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Influence of Organic Matter Content on Hydro-Structural Properties of Constructed Technosols

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ABSTRACT

Constructed Technosols may be an alternative for creating urban green spaces. However, the hydro-structural properties emerging from the assembly of artefacts have never been documented. The soil shrinkage curve (SSC) could provide relevant structural information about constructed Technosols, such as the water holding capacity of each pore system (macropores and micropores). The objectives of this study were (i) to evaluate the SSC and water retention curve (WRC) to describe the structure of constructed Technosols and (ii) to understand the influence of organic matter content on soil hydro-structural properties. In this study, Technosols were obtained by mixing green waste compost (GWC) with the material excavated from deep horizons of soil (EDH). The GWC was mixed with EDH in six different volumetric percentages from 0% to 50% (GWC/total). The GWC and EDH exhibited highly divergent hydro-structural properties: the SSC was hyperbolic for GWC and sigmoid for EDH. All six mixture treatments (0%, 10%, 20%, 30%, 40% and 50% GWC) exhibited the classical sigmoid shape, revealing two embedded levels of pore systems. The 20% GWC treatment was hydro-structurally similar to the 30% and 40% GWC treatments; so, a large quantity of expansive GWC is unnecessary. The relation with the GWC percentage was a second-degree equation for volumetric available water in micropores, but was linear for volumetric available water in macropores and total volumetric available water. Total volumetric available water in the 50% GWC treatment was twice as high as that in the 0% GWC treatment. By combining SSCs and WRCs, increasing the GWC percentage increased water holding capacity by decreasing the maximum equivalent size of water-saturated micropores at the shrinkage limit and increasing the maximum equivalent size of water-saturated macropores, resulting in an increased range of pore diameter able to retain available water.

Key Words: available water, soil shrinkage curve, soil water content, water holding capacity, water retention curve

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INTRODUCTION

Technosols are soils that contain a significant percentage of artefacts (at least 20% in the upper 100 cm), *i.e.*, something in the soil recognizably made or strongly altered by humans or extracted from greater depths (WRB, 2014). Constructed Technosols are mixtures of anthropogenic materials used on purpose to create a new soil dedicated to growing plants (Baize and Girard, 2008). This kind of soil is a new solution in ecological reclamation of degraded land. For example, the addition of urban wastes has been used on decontaminated soil to improve their quality (Séré *et al.*, 2008). In addition, it provides an alternative to using agricultural topsoil to create urban green spaces, which is often necessary because urban soils can be unfavorable for plant growth and development (Craul, 1999; De Kimpe and Morel, 2000).

Adding organic waste to degraded land in urban or rural areas is a practice largely documented in the literature as a way to improve water holding capacity (Epstein *et al.*, 1976; Kelling *et al.*, 1977), hydraulic conductivity (Kumar *et al.*, 1985), aggregation (Zhang, 1994), total porosity (Mathan, 1994), bulk density (Arvidsson, 1998), ability to resist compaction (Soane, 1990; Paradelo and Barral, 2013) and soil quality (Reeves, 1997). Understanding the influence of different percentages of organic matter is essential for improved plant production, since it is useful to identify the percentage of organic matter necessary to create a Technosol with the desired properties without increasing costs.

