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THE EFFECT OF SOIL ORGANIC MATTER ON THE DIFFERENCE BETWEEN PARTICLE-SIZE DISTRIBUTION DATA OBTAINED BY THE SEDIMENTOMETRIC AND LASER DIFFRACTION METHODS

Z. TYUGAI*   E.V. SHEIN   E.Y. MILANOVSKIY

Soil Science Faculty, Moscow State University, Leninskie Gory, Moscow, 119991 Russia
***e-mail : eym@ps.msu.ru**

Abstract: Particle-size distribution in dispersed sediments, soils, atmospheric dust, and other natural objects is their fundamental characteristic. The methods of sedimentometry (the pipette method) and laser diffraction have been applied to study particle-size distribution in a typical chernozem of Kursk region from the Alekhin Central Chernozemic Reserve. The content of the clay fraction as determined by the method of laser diffraction is three to five times lower than the clay content determined by the traditional pipette method. One of the reasons for such a great difference in the results obtained by two different methods is related to the low density of the solid phase of the particles of soil organic matter that have the size corresponding to the fine and medium silt fractions. Owing to this, they fall into the category of the clay fraction during the traditional sedimentometric analysis. The initially water-stable aggregates of 0.25–0.5 mm are subjected to several stages of their breakdown under the impact of ultrasonic dispersion with the detachment of small particles from their surface layers. The remaining aggregates have different resistance to ultrasonic treatment. After the long-term ultrasonic dispersion, the most stable microaggregates still exist in the soil mass. These microaggregates may only be decomposed to elementary soil particles after the addition of sodium pyrophosphate.
Key words: Soil, Particle-size distribution, Laser diffraction, Water-stable aggregates

1. INTRODUCTION

There are dedicated researches covering the issue of comparing the traditional sedimetometric method with the method of laser diffraction. It has been noted that the content of the clay fraction as determined by the laser diffraction method is three to six times lower that those determined by the sedimentometric one. In most cases, this difference between the two methods is explained by the fact that the real shape of soil particles differs from spherical shape, which is accepted in the sedimentometric methods. Furthermore it is due to the assumption about the constant solid phase density for all the elementary soil particles irregardless of their origin and composition. In case of the soils with a high content of organic matter, this assumption may lead to errors. In our research we have studied the effect of organic matter on the interpretation of the results of particle-size distribution analyses obtained by the sedimentometric and laser diffraction methods. Among the particular tasks were

(1) to determine the particle-size distribution in a typical chernozem by the methods of sedimentometry and laser diffraction,
(2) to analyze the particle-size distribution in the clay fraction obtained by the sedimentometric method,
(3) to study the organic matter content in the particle-size fractions, and
(4) to study the stability of microaggregates in the typical chernozem under different chemical and physical impacts.

2. MATERIAL AND METHODS

Typical chernozem from the territory of the Alekhin Central Chernozemic State Biospheric Reserves in Kursk A region in the virgin herbaceous meadow steppe has been studied. In particular this soil type is characterized by high (up to 5% on the average) content of organic carbon in the upper 30 cm, high water stability (up to 65% of water-stable aggregates > 0.25 mm), very high microaggregation (up to 95% of microaggregates > 10 mkm) and a light clayey texture. The pretreatment of the samples for the particle-size distribution analysis by both methods was performed according to standard procedure: the ultrasonic dispersion of soil suspensions in a 0.4% $Na_4P_2O_7$ solution was performed for 3 min at the frequency of 22 kHz (Jury, Gardner W.R., Gardner W.H, 1991; Mathieu, Pieltain, 1998; Shein, 2005, a.o.) The particle-size distribution analyses were carried out by the pipette method of Kachinskii (Vadunina, Korchagina, 1986; Shein, 2005) and by the laser diffraction method (using an Analysette 22 device, Fritch company, Germany) (Shein, Milanovsky, Molov, 2006). In order to study separate particle-size fractions from the genetic horizons of the virgin chernozem, the following fractions were separated using the sedimentation method: >5 mkm (mainly, the medium and coarse silt), 2–5 mkm (fine silt), <3 mkm (clay), and colloids (the particles that do not precipitate upon the centrifuging of the clay fraction).

3. RESULTS AND DISCUSSION

All sedimentology methods and devices (sedigrafy various designs) are based on the use of Stokes equations. The use of these methods we have not real, but so-called hydraulic (or effective) radius of the particles, i.e. particle radius corresponding to a certain speed of their fall. This is a serious admission for partical-size analysis, because the particles can have very different density, multiple forms, different surface properties (hydrophobic and hydrophilic), and other characteristics, casting doubt on the closeness of their real and hydraulic radius. This is just proof of comparison sedimentology and laser-diffraction techniques. Last, we recall registers real radius of the particles to deflect the laser beam and the subsequent interpretation of the diffraction pattern.

