Note

Sorption properties of separate granulometric fractions in Haplic Cambisol

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A b s t r a c t. The research was focused on testing the sorption properties of granulometric fractions isolated from genetic horizons of Haplic Cambisol developed from old-alluvial deposits of the Vistula River valley. The granulometric fractions were isolated using the Atterberg method, without centrifugation and application chemical peptizers. Granulometric fraction exchangeable sorption capacity was particularly similar to the fraction of soils developed from post-glacial rocks in the studied soil. The cation exchange capacity of the granulometric fractions increased with decrease of grain dimensions with mean value in cmol(+)kg^{-1} and contribution in particular fractions at 1-0.1 mm – 0.89 (0.9%), 0.1-0.02 mm – 2.3 (2.2%), 0.01-0.02 mm – 7.91 (8.0%), 0.01-0.005 mm – 16.17 (15.6%), 0.005-0.002 mm – 27.6 (27.6%) and <0.002 mm – 78.98 (45.7%). Sorption properties of the examined soil determine its high agricultural value and resistance to chemical degradation. The dominating cations in the particular granulometric fractions sorption complex were exchangeable calcium and hydrogen, and the leaching process reduced the granulometric fraction calcium content in the surface levels and at the same time increased the hydrogen content. Leaching process intensity in individual fractions decreased gradually as their dimensions decreased, which explains the high susceptibility of coarse-grained soils (sandy soils) to this process.

K e y w o r d s: granulometric fractions, cation exchange capacity

INTRODUCTION

Soil granulometric composition has great influence on sorption (Skic *et al.*, 2016; Czaban *et al.*, 2014), physical features (Brogowski and Kwasowski, 2015; Brogowski *et al.*, 2014; Rafraf *et al.*, 2016; Malik *et al.*, 2014), biological properties (Stemmer *et al.*, 1998), soil typology (Kozłowski and Komisarek, 2017a, b; Musztyfaga and Kabała, 2015) and determines soil fertility and management (Kalembasa *et al.*, 2011). So far, to recognize the role of grain size, extensive studies were performed on the sorption properties of particular granulometric fractions (Okołowicz, 1996; Asadu *et al.*, 1997) and analysis of surface microstructures to understand the weathering process and formation of sorption properties (Morrás, 1995; Brogowski and Kocoń, 1984). These studies allow for further recognition of the mechanisms of sorption, desorption, migration of macro- and microelements (Jović *et al.*, 2017), heavy metals (Dąbkowska-Naskręt *et al.*, 2016; Roth *et al.*, 2012) and other harmful substances (Korobova *et al.*, 2014). The results of these investigations may contribute to the limitation of the mobility of elements and harmful substances in the environment and their leakage into the food chain. It should be emphasized that while soil science literature (Polish and international) supplies numerous data on the sorption properties determined in the entire soil mass (Chojnicki, 2002; Labaz and Kabala, 2016; Scarciglia *et al.*, 2011) there are rather few studies devoted to the sorption capacity of particular granulometric fractions (Okołowicz, 1996; Soares *et al.*, 2005). One of the reasons is the time-consuming and labour-intensive analytical process of distinguishing particular granulometric fractions from the solid phase of soils without centrifugation and use of chemical peptizers.

The research focused on testing the sorption properties of particular granulometric fractions distinguished from the genetic horizons of Haplic Cambisol. This is cultivated soil developed from old-alluvial deposits of the Vistula valley, which represents fertile farmland covering about 0.8 million ha of Poland (Chojnicki, 2002; Dąbkowska-Naskręt, 1990). Deeper knowledge of the sorption properties of these soils is of great importance for their rational agricultural utilisation and environmental protection. Sorptive properties of soils and fractions are the basis

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for the application of an appropriate technology for their fertilization and minimizing the washout of biogens into the environment (ground and surface waters). They also determine the possibility of sorbing harmful compounds of active pesticide substances (Martins *et al.*, 2018; Singh *et al.*, 2014) and heavy metals (Roth *et al.*, 2012).

