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Note

Comparison of soil texture determined by two dispersion units of Mastersizer 2000**

A. Sochan[1]*, *A. Bieganowski*[1], *M. Ryżak*[1], *R. Dobrowolski*[2], *and P. Bartmiński*[2]

[1]Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland
[2]Department of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, Akademicka 19, 20-033 Lublin, Poland

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Abstract. The comparison of particle size distributions measured by sedimentation methods and laser diffraction shows the underestimation of the fine (clay) fraction. This is attributed mainly to the shape of clay particles being different than spherical. The objective of this study was to demonstrate differences in the results of particle size distributions of soils determined with the method of laser diffraction using two different dispersion units of the Malvern Mastersizer 2000.

Keywords: particle size distributions, sedimentation, laser diffraction, Mastersizer 2000

INTRODUCTION

Particle size distribution (PSD) of soils is one of the fundamental parameters permamently used in soil science (Brzezińska *et al*., 2011; Joó *et a*l., 2010; Nosalewicz and Nosalewicz, 2011; Sławiński *et al.*, 2011; Tóth *et al*., 2009). More and more often the determinations of that parameter is made with the use of the method of laser diffraction (Blott and Pye, 2006; Pye and Blott, 2004; Sperazza *et al*., 2004). The method consists in measuring the intensity of laser light scattered on the particles measured. The intensity of scattered light depends on the size of the particles in the measurement system. The smaller the particle, the greater the angle at which the light is scattered/refracted.

The method of laser diffraction has been compared many times with the earlier methods of PSD determination – the sedimentation methods (Arriaga *et al.*, 2006; Beuselinck *et al.*, 1998; Ryżak and Bieganowski, 2010; Tauber *et al.*, 2008). In certain of such reports one can encounter information about underestimation of the fine (clay) fraction content in measurements performed with the method of laser diffraction as compared to the sedimentation methods (Beuselinck *et al.*, 1998; Eshel *et al.*, 2004; Konert and Vanderberghe, 1997). The underestimation of the clay fraction content is attributed mainly to the shape of clay particles being different than spherical (Konert and Vendenberghe, 1997). Those authors pointed out that the divergent results might be also related to problems with the selection of optical parameters for the clay fraction (Eshel *et al.*, 2004) or with the limited measurement range, especially of the older types of apparatus (Beuselinck *et al.*, 1998).

Apart from the above potential causes of the underestimated clay content in soils studied careful analysis of the literature on the determination of PSD with the method of laser diffraction leads also to further conclusions. One of the more important reasons for the lack of comparability of results lies in the use of laser diffractometers of various manufacturers or various models (generations) of equipment of this type from a single manufacturer. Another problem is the frequent lack of information – in research publications – on the type/model of apparatus used and/or on its equipment.

The objective of this study was to demonstrate differences in the results of PSD of soils determined with the method of laser diffraction using two different dispersion units of the Malvern Mastersizer 2000 apparatus.

MATERIAL AND METHOD

The investigations were conducted for 23 soil samples from the arable layer (5-20 cm). The soil samples represented: Haplic Phaeozems – 6, Eutric Cambisols – 5, Dystric Arenosols – 3, Mollic Leptosols – 3, Arenic Luvisols – 2, Calcaric Cambisols – 2, Eutric Fluvisols – 1 and Mollic Gleysols – 1.

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*Corresponding author's e-mail: a.krusinska@ipan.lublin.pl
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Particle size distribution was determined using the Mastersizer 2000 (Malvern, UK) laser diffractometer. The measurements were conducted using two dispersion units - Hydro MU and Hydro G. The two dispersion units differ considerably in their design. In the Hydro MU the sample inlet into the measurement system is situated relatively high in the container in which the sample suspension is stirred (Fig. 1a). In the Hydro G the suspension is fed from the lower part of the container to the cell (Fig. 1b). As in the Hydro MU unit the inlet is situated relatively high, the stirring energy may not ensure sufficient homogenisation of the sample (especially in the case of heavier particles *eg* the sand fraction), which may be the cause of differences in results obtained with the two dispersion units.

