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Total applied energy *versus* cavitation intensity: How the soil aggregate stability can be assessed using ultrasound?

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INTRODUCTION

- The soil aggregate stability assessment is a common analysis in Soil Science since many process depends on soil aggregation conditions;
- Many methods have been proposed to evaluate the soil aggregate stability: wet-sieving using the end-over-end shaking (Yoder, 1936); raindrop impact (Imeson and Vis, 1984); high-energy moisture characteristic method (Pierson and Mulla, 1989; Levy and Mamedov, 2002); and ultrasonic method (North, 1976; Raine and So, 1993, 1994; Mayer *et al.*, 2002; Schomakers *et al.*, 2011; Ribeiro *et al.*, 2013).
- The main advantage of ultrasonic method is the measurement of the energy level required to promote the soil dispersion allowing to compare results obtained for different soils (Raine and So, 1993, 1994). However, several experimental conditions can influence the results: i) the output power displayed may differ from the actual power depending on equipment, insertion depth and geometry of the ultrasonic probe (Mayer *et al.*, 2002; Schmidt *et al.*, 1999); ii) the soil-water ratio affects the effectiveness of the ultrasonic dispersion (Schomakers *et al.*, 2011); iii) the cavitation phenomenon is reduced if the temperature of soil suspension exceeds 40° C (Roscoe *et al.*, 2000); iv) the vibration amplitude of the probe (Mayer *et al.*, 2002).
- This work was carried out to evaluate the aggregate breakdown and dispersion of an Oxisol influenced by different ultrasonic cavitation intensities producing the same applied total energy, aiming to contribute to the development of the soil aggregate stability assessment by ultrasonic method.

MATERIAL AND METHODS

- Topsoil samples (0-5 cm layer) from an Acrudox;
- 10 g of aggregates (size 4-8 mm) in 200 mL of distilled water using a 250-mL glass beaker;
- Sonication using a probe-type QSonica equipment with a titanium probe (diameter of 19.1 mm) immersed 2.5 cm into the soil suspension;
- Sonication procedure: i) 20 W during 500 s; ii) 30 W during 333.33 s; iii) 40 W during 250 s and (iv) 50 W during 200 s. In all conditions the total energy applied was 10,000 J (40 J mL^{-1} or 1,000 J g^{-1});
- After sonication the soil-aggregates suspension was gently wet-sieving (2 mm; 1 mm; 0.5 mm and 0.25 mm sieves). The soil mass retained in each sieve was oven-dried at 105° C for 48 hours, weighted and finally calculated the amount of aggregates by size fraction (8-2 mm; 2-1 mm; 1-0.5 mm; 0.5-0.25 mm; and < 0.25 mm);
- The displayed output power was checked based on calorimetric techniques (Raine and So, 1993, 1994), according to the following equation:

$$P=\left[\left((m_a.c_a)+c_g\right).\frac{\Delta T}{\Delta t}\right]$$

Where: P is the calorimetrically determined power (W); m_a is the mass of water (200 g); c_a is the water specific heat capacity [4,186J $(g°(C)^{-1}]$; c_g is the beaker specific heat capacity (J $°C^{-1}$); ΔT is the increase of water temperature during the time period Δt.

- The beaker specific heat capacity (c_g) was calculated by equation:

$$c_g=c_v.m_b$$

Where: c_g is the beaker specific heat capacity (J $°C^{-1}$); c_v is the glass specific heat capacity (840 J $°C^{-1}$ kg^{-1}); and m_b is the mass of beaker (kg).

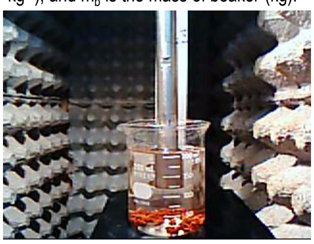

Figure 1. Experimental apparatus: soil aggregates into a 250-mL beaker containing 200 mL of distillied water (soil:water ratio 1:20).

RESULTS

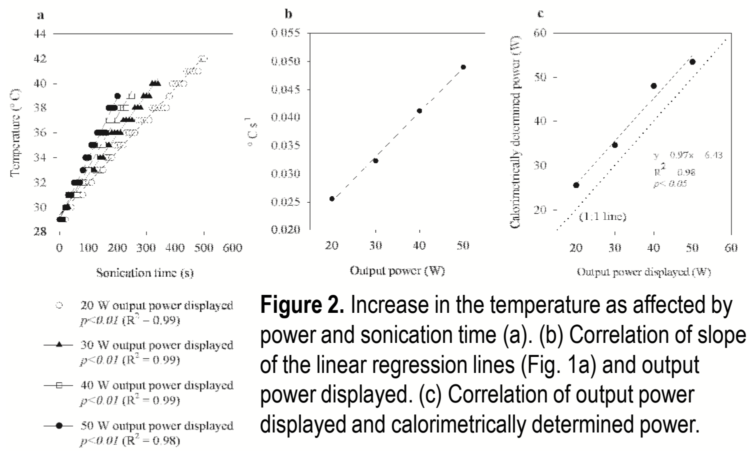

Figure 2. Increase in the temperature as affected by power and sonication time (a). (b) Correlation of slope of the linear regression lines (Fig. 1a) and output power displayed. (c) Correlation of output power displayed and calorimetrically determined power.

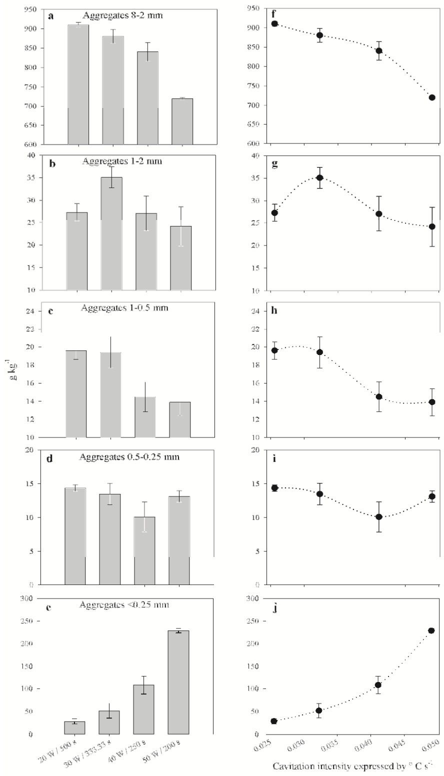

Figure 3. Mass of each aggregate size fraction recovered after the four ultrasonic conditions adopted: 20 W during 500 s; 30 W during 333.33 s; 40 W during 250 s; and 50 W during 200 s. Errors bars indicate the standard deviation (n=3).

CONCLUSIONS

1. High output power and short-time had more effect than low output power and length of time, although the combination of these conditions had produced the same amount of energy**.**

2. The increasing temperature rate (°C s^{-1}) of soil-water suspension is easily determined and may be used as way to measure the cavitation intensity.

3. The stepwise breakdown of aggregates was showed varying with the cavitation intensity.

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