MATERIALS AND METHODS

The studied soil according to FAO-WRB classification (IUSS Working Group WRB, 2015) was defined as Haplic Cambisol and is located in Kazuń Polski (52° 24'08.5 "N - 20 ° 40'46.2" E) about 40 km north of Warsaw. Fieldwork including profile description and sampling was carried out according to Jahn *et al.* (2006). The granulometric fractions were distinguished using the Atterberg method (USDA SCS, 1992) without application of chemical compounds for peptization. Peptization was performed using the thermal-mechanical technique by boiling soil with redistilled water (0.5 h) and mixing with a rotary agitator for about 10 minutes. Boiling and mixing was repeated till complete isolation of the <0.002 mm fraction. The >0.002 mm fractions were isolated similarly, but without further boiling, whereas the 1-0.1 mm fraction was separated on sieves after drying. The fractions were dried in evaporators in a heated bath and further in a drier at the temperature of 80-90°C. The granulometric composition was calculated from the content of the distinguished granulometric fractions after drying and weighing.

Laboratory analysis determined pH in distilled water and 1 M KCl, potentiometrically, at a soil:liquid ratio of 1:2.5 (v/v), total organic carbon (TOC) using the Tiurin method. Due to the lack of calcium and/or magnesium carbonates in the soils, total carbon is equivalent to TOC. Total fraction and soil potential acidity (H) was determined by means of the Kappen method (extraction using 1 mol dm^{-3} calcium acetate and titration using 0.1 mol dm^{-3} NaOH), exchangeable base cations (Ca^{2+}, K+, Mg^{2+}, Na^+) were extracted using 1 M ammonium acetate at pH = 7 and analyzed by atomic absorption spectrometer (Thermoelemental SOLAAR M6). The cation exchange capacity (CEC) and base saturation (BS) were calculated based on the sum of total exchangeable base cations (BC) and the potential acidity (H). For evaluation of relationships between cation exchange capacity and fraction diameter analysis of regression was applied.

RESULTS AND DISCUSSION

To the depth of 150 cm, the studied soil shows a granulometric fraction of sandy loam underlain by sand (Table 1). The fine sand fraction (0.25-0.1 mm) dominates in the entire profile, whereas coarse sand (1-0.5 mm) occurs in trace quantities. Acidic reaction observed in the surface horizons changes into poorly acidic with depth while the saturation of the sorption complex by alkaline cations (BS) increases with depth (Table 2). The investigated soil shows a low total organic carbon content, the quantity of which

Ta b l e 1. Particle size distribution of soil

Horizon	Depth (cm)	% Diameter content fractions (mm)								
		1-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002
A	5-30	1.0	7.1	33.2	13.1	18.0	6.7	4.3	3.5	13.0
ABw	30-50	1.1	6.3	34.9	13.3	18.9	6.5	3.1	3.5	12.4
Bw	50-70	0.5	3.8	27.7	13.0	15.6	6.2	3.4	4.1	24.4
BwC	70-90	0.2	1.0	30.6	34.8	11.6	2.1	2.3	1.6	15.8
C	90-120	0.2	2.8	48.7	14.6	14.3	2.7	1.8	1.4	13.5
C	120-150	0.2	5.0	40.0	16.3	18.4	3.1	1.9	2.4	12.7
IIC	150-175	0.3	20.2	46.4	11.0	12.7	4.0	0.6	1.0	3.8
IIC	175-200	0.2	26.1	52.6	10.2	4.6	0.8	0.5	0.6	4.4
Average		0.5	9.0	39.3	15.8	14.3	4.0	2.2	2.3	12.6

Ta b l e 2. Physicochemical properties of soil

Horizon	Depth (cm)	pH		Ca^{2+}	Mg^{2+}	K^+	Na^+	TEB	H^+	CEC	BS	TOC
		H_2O	KCl	cmol(+)$kg^{-1}$of soil							(%)	
A	5-30	5.0	4.0	2.17	0.78	0.10	0.14	3.19	2.84	6.03	52.9	0.70
ABw	30-50	5.4	4.1	3.60	1.47	0.11	0.23	5.41	2.47	7.88	68.6	0.19
Bw	50-70	5.6	4.1	6.30	2.13	0.14	0.30	8.87	2.28	11.15	79.5	0.18
BwC	70-90	5.7	4.2	7.80	2.37	0.17	0.47	10.81	2.81	13.62	79.4	0.17
C	90-120	5.7	4.2	4.82	1.00	0.11	0.63	6.56	1.62	8.18	80.2	0.05
C	120-150	5.6	4.3	6.15	1.08	0.14	0.63	8.00	1.50	9.50	84.2	0.07
IIC	150-175	6.4	5.5	4.83	1.00	0.10	0.45	6.37	0.82	7.20	88.6	0.02
IIC	175-200	6.9	6.1	2.87	0.40	0.07	0.09	3.43	0.50	3.93	87.3	0.01