In both cases the method of dispersion of soil samples was the same: 30 s of ultrasound treatment with maximum power (35W), applied by means of inbuilt probe. In each measurement the amount of soil sample placed within the measurement system was such that the value of obscurance fell within the range of 10-20%. If after the ultrasonic treatment the value of obscurance was higher than 20%, a procedure for its lowering was applied (Bieganowski *et al.*, 2010).

The Hydro MU dispersion unit has an integrated stirrer and pump. The speed of the pump and stirrer (2500 r.p.m.) was selected so as to obtain maximum homogenization of the suspension in the beaker while eliminating air bubbles from the suspension. The Hydro G dispersion unit permits separate programming of the pump and stirrer speeds. In this case the pump speed was set at 1750 r.p.m., and that of the stirrer at 700 r.p.m.

The intensity of laser light registered on the particular detectors of the measurement system can be converted to particle size distribution according to the Mie theory or the Fraunhofer theory. The choice of the theory is up to the performer of the measurements. The standard ISO 13320 (2009) recommends the application of the Mie theory for particles smaller than 50 μm and informs that for larger particles both theories provide similar results. However, in the case of applying the Mie theory, it is necessary to determine the values of the indices of absorption and refraction of light by the particles studied and of the light refraction index for the dispersing phase. As soil is a mixture of many different particles, with various values of the optical parameters, the determination of a single (common for all samples) value for each of the two indices is the source of uncertainty that is hard to estimate. Hence, in practice the application of both theories with relation to soil yields similar results (Ryżak and Bieganowski, 2011). In this study the Mie theory was applied, assuming the following values of the indices: refraction index 1.52 and absorption index 0.1 for the dispersed phase, and refraction index of 1.33 for water as the dispersing phase.

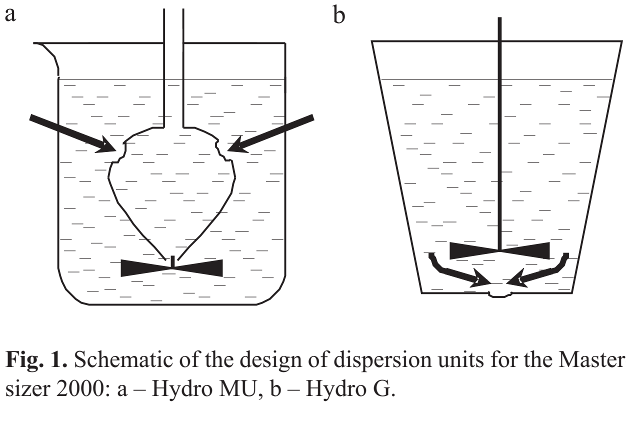

Fig. 1. Schematic of the design of dispersion units for the Mastersizer 2000: a – Hydro MU, b – Hydro G.

RESULTS AND DISCUSSION

The results obtained with the two dispersing units were different. A compilation of the results is given in Table 1. In seven cases the differences of such a magnitude that based on the results obtained the soils were classified in other particle size groups (lines highlighted in grey in Table 1) – taking into account both the World Reference Base for soil resources (WRB) and Polish Society of Soil Science (PSSS) classifications. A comparison of the contents of the particular fractions, measured using both dispersion units (Hydro G and Hydro MU), is presented in Fig. 2. In the case of the coarser fractions (sand and silt), the values of the content of the fractions obtained with the use of the Hydro G dispersion unit were higher than those obtained with the Hydro MU – in both cases the slopes of the lines were *ca*. 0.7. An opposite situation was observed for the finest fraction (clay), where the Hydro MU dispersion unit gave higher results than the Hydro G (slope of ca. 1.1).

