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PARTICLE SIZE DISTRIBUTION OF AGROSODDY-PODZOLIC SOIL MORPHONS AND MORPHEMES BY LASER DIFFRACTION ANALYSIS

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Abstract. Improvement of instrumental methods observed in the recent decades resulted in the growing potential of "information capacity" of the obtained data. Determination of particle size distribution (PSD) with the use of laser diffraction (LD) has a number of important advantages as compared with other techniques, among them: express analysis, small size of samples (50-600 mg) required and continuous PSD curve. In this work we tried to disclose the given advantages of this method used to analyze soil functioning processes with agrosoddy-podzolic soil of El'digino village (Moscow region) taken as an example. Ability of the LD method to analyze mg-degree samples made it possible to investigate minor soil components such as cutans and other soil neo-formations which was demonstrated in our research. We attempted to give a new vision of textural differentiation of soils. For this purpose we investigated PSD of average samples and made a comparative layer-by-layer analysis of cutans samples and intraped soil mass picked out from different depths. Also, we examined a possibility to adapt the grain-size soil characteristics obtained by other grain-size analysis methods to the outcomes of the LD analysis.

Introduction. Examination of the research results of soil samples with their interdependencies understood as morphological soil components can give better understanding of soil functioning processes. However, often it is not possible to investigate a lot of interesting properties of the analyzed sample because of insufficient amounts of material required for the analysis.

Classical techniques (pipette-method (PM), areometric method) require ~5-30 g of sample, while LD requires only ~50-600 mg. This LD advantage enables a micro-level soil analysis and investigation of PSD for soil neo-formations and ped surfaces being the most dynamic and representative component of a solid phase.

LD results are a continual PSD. This enabled us to consider soil texture in a different way, not only as a proportion between the size fractions of elementary soil particles (ESP). A detailed study of continual PSD could reveal complex PSD indices. An interesting example of such approach is the analysis of integral PSD curves made by P.N. Berezin [1, 2] which made it possible to deduce four probability rates giving the extended information about soil genesis.

In spite of the wide use of LD in soil science and its increasing impact a lot of methodological problems remain unsolved. In our research we tried to uncover the capabilities of the described above LD method applied in soil science and to consider possible application of Berezin's probability rates in the context of LD data.

Objects and methods. Field stage of soil investigations included morphological description and sampling. Selection and indication of samples were performed according to the established order of soil profile description [3, 4, 5, 6]. This work was carried out at Zelenograd station of V.V. Dokuchaev Soil Science Institute in Pushkin district, Moscow region, Russia. The object of research was agrosoddy-podzolic soil on clay loam mantle laying on non-carbonate moraine at the depth of 2-3 m. Research was performed in a trench (length 20 m, depth 2,2 m) at the experimental ground of Zelenograd station.

Average samples of the total mass (TM) were selected layer-by-layer (with a step of 10 cm) in accordance with the profile genetic horizons. Samples of morphological components of various profile hierarchy structure levels were represented by: intra-ped mass (IPM); intra-fracture mass (IFM) - soil material, which in terms of its properties had sharp visual

distinctions as compared with the enclosing horizon; eluvial (clarified) zone of IFM (IFMe); humic-clay and clay cutans (IFMt); inter-fracture mass (InFM) - transition part from IPM to IFM close to ped surface, which could have morphological features of gleying (InFMg).

For our analysis we selected a soil profile on 13 m of a trench and three morphons: morphon 1 - 13 m, clay-humic cutan on the main fracture surface stretching from 80 to 170 cm in depth and about 50 cm in width; morphon 2 - 14.5 m, pseudomorphosis in fracture from eluvial to textural horizon with the depth ranging from 44 to 76 cm; morphon 3 - pseudomorphosis in the vein fracture from eluvial to textural horizon spreading from 88 to 164 cm in depth.

Analysette 22 comfort (Fritsch, Germany) was used for PSD analysis. Calculations were based on the Mie theory. Refractive index value for solid phase was selected as 1.55, for liquid phase - 1.33. Before the PSD analysis roots were removed from the samples, then grinded with a rubber pestle and sifted through a sieve (mesh aperture 1 mm).

After that the samples were dispersed by ultrasound on a sound-type dispergator Digital Sonifier 250 (Branson Ultrasonics, USA) with a standard disruptor horn tip during 5 minutes at 40%W. In this case dispergation energy reached ~ 500 J/ml. Dispergator was calibrated beforehand, according to the accepted methodology [7]. In addition, PSD of GM samples was analyzed by PM with the same pretreatment and dispergation.

Also probability rates of all samples were calculated by Berezin method including: two for clay components (particles < 1 μm) - F5 and k, two for sand components (5-1000 μm) - α and n.

Results and discussion. PSD results obtained for GM samples are shown in Table 1. There are essential differences between the absolute values of size fractions determined with different methods. However, both methods give similar or analogical results of physical clay (particles < 10 μm) content except humus-accumulated horizons.

Fine sand and coarse silt fractions have accumulative distribution in soil profile. Middle silt content was constant, fine silt and clay had eluvial distribution (Fig. 1).