gradually decreases with depth in the profile, whereas the cation exchange capacity varies in particular horizons and is related to their granulometric composition.

The cation exchange capacity of soil depends on its granulometric composition and type of sorbents within the granulometric fractions (clay minerals, humus compounds, iron and manganese oxides). The quantitative and qualitative composition of exchangeable cations in soils depends also on the energy of bonds between particular cations.

In the studied soil, exchangeable calcium is bound by the clay fraction <0.002 mm, which sorbs averagely up to 62.1% of this element (Fig. 1) and varies between 58.3 and 66.2% (Table 3). The remaining five fractions 1-0.002 mm contain only 33.8% of exchangeable calcium, with the following contents in particular fractions: 1-0.02 mm – 2.2%, 0.02-0.01 mm – 6.0%, 0.01-0.005 mm – 11.6% and 0.005-0.002 mm – 18.1%. The contribution of the 1-0.002 mm fractions binding calcium increases gradually whereas significant increase occurs in the <0.002 mm fraction. In the entire profile, the richest in exchangeable fraction are most granulometric fractions from the arable-humus horizon and the fraction from the deepest parts of the profile. Gradual increase of the exchangeable calcium content in the fractions with depth is the result of leaching processes. These processes occur only partly within the 0.02-0.01 and 0.01-0.005 mm fractions from the BwC horizon, which are rich in exchangeable calcium. At the same time the 0.005-0.002 and <0.002 mm fractions contain the smallest amount of this element.

The content of exchangeable magnesium increases with smaller size of the granulometric fractions and is much lower than that of calcium (Table 3). The 1-0.02 mm fraction, averagely contributing to 80% of the soil mass (Table 1), averagely bonds only 1.3% of this element (Fig. 1). The significantly highest average contribution in binding magnesium have the smallest fractions: <0.002 mm – 56.0%, varying from 44.8 to 67.1% and 0.005-0.002 mm – 26.7%, varying from 12.5 to 36.9% in the soil profile
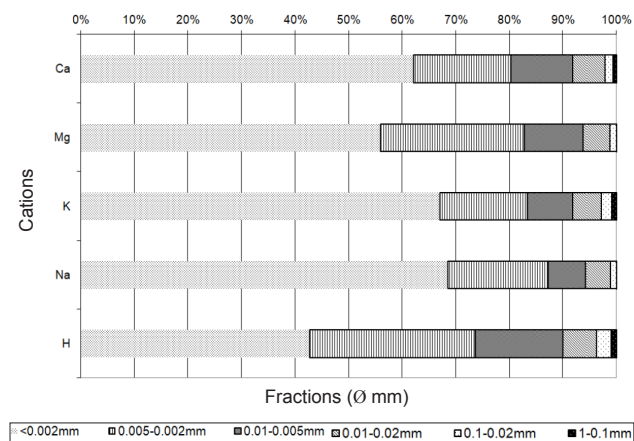
(Table 3). The 0.02-0.01 mm, 0.01-0.005 mm and 0.005-0.002 mm fractions isolated from horizon BwC and parent rock C reveal the highest contribution of exchangeable magnesium, similarly as calcium, in comparison to these fractions from the remaining horizons in the soil profile. In turn, the highest content of exchangeable magnesium in the <0.002 mm fraction was observed in the surface humus horizon, where it is twice as large in this fraction as in the remaining horizons.