Analysing the results presented in the graphs in Fig. 2 one should note that in none of the three cases the interpolated line intersects the origin of the system. The highest value of the free term was obtained for the clay fraction (ca. 22.1). In reality it is not possible that with zero content of a given fraction obtained with the use of the Hydro G dispersing unit the value obtained with the Hydro MU would have a non-zero value. Therefore, the graphs have to be corrected by enforcing the intersection of the origin of the system by the interpolated line. After the realisation of this postulate, the equations of the interpolated lines with their coefficients of determination were as follows:

– for sand fraction: $y = 0.7810$ ($R^2 = 0.9474$);
– for silt fraction: $y = 1.0694$ ($R^2 = 0.6653$);
– for clay fraction: $y = 1.3588$ ($R^2 = 0.8253$).

It could have been expected, that values of the determination coefficients decreased – mostly for silt fraction.

Considering the results obtained it should be stated that for the purposes of soil science and sedimentology, where the objects studied may contain heavier particles, the Hydro G dispersing unit is the better choice. The Hydro MU dispersing unit, at the maximum intensity of stirring ('maximum' does not mean here the maximum speeds of the pump and stirrer provided for by the manufacturer, but the highest at

T a b l e 1. Clay, silt and sand fractions (in volume percentage) obtained by two dispersion units (Hydro G and Hydro MU) of laser diffractometer Mastersizer 2000. Rows in dark colour show differences in particle size groups classified according to the displayed data (both for WRB and PSSS classifications)

Sample No.[1]	Hydro G unit					Hydro MU unit				
	Clay	Silt	Sand	Particle size group		Clay	Silt	Sand	Particle size group	
	(mm)					(mm)				
	< 0.002	0.002-0.05	0.05-2.0	(WRB)	(PSSS)[2]	< 0.002	0.002-0.05	0.05-2.0	(WRB)	(PSSS)[2]
553	5.26	74.37	20.37	silt loam	loamy silt	7.40	75.72	16.88	silt loam	loamy silt
557	5.36	50.30	44.34	silt loam	loamy silt	8.60	62.81	28.60	silt loam	loamy silt
560	1.87	28.45	69.68	sandy loam	sandy loam	3.55	53.03	43.42	silt loam	loamy silt
562	5.10	50.47	44.42	silt loam	loamy silt	8.68	67.49	23.83	silt loam	loamy silt
565	6.78	54.33	38.89	silt loam	loamy silt	8.36	58.91	32.74	silt loam	loamy silt
566	0.89	15.76	83.35	loamy sand	loamy sand	1.96	32.32	65.72	sandy loam	sandy loam
568	6.31	78.06	15.63	silt loam	loamy silt	7.93	75.23	16.84	silt loam	loamy silt
569	4.53	72.90	22.57	silt loam	loamy silt	4.92	72.68	22.39	silt loam	loamy silt
570	5.01	73.59	21.39	silt loam	loamy silt	6.63	70.97	22.40	silt loam	loamy silt
586	5.26	77.14	17.60	silt loam	loamy silt	7.83	75.71	16.46	silt loam	loamy silt
589	1.25	17.28	81.47	loamy sand	loamy sand	2.72	35.68	61.60	sandy loam	sandy loam
591	4.71	69.17	26.12	silt loam	loamy silt	5.51	72.16	22.33	silt loam	loamy silt
593	2.35	34.50	63.15	sandy loam	sandy loam	4.15	45.21	50.64	sandy loam	sandy loam
597	2.02	20.80	77.18	loamy sand	loamy sand	3.08	35.47	61.45	sandy loam	sandy loam
601	5.47	78.48	16.05	silt loam	loamy silt	7.62	77.10	15.28	silt loam	loamy silt
605	0.96	9.79	89.26	sand	weakly loamy sand	2.49	25.61	71.90	sandy loam	sandy loam
610	0.51	8.73	90.76	sand	loose sand	1.97	24.88	73.15	sandy loam	loamy sand
611	1.86	17.34	80.80	loamy sand	loamy sand	3.20	31.99	64.81	sandy loam	sandy loam
613	4.46	58.62	36.92	silt loam	loamy silt	5.06	66.21	28.73	silt loam	loamy silt
619	3.76	58.92	37.32	silt loam	loamy silt	4.10	58.07	37.83	silt loam	loamy silt
621	4.34	64.69	30.96	silt loam	loamy silt	4.75	69.50	25.75	silt loam	loamy silt
622	4.97	74.39	20.64	silt loam	loamy silt	6.26	79.83	13.92	silt loam	loamy silt
623	5.18	72.53	22.29	silt loam	loamy silt	7.93	72.91	19.16	silt loam	loamy silt