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Many recent studies on Technosols focus on physical, physico-chemical and chemical parameters, such as pH, available nutrients, bulk density (Rokia *et al.*, 2014), available water (Molineux *et al.*, 2009), electrical conductivity (Rowe *et al.*, 2006), particle size distribution (Olszewski *et al.*, 2010), and water flow (Séré *et al.*, 2012), which can control the quality of the substrate and, therefore, plant development. To our knowledge, the hydro-structural properties of constructed Technosols have never been studied by combining water retention curve (WRC) and soil shrinkage curve (SSC). The WRC defines the relation between soil water potential and water content, while the SSC represents the concomitant decrease in soil volume and water mass during drying (Haines, 1923). The shape of the SSC depends on soil structure and composition (organic and mineral). Peng and Horn (2013) distinguished six types of SSC, which depend on the presence or absence of one or two of the four SSC shrinkage phases (interpedal/saturated (in), structural (st), basic (ba) and residual (re) shrinkage phases) described by Braudeau *et al.* (1999), Groenevelt and Grant (2001), and Peng and Horn (2005). Recently, Leong and Wijaya (2015) developed an empirical universal SSC equation for all types of soil. Braudeau *et al.* (2004) developed a conceptual model that defined quantitative analysis of soil structure (arrangement of soil particles and associated pores) by distinguishing two pore systems (elementary particle arrangement, defining primary peds and associated micropores; primary ped arrangement, defining macropores) and characterizing hydraulic properties for each of them (Braudeau *et al.*, 2004; Assi *et al.*, 2014).

Other studies have combined WRC and SSC, such as that by Braudeau *et al.* (2005), who characterized soil structure of natural soils, and that by Boivin *et al.* (2006), who used the van Genuchten equation to describe the two curves. Guimarães Santos *et al.* (2011) argued that these curves are indicators for evaluating soil physical quality. Alaoui *et al.* (2011) relied on these curves to discuss soil deformation, and Kechavarzi *et al.* (2010) used them to explain the influence of long-term changes in peat soils and characterize hydro-structural properties.

A huge number of organic and mineral wastes can be used for the construction of Technosols. For example, Rokia *et al.* (2014) tested mixtures of 11 different materials to evaluate the additivity of their physico-chemical properties. Here, this study used two urban wastes, known for their abundance, the financial interest of recycling them, and their physico-chemical and agronomic properties, to construct Technosols: one mineral material excavated from deep horizons of soil and one organic material, green waste compost (GWC), with the latter added in six different volumetric percentages (from 0% to 50%). We then determined the SSC of constructed Technosols to describe hydro-structural properties, as proposed by Assi *et al.* (2014). The WRCs were also determined to provide complementary information about the pore size distribution in constructed Technosols, as applied by Milleret *et al.* (2009). The objectives of this study were to evaluate the validity and relevance of WRC and SSC for physically characterizing constructed Technosols and to understand how Technosol structure is influenced by organic matter content.

MATERIALS AND METHODS

Technosol parent materials

The mineral material excavated from deep horizons of soil (EDH) used in this study was provided by the ECT Company (Villeneuve sous Dammartin, France). This material is typically what is found when foundations are dug in the Ile-de-France. It is mainly the result of the weathering of carbonated rock fragments of the Parisian Basin (France) from the Eocene. In this study, 500 kg of EDH at eight locations were collected from the base of urban waste dump of the ECT company in order to have a composite sample representative of what may be used to construct Technosols around Paris. The EDH is classified as a carbonated sandy soil (Nachtergaele, 2001). The material was composed of 880 g kg^{-1} sand, 100 g kg^{-1} silt and 20 g kg^{-1} clay after carbonate removal, which represents 431 g kg^{-1} of total dry mass. Without carbonate removal, the EDH was composed of 110 g kg^{-1} particles of $<$ 2 μm in size, 300 g kg^{-1} particles of 2–50 μm, and 590 g kg^{-1} particles of 50 μm–2 mm. The X-ray diffraction performed with a Siemens D500 diffractometer (CuK_{a}, 40 kV, 30 mA) identified quartz, calcite and dolomite as major minerals. The concentrations of organic carbon and nitrogen were measured by elemental analysis (Vario EL III, Elementar, Hanau, Germany). The GWC used in this study was composed of cuttings from urban areas. Table I shows the main chemical properties of the EDH and GWC materials.

Both materials were air-dried and sieved to 4 mm before mixing by an electrical concrete mixer with a 100 L capacity and 690 W power, at 390 round min^{-1} for 10 min. Six different mixture treatments of 20 Leach were prepared, with 0%, 10%, 20%, 30%, 40% and 50% (GWC/total, volume/volume) of GWC, respectively.