The content of exchangeable potassium, similarly as of the remaining fractions, increases gradually from the coarsest to the finest fractions at a very significant increase of its contribution in the <0.002 mm fraction (Table 3). Therefore the percentage content of the particular granulometric fractions in the accumulation of exchangeable potassium reaches averagely: 1.0-0.02 mm – 2.9%, 0.02-0.002 mm – 30.0% and colloidal clay 67%, varying from 54.0 to 82.9% in the soil profile (Fig. 1, Table 3). All fractions isolated from the humus horizon were definitely richer in exchangeable potassium in comparison to fractions from deeper soil horizons. The only exceptions are the 0.02-0.01 mm and 0.01-0.005 mm fractions from the BwC horizons, in which high contents of the exchangeable forms of this element, similarly as calcium and magnesium, were noted. Migration of exchangeable potassium in deeper parts of the soil profile were not observed in any of the analyzed fractions, whereas its significant accumulation in fractions from the humus horizon results from bioaccumulation and fertilizing.

The content of exchangeable sodium is much higher that the content of exchangeable potassium in the studied soil fractions (Table 3). The content and percentage contribution of particular fractions in the sorption of exchangeable sodium increases with decreasing grain dimensions. As a result, the following average content of particular fractions was noted in this process: 1-0.02 mm – 1.1%, 0.02-0.002 mm – 30.3% and <0.002 mm – 68.5% (Fig. 1). In the soil profile, the highest contents of exchangeable sodium occur in fractions from the surface humus horizon, to decrease gradually to the depth of 175 cm, and increase again in the particular fractions in the deepest part of the profile.
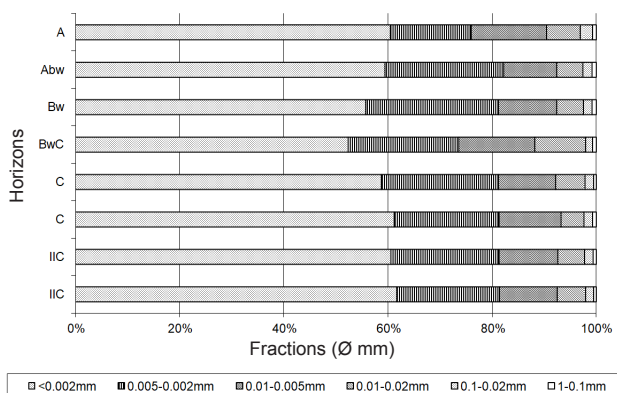
The content of exchangeable hydrogen, similarly as in the case of the cations presented above, increases in the particular granulometric fractions with grain dimensions (Table 3). However, the increase of the hydrogen content is gradual in particular fractions, with a much less dominating content of the clay fraction (Fig. 1). The average contributions of fractions in the sorption of exchangeable hydrogen are as follows: 1-0.02 mm – 3.8%, 0.02-0.002 mm – 53.5% and <0.002 mm – 42.7%. The leaching process has caused the highest contents of exchangeable hydrogen to occur in all fractions of the surface humus horizon and to successively decrease with depth. The largest decrease of the hydrogen content with depth of the soil profile was observed

Fig. 1. Average percentage share of the fractions in sorption of the exchangeable cations.

Table 3. Exchangeable cations content in granulometric fractions and their percentage share