[1] Sample numbers from the bank of soil samples of the Institute of Agrophysics PAS in Lublin, Poland (Gliński *et al.*, 1991), [2] Polish Soil Science Society.

which air bubbles are not drawn into the measurement system), is unable to carry the heaviest particles and achieve uniformity of their concentration within the whole sample volume. Since the inlet to the measurement system in that dispersing unit is relatively high, the amount of particles of the coarser fraction taken into the measurement cell is smaller than in the case when the inlet is situated lower. The Hydro G dispersing unit is free of that shortcoming.

The results presented here pertain to 2 dispersion units for a single type of apparatus of one manufacturer. If we take into consideration all types of apparatus available in the market (all generations and models from all manufacturers) one can imagine that the comparison of results obtained with their use (as well as the comparison of the results with those obtained with other methods) can be burdened with a considerable error.

CONCLUSIONS

1. Taking into account the design of the dispersing units (Hydro G and MU) for the Malvern Mastersizer 2000, for the purposes of soil science and sedimentology, where the objects studied may contain smaller particles, the Hydro G dispersing unit is the better choice.

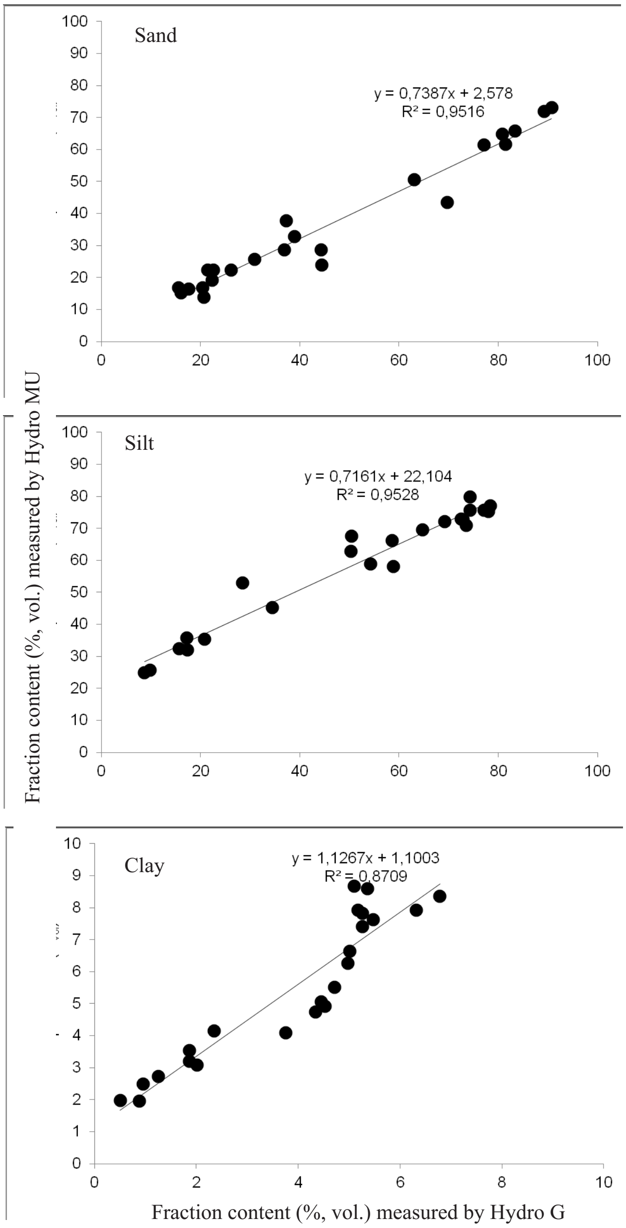

Fig. 2. Comparison of particular fractions contents measured using two dispersion units: Hydro G and MU.