Differentiation of morphon 1 components is higher than that of GM samples. Differentiation coefficient of clay (ratio of clay contents in eluvial to textural horizons) is 1.7.

Clay-humic cutan, most massive at 90-135 cm depth, is sharply distinct from IPMg and IPM part (Fig. 2). The content of <0.7 μm fraction is increased by 3-4 times as compared with IPM. The most contrast distinctions were noted for cutans with IPMg, which represented a less heavy texture morphon component. Clay-humic cutan contains from 11 to 19% of fraction >10 μm. This fraction in IPM contains about 50% of all particles.

Similar relationships between morphemes were observed in the 3rd morphon. IFM is humic-clay cutan material light in the upper layer and getting darker with the depth which is the most interesting quality of the morphon. Coarse silt was sharply decreasing (from 53 to 7%) with a notable increase in the clay and fine silt fraction (from 18 to 29 and from 36 to 49 %, respectively) with the depth in comparison with IPM. Content of clay particles is lower in the upper part and higher (in 3-4 times) in the lower part of IPM.

For the 2nd morphon a clarified IPM is depleted with clay and fine silt fractions as compared with IPM while a coarse silt fraction increased nearly to 65%. There is a more sharp differentiation between IFP and InFM. InFM has a more heavy texture of morphon.

Content of clay components (F5, %) is more variable than that of silt fraction depending on the soil profile. There is a clear minimum of F5 in EL horizon.

K rate represents a share of coarse material in clay components [2]. Therefore, K describes the degree of coarse material weathering. By Berezin's classification all of the analyzed GM samples and morphemes belong to a coarse dispersed category. But K is not constant varying

from 0.89 to 1.34 in different parts of soil profile (Fig. 3). Humic horizon has the highest K values.

This K rate "non-susceptibility" can be explained by the specific nature of LD data: higher fine silt and lower clay fraction content as compared with other methods of grain-size analysis. The analyzed samples belong to a coarse-dispersed category because a fine silt contribution to clay components is always very high. For now we can confirm that K values could be described as a relative value, as an increase or decrease in the dust content (or coarseness) of clay components. K increases (to 0.98-1.05) in the lower part of soil profile (100-150 cm). Gravel inclusions were found at the depth more than 200 cm. Also this layer includes medium and coarse sand fractions. In general K rate has a regressive-accumulate type of distribution.

According to Berezin [2], in the same conditions an average diameter of sand components (α) indicates the time when a parent rock was exposed to formative factors. Sand soil components belong to a non-grained category ($\alpha < 20$ μm) except the lowest part of humic horizon which is fine-grained. The size of sand components decreases with the depth (Fig. 3).

Sorting rate n characterises monodispersity of soil sand components. The analyzed soil was characterised by a sharp transition in the textured profile part with n rate amounting to <1 (Fig. 3).

Clay-humic cutans of agrosoddy-podzolic soil are characterized by the following qualities: the highest content of clay components; the lowest K rate values, i.e. the highest slit enrichment of clay particles < 1 μm; decreased K rates with the depth in clay-humic cutan of the 3rd morphon; the smallest diameters of sand components; high values of sorting rate for particles larger than 5 μm.

On the contrary, a clarified soil IFM is characterised by the increased dust content (K rate) and greater sizes of sand components as compared with IPM.

Conclusions. Comparative analysis of data obtained by PM and LD methods in the aggregate with a probability rates application showed that any adaptation of PSD parameters previously deduced by methods based on other physical principles required additional investigation and sometimes even a revision of fraction boundaries.

PSD analysis of agrosoddy-podzolic soil by LD makes it possible to come to the following conclusions:

1. Profile textural differentiation is more distinct between the morphological components of lower levels than soil horizons.

2. Concentration of clay material in the form of clay-humic cutans is considerably higher (by 3-4 times than in IPM) in the main fractures. Clay material includes not only clay fraction but also fine silt. IPMg has the lightest composition of morphons.

3. Soil PSD probability rates described by P.N. Berezin make it possible even in its present non-adapted state to obtain additional information about the nature of differentiation process in soil solid phase.

<div align="center">REFERENCES</div>

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Table 1. PSD of agrosoddy-podzolic profile (PM – in numerator, LD – in denominator)