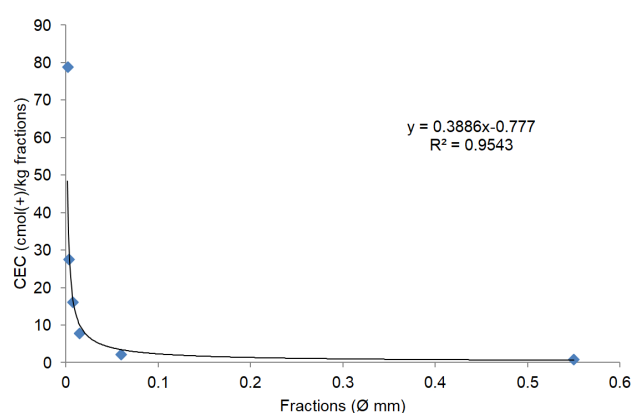| Horizon	Depth (cm)	cmol(+)kg^{-1} of fractions in diameter (mm)						% share of fractions diameter (mm)					
		1-0.1	0.1-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002	1-0.1	0.1-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002
						Ca^{2+}							
A	5-30	0.67	1.73	5.42	13.60	13.70	60.94	0.7	1.8	5.6	14.2	14.3	63.4
ABw	30-50	0.62	0.93	3.60	6.34	14.05	50.14	0.8	1.2	4.8	8.4	18.6	66.2
Bw	50-70	0.58	0.90	3.12	7.00	17.10	47.72	0.8	1.2	4.1	9.2	22.4	62.3
BwC	70-90	0.44	0.74	6.15	8.95	8.84	35.32	0.7	1.2	10.2	14.8	14.6	58.3
C	90-120	0.33	1.00	4.06	7.45	13.72	46.60	0.4	1.4	5.5	10.2	18.8	63.7
C	120-150	0.51	1.32	3.75	9.25	14.50	45.43	0.7	1.8	5.0	12.4	19.4	60.7
IIC	150-175	0.51	1.68	5.60	11.00	16.20	52.80	0.6	1.9	6.4	12.5	18.5	60.1
IIC	175-200	0.53	1.70	6.25	11.00	18.00	62.21	0.5	1.7	6.3	11.0	18.1	62.4
						Mg^{2+}							
A	5-30	0.05	0.15	0.87	4.00	3.12	16.72	0.2	0.6	3.5	16.1	12.5	67.1
ABw	30-50	0.04	0.17	0.41	1.08	3.78	6.95	0.3	1.4	3.3	8.7	30.4	55.9
Bw	50-70	0.03	0.10	0.80	2.16	5.33	8.75	0.2	0.6	4.7	12.6	36.9	45.0
BwC	70-90	0.05	0.06	2.02	2.62	4.32	7.80	0.3	0.4	12.0	15.5	25.6	46.2
C	90-120	0.07	0.25	1.23	2.00	4.50	6.52	0.5	1.7	8.4	13.7	30.9	44.8
C	120-150	0.04	0.17	0.38	0.92	2.77	7.22	0.3	1.5	3.3	8.0	24.1	62.8
IIC	150-175	0.03	0.15	0.24	0.71	4.00	9.30	0.2	1.0	1.7	4.9	27.7	64.5
IIC	175-200	0.03	0.11	0.34	1.03	3.22	7.90	0.2	0.9	2.7	8.2	25.5	62.5
						K^+							
A	5-30	0.10	0.19	0.42	1.10	0.73	12.40	0.7	1.3	2.8	7.4	4.9	82.9
ABw	30-50	0.10	0.16	0.23	0.31	0.80	4.20	1.7	2.8	4.0	5.3	13.8	72.4
Bw	50-70	0.06	0.12	0.22	0.26	0.70	2.37	1.6	3.2	5.9	7.0	18.8	63.5
BwC	70-90	0.03	0.07	0.54	0.68	0.70	2.38	0.7	1.6	12.3	15.5	15.9	54.0
C	90-120	0.04	0.07	0.18	0.23	0.35	2.09	1.3	2.4	6.1	7.8	11.8	70.6
C	120-150	0.01	0.01	0.06	0.12	0.41	1.24	0.5	0.5	3.2	6.5	22.2	67.1
IIC	150-175	0.01	0.02	0.10	0.20	0.48	1.36	0.5	0.9	4.6	9.2	22.1	62.7
IIC	175-200	0.01	0.04	0.07	0.15	0.35	1.08	0.6	2.4	4.1	8.8	20.6	63.5
						Na^+							
A	5-30	0.09	0.32	2.80	2.70	2.86	14.75	0.4	1.4	11.9	11.5	12.2	62.6
ABw	30-50	0.03	0.12	0.34	0.48	2.40	5.65	0.3	1.3	3.8	5.3	26.6	62.7
Bw	50-70	0.02	0.10	0.32	0.54	1.25	2.34	0.4	2.2	7.0	11.8	27.4	51.2
BwC	70-90	0.02	0.03	0.24	0.36	0.92	1.81	0.6	0.9	7.1	10.6	27.2	53.6
C	90-120	0.01	0.04	0.16	0.36	1.47	5.36	0.1	0.5	2.2	4.9	19.9	72.4
C	120-150	0.01	0.02	0.11	0.21	1.08	7.40	0.1	0.2	1.2	2.4	12.2	83.9
IIC	150-175	0.01	0.03	0.08	0.17	1.08	8.20	0.1	0.3	0.8	1.8	11.3	85.7
IIC	175-200	0.00	0.08	0.32	0.84	1.40	8.16	0.0	0.7	3.0	7.8	13.0	75.5
						H^+							
A	5-30	0.52	2.12	3.28	6.32	10.24	14.60	1.4	5.7	8.8	17.0	27.6	39.5
ABw	30-50	0.28	0.90	2.17	5.18	9.18	11.80	0.9	3.0	7.4	17.6	31.1	40.0
Bw	50-70	0.36	0.83	2.18	4.31	8.16	10.12	1.4	3.2	8.4	16.6	31.4	39.0
BwC	70-90	0.25	0.61	2.14	3.95	9.37	12.13	0.9	2.1	7.5	13.9	32.9	42.7
C	90-120	0.17	0.50	1.02	2.82	6.31	8.18	0.9	2.6	5.4	14.8	33.2	43.1
C	120-150	0.19	0.37	0.84	3.20	4.82	9.24	1.0	2.0	4.5	17.1	25.8	49.6
IIC	150-175	0.15	0.28	0.76	2.56	5.26	7.31	0.9	1.7	4.7	15.7	32.2	44.8
IIC	175-200	0.14	0.21	0.45	2.20	4.12	5.34	1.1	1.7	3.6	17.7	33.1	42.8