2. Design differences among various types of apparatus (various models and generations of equipment from the same manufacturer and various manufacturers) may be the cause of differences in results obtained by means of various laser diffractometers and diversity of results obtained with different methods.

REFERENCES

Arriaga F.J., Lowery B., and Mays M.D., 2006. A fast method for determining soil particle size distribution using a laser instrument. Soil Sci., 171, 663-674.

Beuselinck L., Govers G., Poesen J., Degraer G., and Froyen L., 1998. Grain-size analysis by laser diffractometry: comparison with sieve-pipette method. Catena, 32, 193-208.

Bieganowski A., Ryżak M., and Witkowska-Walczak B., 2010. Determination of soil aggregate disintegration dynamics using laser diffraction. Clay Minerals, 45, 23-34.

Blott S.J. and Pye K., 2006. Particle size distribution analysis of sand-sized particles by laser diffraction: an experimental investigation of instrument sensitivity and the effect of particle shape. Sedimentology, 53, 671-685.

Brzezińska M., Rafalski P., Włodarczyk T., Szarlip P., and Brzeziński K., 2011. How much oxygen is needed for acetylene to be consumed in soil? J. Soils Sediments, 11, 1142-1154.

Eshel G., Levy G.J., Mingelgrin U., and Singer J.M., 2004. Critical evaluation of the use of laser diffraction for particle-size distribution analysis. Soil Sci. Soc. Am. J., 68, 736-743.

Gliński J., Ostrowski J., Stępniewska Z., and Stępniewski W., 1991. The bank of representative mineral soils of Poland (in Polish). Problemy Agrofizyki, 66, 5-57.

ISO 13320, **2009**. Particle size analysis – laser diffraction methods.

Joó S., Tóth J., Samua G., and Földényi R., 2010. Investigation of humic substances by particle size distribution of soils and by determination of zeta potential. Proc. 15th Meet. Int. Humic Substances Soc., June 27 – July 2, Tenerife, Spain.

Konert M. and Vandenberghe J., 1997. Comparison of laser grain size analysis with pipette and sieve analysis: a solution for the underestimation of the clay fraction. Sedimentology, 44, 523-535.

Nosalewicz A. and Nosalewicz M., 2011. Effect of soil compaction on dehydrogenase activity in bulk soil and rhizosphere. Int. Agrophys., 25, 47-51.

Pye K. and Blott S.J., 2004. Particle size analysis of sediments, soils and related particulate materials for forensic purposes using laser granulometry. Forensic Sci. Int., 144, 19-27.

Ryżak M. and Bieganowski A., 2010. Determination of particle size distribution of soil using laser diffraction - comparison with areometric metod. Int. Agrophys., 24, 177-181.

Ryżak M. and Bieganowski A., 2011. Methodological aspects of determining soil particle-size distribution using the laser-diffraction method. J. Plant Nutr. Soil Sci., 174(4), 624-633.

Sławiński C., Witkowska-Walczak B., Lipiec J., and Nosalewicz A., 2011. Effect of aggregate size on water movement in soils. Int. Agrophys., 25, 53-58.

Sperazza M., Moore J.N., and Hendrix M.S., 2004. High-resolution particle size analysis of naturally occurring very fine-grained sediment through laser diffractometry. J. Sedimentary Res., 74, 736-743.

Taubner H., Roth B., and Tippkötter R., 2009. Determination of soil texture: Comparison of the sedimentation method and the laser-diffraction analysis. J. Plant Nutr. Soil. Sci., 172, 161-171.

Tóth G., Makó A., and Máté F., 2009. Designation of local varieties in the Hungarian soil classification system: Remarks from a viewpoint of land evaluation application. Eurasian Soil Sci., 42(13), 1448-1453

Włodarczyk T., Stępniewski W., Brzezińska M., and Majewska U., 2011. Various textured soil as nitrous oxide emitter and consumer. Int. Agrophys., 25, 287-297.