The clay content determined by the laser diffractometry method is usually three to four times lower than that determined by the pipette method; at the same time, the contents of the fine and medium silt fractions are higher when invoking the method of laser diffractometry (Figure1).

To study the reasons for these differences, we have analyzed a texture of the clay fraction obtained with the help of the pipette method. The determination of the particle-size distribution in this clay sample by the method of laser diffraction demonstrated that the particles have a bimodal distribution: particles with a size of less than 1 mkm have with the average diameter of 0.56 mkm and constitute 47% of the sample, and particles with a size of more than 1 mkm have the average diameter of 1.7 mkm. The same velocity of sedimentation (0.26 cm/h) of these particles can only take place, if the solid phase density of larger particles does not exceed 1.2–1.4 g/cm^3. Such values of the solid phase density are typical for highly decomposed peat and soil humus. The organic nature of the particles >1 mkm and having the average diameter of 1.7 mkm within the clay fraction separated by the sedimentation method is proved by the data on the particle-size distribution in this fraction after the preliminary pretreatment with H_2O_2. It is also proved by the comparison of the particle-size distribution curves (in the clay fraction) obtained from the humus and the BCk horizons. In the first case, the second maximum of larger particles disappears and the particle-size distribution curve becomes similar to that obtained for the clay fraction from the BCk horizon. Thus, one of the factors affecting the difference between particle-size distribution data obtained by the pipette and laser diffraction methods is the use of the overestimated solid phase density in the calculations of the velocity of sedimentation of the particles having organic nature. Therefore particles from the fine silt fraction fall into the category of clay fraction. It should be noted that organic soil particles are mainly localized in the medium and fine silt fractions (1–10 mkm). This assumption is ¨verified by the data on the direct determination of organic carbon in the colloidal, clay (<2 mkm), fine silt (2–5 mkm), and the sum of the medium and coarse silt (>5mkm) fractions.

We have also investigated the stability of soil aggregates (0.25–0.50 mm). The water stable aggregates were subjected to the following treatments: (1) dispersion in water during 1, 4 and 10 min (variants “water 1”, “water 4” “water 10”); (2) ultrasonic dispersion of 75W and 150 W intensity (variants US-75 and US-150) and (3) the treatment of the latter subfraction of microaggregates resistant to the ultrasonic dispersion with sodium pyrophosphate (variant US+pyrophos). The obtained results suggest that the initial aggregates of 0.25–0.5 mm in size are gradually transformed under the impact of ultrasonic dispersion (Figure 2).

Several stages of this transformation can be registered; during each of these stages, the aggregates with different resistance to the ultrasonic dispersion are left in the soil. Finally, the most resistant fraction of microaggregates remains in the soil. Its further treatment with ultrasound does not affect its composition. The following 3 stages are distinguished: 1) a spontaneous breakdown of aggregates of 250–500 mkm in size to microaggregates of 30–100 mkm in size with their further breakdown to the fraction with the median diameter of 25 µm and a slight increase in the content of the fraction of <2 µm. It can be supposed that the detachment of soil particles from the surface of microaggregates with a decrease in the size of the latter takes place during this phase; (2) a stage of a gradual decrease in the median size of microaggregates from 25 mkm down to the formation of stable cores of microaggregates with a predominant diameter of 15 mkm; (3) a breakdown of the stable core part of microaggregates takes place upon the soil treatment with sodium pyrophosphate.

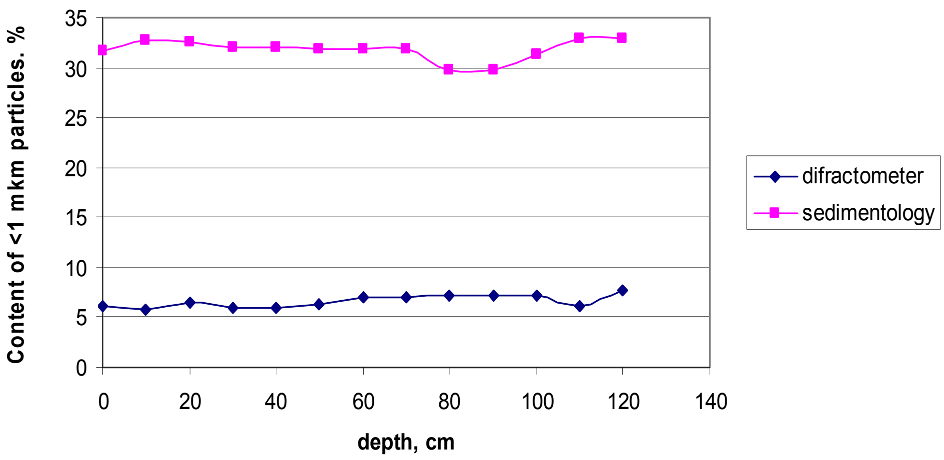

Figure 1. Distribution of the granulometric particles <1 mkm content (%) through the depth (cm) of the chernozem profile defined by the methods of laser difractometer and pipette method (sedimentology)

