomie brunatnienia. Dodanie węgla wapnia do gleby brunatnej leśnej w wyraźny sposób obniżyło wartość wskaźnika eluwiacji. Zmieniły się znacznie współczynniki: koagulacji, stabilizacji i ruchliwości.

Istnieje prawie liniowa zależność między odczynem gleby a wartością wskaźnika eluwiacji. Uzyskany wskaźnik dla frakcji $<2 \mu\text{m}$ pozwala określić przy jakich wartościach pH roztworu glebowego zaczyna się uruchamianie i wypłykiwanie koloidów glebowych.

Wydaje się, że tego typu badania umożliwiają nam poznanie mechanizmów degradacji gleb pod wpływem zakwaszenia oraz określenie sposobów ich zapobiegania.

S ł o w a k l u c z o w e: gleby lessowe, dynamika koloidów.