| Horizon	depth, cm	Content (%) of fraction ESP (μm)							Classification by N.A. Kachinskiy
		>250	250-50	50-10	10-5	5-1	<1	<10	
Ap'	0-10	0	3.63 / 13.4	42.88 / 53.7	16.44 / 11.9	33.68 / 14.0	3.36 / 7.1	53.48 / 33.0	Light clay / Medium loam
Ap"	20-30	0	1.41 / 10.6	53.79 / 54.6	13.78 / 9.7	25.34 / 13.6	5.69 / 11.4	44.81 / 34.7	Heavy loam / Medium loam
Elfrag-ElB	30-40	0	1.33	54.54	16.27	21.73	6.13	44.13	
	40-50	0	0.14 / 10.4	48.71 / 39.6	15.0 / 11.5	27.69 / 14.9	8.46 / 23.5	51.16 / 50.0	
B2	60-70	0	0.44 / 7.9	48.49 / 42.0	15.36 / 13.2	27.36 / 16.5	8.36 / 20.4	51.08 / 50.1	
B3	80-90	0	0.82 / 9.5	47.31 / 39.7	15.02 / 6.4	28.40 / 19.6	8.45 / 24.8	51.87 / 50.8	Light clay / Light clay
	100-110	0	0.03	43.43	16.48	30.83	9.23	56.54	
	120-130	0	0.20 / 2.8	42.91 / 43.1	16.47 / 11.1	31.71 / 18.9	8.71 / 24.2	56.8 / 54.2	
B4	140-150	0	0.01	37.59	16.86	35.67	9.87	62.40	
	160-170	0	0.24	36.93	16.20	36.38	10.26	62.83	
	180-190	0.47 / 0.5	0.21 / 8.2	35.72 / 34.8	16.41 / 13.1	36.74 / 21.4	10.46 / 22.0	64.48 / 56.5	
BC	200-210	1.88	0.27	30.28	17.50	40.12	9.94	69.06	
	220	1.91 / 1.9	0.70 / 10.9	27.85 / 30.7	18.03 / 13.1	41.74 / 22.8	9.76 / 20.6	71.22 / 56.5	Medium clay / Light clay
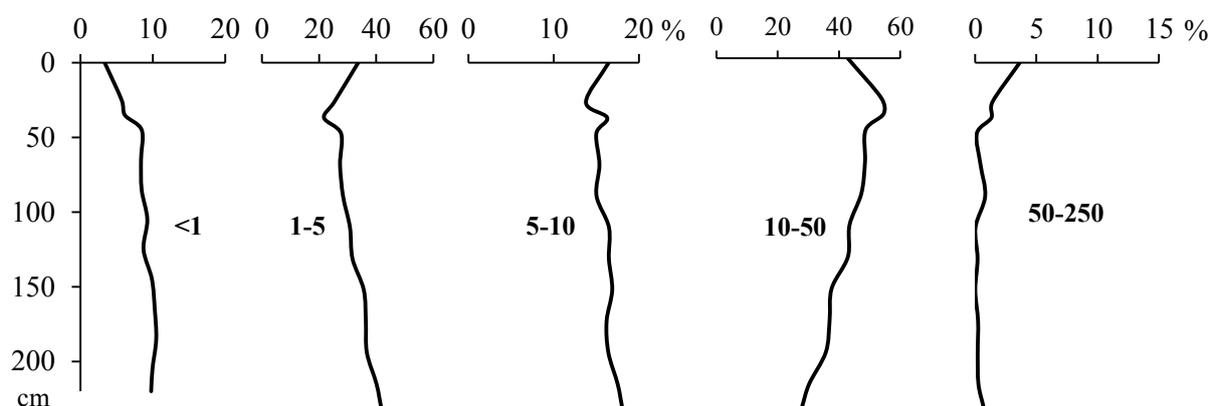
Fig.1 PSD in soil profile
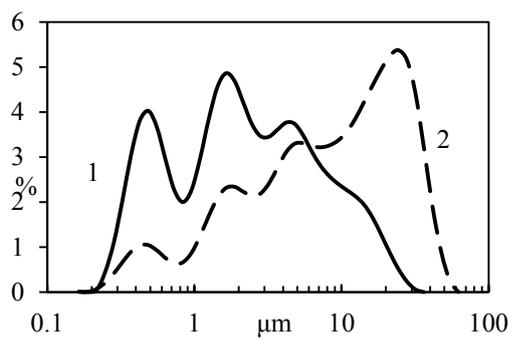
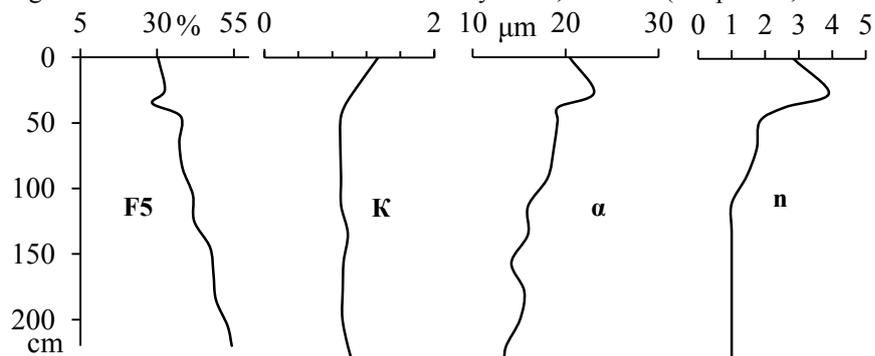Fig.2 Differential PSD curve: 1 – humic-clay cutan, 2 – IPM (morphon 1, 90-135 cm)

Fig. 3 PSD probability rates of agro-soddy-podzolic soil