Table 4. Cation exchange capacity of granulometric fractions

Horizon	Depth (cm)	cmol(+)kg⁻¹ of fractions in diameter (mm)					
		1-0.1	0.1-0.02	0.02-0.01	0.01-0.005	0.005-0.002	<0.002
A	5-30	1.43	4.51	12.80	27.71	30.65	119.41
ABw	30-50	1.07	2.28	6.75	13.40	30.21	78.74
Bw	50-70	1.05	2.05	6.64	14.27	32.54	71.30
BwC	70-90	0.80	1.45	11.09	16.56	24.15	59.44
C	90-120	0.62	1.86	6.65	12.86	26.35	68.75
C	120-150	0.76	1.90	5.14	13.70	23.18	70.53
IIC	150-175	0.71	2.16	6.78	14.64	27.02	78.97
IIC	175-200	0.71	2.13	7.43	15.22	27.09	84.69
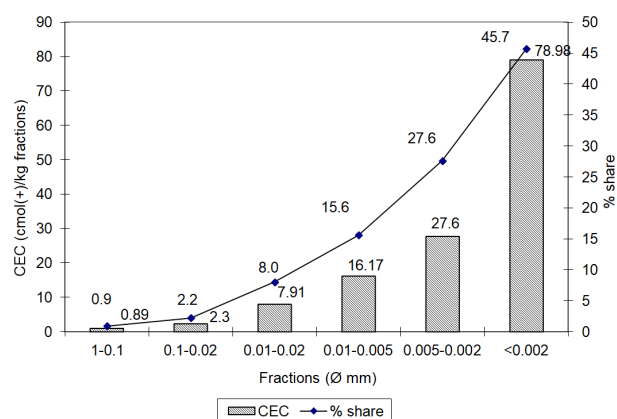
Fig. 2. Average cation exchange capacity (CEC) of the isolated fractions and their percentage contribution.

Fig. 4. Relationship between cation exchange capacity of the fractions and their diameter.

Fig. 3. Percentage contribution of the isolated fractions in the cation exchange capacity.

successively in the following fractions: 0.1-0.02 mm > 0.02-0.01 mm > 1-0.1 mm, whereas the remaining fractions did not show such a significant decrease.