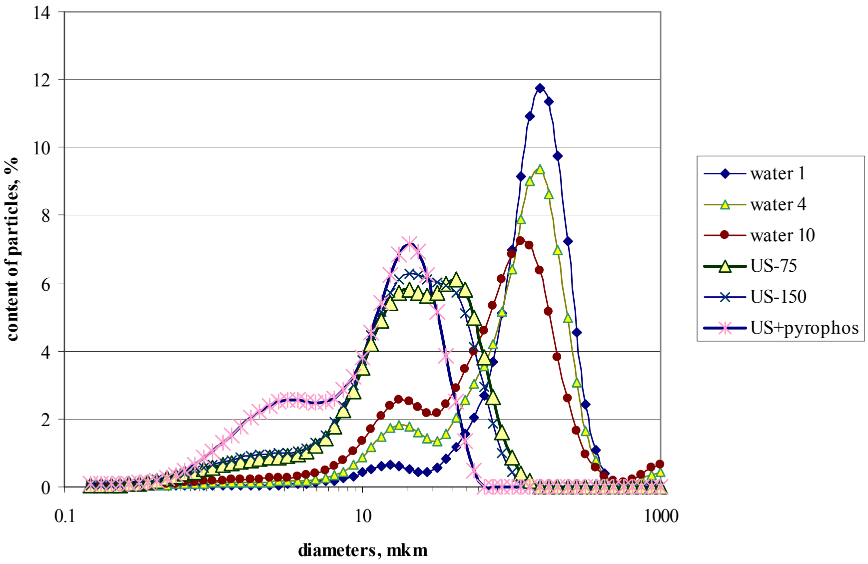

Figure 2. Granulometric composition of water stable 0.25-0.5 mm aggregate dispersion under different types of treatments (explanations in the text)

Thus, the sharp decrease (4-6 times) the content of silt fraction and the increase (1.5-2 times) the number of particles of 1-10 microns in using the method of laser diffraction is noted. This phenomenon was observed in earlier experiments with laser difractometer (Fedotov, 2007; Shein, Milanovsky, Molov, 2006). To explain the causes of discrepancies in the results will analyze the physical principles underlying the sediment and diffraction analysis methods.

The rate of sedimentation, according to Stokes, (v) of particles in stagnant water depends on their radius (r^2), and the density of the solid phase particles (ρ_s).

$$v = \frac{2}{9} \cdot \frac{g \cdot r^2 (\rho_s - \rho_w)}{\eta} \qquad (1)$$

Since Stokes' law variable is represented by ($r^2 \cdot \rho_s$), and the calculations used weighted averages ρs, the particles with different size and density of the solid phase can potentially have the same sedimentation rate and fall in the analysis by pipette into a single faction. For example, the fraction of organic matter, with a density of 1.2-1.4 g/cm^3 is in sedimentology analysis in a clay or fine silt factions. With laser diffraction organic substances, according to their diameter should be in the fraction of the medium and coarse silt. And microskopic observations selected fractions confirmed the fact that the globular hydrophpbic agents is concantrated in the fraction of fine silt. As seen, the difference of results of methods, which have different physical bases, leads to significant changes in the results. Moreover, in this case is difficult to find a universal correspondence of these two methods, having different physical justification.

4. CONCLUSION

The clay content as determined by the method of laser diffractometry is three to five lower than the clay content determined by the traditional pipette method. This difference between the two methods may be due to low solid-phase density of organic particles that have the size of fine and medium silt but fall into the category of clay fraction upon sedimentometric analysis. The initial water-stable aggregates (0.25–0.5 mm) of typical chernozem pass through several stages of their breakdown under the impact of ultrasonic dispersion. During these stages, elementary soil particles and microaggregates of a smaller size are detached from the surface of the water-stable aggregates. Finally the remaining part of the microaggregates that are resistant to ultrasonic dispersion is formed. The further decomposition of these microaggregates to the elementary soil particles is only possible after the addition of sodium pyrophosphate.

5. ACKNOWLEDGEMENT

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