The cation exchange capacity of the studied granulometric fractions increases with decreasing grain size (Table 4, Figs 2 and 3) and this relationship is statistically significant (Fig. 4). The average contribution of granulometric fractions in the cation exchange capacity is 1-0.02 mm – 3.1% (from 0.7 to 2.8%), 0.02-0.01 mm – 8.0% (from 6.3 to 12.5%), 0.01-0.005 mm – 15.6% (from 12.5 to 18.7%), 0.005-0.002 mm – 27.6% (from 18.9% to 32.8%) and fraction <0.002 mm – 45.7%, varying from 38.9 to 51.8%. Similar values of cation exchange capacity were also observed in the granulometric fractions of soils in eastern Germany (Leinweber et al., 1993), in limestone soils in Spain (Caravaca et al., 1999), in some soils in the USA (Joffe and Kunin, 1943), Ireland (McAleese and McConaghy, 1957) and sand and loam soils in Poland (Okołowicz, 1996). The size of cation exchange capacity in the studied fractions was particularly similar to fractions in soils developed from glacial rocks. A significantly larger cation exchange capacity of all fractions in the humus horizon, as also confirmed by other authors (Asadu et al., 1997, Okołowicz, 1996), is caused by a content of humus in this horizon. The sorption properties of the soil and fractions determine its high agricultural value and limit leaching of mineral nutrients and harmful elements and compounds to other parts of the environment. Generally, the cation exchange capacity in particular horizons of the soil profile showed a relatively low variability. This points to substantial homogeneity of the grain size

and mineral composition of the analyzed soil, developed from alluvial deposits, which very often indicate high variability of grain size (Chojnicki, 2002). Our studies and the reports of other authors indicate that the sorption properties of particular granulometric fractions depend on the origin and properties of the parent rock and the pedogenic processes. Of great significance are the mineral composition of the rocks, including properties and susceptibility of particular minerals to weathering, climate conditions, including temperature and humidity deciding on the intensity of weathering processes and the intensity and duration of pedogenic processes.

In the deeper part of the profile, some fractions from the BwC horizon indicate diverse sorption properties compared to fractions from the remaining horizons. The 0.02-0.01 mm and 0.01-0.005 mm fractions from this horizon are distinguished by a much larger cation exchange capacity, whereas the 0.005-0.002 mm and <0.002 mm fractions have the smallest cation exchange capacity compared to the fractions from the remaining subsurface horizons. Large sorption capacity of silts fractions (0.05-0.002 mm) was also noted in some soils from Argentina (Morrás, 1995), Ireland (McAleese and Mitchell, 1958), Africa (Asadu *et al.*, 1997), Brazil (Soares *et al.*, 2005) and USA (Tedrow, 1966). These reports have indicated that high contributions of feldspars, micas and silicates in the silt fraction significantly increased its cation exchange capacity whereas the dominating contribution of quartz decreased the capacity of this fraction. Based on scanning electron microscope (SEM) and transmission electron microscope (TEM) analyses, Morrás (1995), and McAleese and Mitchell (1958) concluded that weathering micas (surface flaking, opening of inter-layer space) as transitional type of minerals between primary and secondary clay minerals have the greatest contribution in the sorption capacity of the silt fraction. These authors attributed the lower contribution in the capacity of this fraction to weathering feldspars, coatings of clay minerals and humus on the surface of silt grains, clay aggregates and biogenic silica. Soares *et al.* (2005) emphasize also the high possible contribution in the sorption capacity of mineral and organic colloids accumulated in grain caverns, formed during chemical weathering, in the silt and sand fractions. Extensive studies of soils from Brazil have indicated that not only silt but also sand fractions in soils developed from clay shales and basalt have a very high cation exchange capacity (Soares *et al.* 2005).

CONCLUSIONS

1. The cation exchange capacity of granulometric fractions in the studied Haplic Cambisol soil developed from old alluvial sediments was particularly similar to fractions in soils developed from glacial rocks. The cation exchange capacity of particular granulometric fractions increased with decreasing grain size; its average value in cmol(+)

kg^{-1} and contribution in particular fractions was 1-0.1 mm – 0.89 (0.9%), 0.1-0.02 mm – 2.3 (2.2%), 0.01-0.02 mm – 7.91 (8.0%), 0.01-0.005 mm – 16.17 (15.6%), 0.005-0.002 mm – 27.6 (27.6%) and <0.002 mm – 78.98 (45.7%). Sorption properties of the examined soil determine its high agricultural value and resistance to chemical degradation.

2. The dominant cations in the sorption complex of individual granulometric fractions were exchangeable calcium and hydrogen and the leaching process reduced the content of calcium in the granulometric fractions of the surface levels while at the same time increasing their hydrogen content. The intensity of the leaching process in individual fractions decreased successively as their dimensions decreased, which explains the high susceptibility of coarse-grained soils (especially sandy soils) to this process.

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