

Effects of sewage sludge amendment on the properties of two Brazilian oxisols and their humic acids

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Abstract

The effect of sewage sludge (SS) amendment on the general properties of the top layers of a sandy and a clayey oxisols and on the nature of their humic acid (HA) fractions was evaluated by chemical and physico-chemical techniques. The amended soils, especially the sandy soil, benefited of SS amendment by increasing their pH to above neutrality and enhancing the contents of C, N, P, and Ca and cation exchange capacity. The SS–HA-like sample showed larger H and N contents and a greater aliphatic character and humification degree than the HAs isolated from non-amended soils. The composition and structure of amended soil HAs were affected by SS application as a function of soil type and layer. In particular, N-containing groups and aliphatic structures of SS–HA-like sample appears to be partially incorporated in the amended soil HAs, and these effects were more evident in the HAs from the sandy oxisol. © 2007 Elsevier Ltd. All rights reserved.

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1. Introduction

Recycling of municipal sewage sludge (SS) as soil organic amendment represents a convenient alternative to landfill disposal, especially in intensely populated areas where the SS production and the reduction of available disposal sites are problems increasing on a daily basis. For example, a recent report suggests that only the metropolitan area of São Paulo City, Brazil, is expected to produce ~ 1500 Mg SS day⁻¹ in 2015 (Vanzo, 2005).

Soil manuring with sewage sludge has been shown to increase the yield of several crops (Anjos and Mattiazzo, 2000a; Bertoncini et al., 2004; Bovi et al., 2007), probably because of the direct effect of its high organic matter content on soil capacity for holding water and plant nutrients. However, the disposal of raw SS on soils can also increase

the rate of nitrate leaching (Anjos and Mattiazzo, 2000b), contaminate crops with heavy metals (Wang et al., 1997), promote nutritional disorders in crops and increase the soil salinity (Oliveira et al., 2002), pollute the watertable with pathogens, pesticides, hormones and pharmaceuticals (Birkett and Lester, 2003), and decrease the stability of native soil organic matter (Bertoncini et al., 2005). Further, in tropical conditions the turnover and mineralization rates of SOM are higher than those in temperate climatic zones, and the application of organic waste material represents the best solution to maintaining SOM content and to improve nutrient bioavailability (de Melo et al., 2002).

The application of allochthonous organic matter, however, may produce more adverse than beneficial effects on general soil properties, including the modification of the status, quality and functions of native soil organic matter (SOM), and especially of its more active components such as humic acids (HAs). Thus, to ensure the environmentally safe and agronomically efficient use of SS as a soil amendment, a number of prerequisites are considered essential in

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order to avoid or, at least, limit any hazard for soil properties, crop production, and water quality which may derive by the application of SS. These include sanitation, reduction of metal and organic contaminants, and the extended conversion of the initial “fresh” organic matter into stabilized organic forms.

In order to obtain a reduced environmental impact and successful agronomic performance in soil, it is important to control the chemical quality of organic matter in SS. In particular, the compositional, functional and structural properties of the SS–HA-like fraction, which are a good indicator of its biological and chemical stability, should resemble as much as possible those of native soil HAs (Senesi et al., 1996). Several studies have been performed in this direction in order to clarify the SOM changes occurring in Brazilian SS-amended soils. Bertoncini et al. (2005) analyzed by fluorescence and total luminescence spectroscopies the HAs and fulvic acids (FAs) isolated from two Brazilian oxisols amended with dried SS. Results of this study indicated a lower heterogeneity and less aromatic character, polycondensation and humification degree for HAs and FAs from SS-amended soils with respect to soil native HAs and FAs. These results thus suggested the possible incorporation of molecular components of relatively small molecular size of SS–HA- and FA-like fractions into native soil HAs and FAs. Similarly, González-Pérez (2006) showed that HAs isolated from the top layer of a Brazilian oxisol two years after application of 0, 3.5, 7.0, 14, and 28 Mg ha⁻¹ of dried SS exhibited a decrease of semiquinone-type free radicals concentration, which confirmed the incorporation of less aromatic components into soil native HAs with consequent decreasing of their humification degree. Further, changes were observed in the structure of humic substances isolated from two Brazilian oxisols 20 months after the incorporation of 80 Mg ha⁻¹ SS (Canellas et al., 2001). In particular, with respect to soil native HA, the ratio HAs/FAs decreased and the HAs isolated from amended soils showed a lower alkyl-C content and a greater C content probably due to polysaccharidic components.

Since limited information is available on the impact of SS amendment on tropical soils, the objectives of the present study were to evaluate the effects of this practice on the general properties of the top layers of two different Brazilian oxisols and on some chemical and physico-chemical characteristics of their HA fractions.

2. Methods

2.1. Sewage sludge and soil samples

The SS sample used in this study was the semisolid sludge obtained from the Barueri sewage treatment plant located in a large industrial area in the metropolitan region of São Paulo State, Brazil. In this plant, SS was subjected to conventional aerobic and anaerobic treatments, and then treated with CaO and FeCl₃.

The soils, both classified as Typic Hapludox (Soil Survey Staff, 1998), currently named oxisols, either non-amended (TH1 and TH2) or amended with a SS total amount equivalent to 390 Mg ha⁻¹ on a dry weight basis (TH1SS and TH2SS) were placed in 0.5 m³-pots. The experiment was performed according to a completely randomized statistical design and a factorial outline 2 × 2 was used, with four replicates, and a total amount of 16 repetitions. The SS was applied and incorporated in the superficial soil layer (0–20 cm) every 2 months in five successive steps. Both non-amended and SS-amended soils were cropped with corn, and 7 months after the last application, i.e., 17 months after the first application, soil samples were collected from the surface (s, 0–25 cm, TH1s and TH1sSS, and TH2s and TH2sSS) and subsurface (ss, 25–50 cm, TH1ss and TH1ssSS, and TH2ss and TH2ssSS) layers, dried at 60°C, crushed, sieved at 2 mm, and then analyzed for their main physical and chemical properties.

2.2. Sewage sludge and soil analyses

The SS sample was analyzed in triplicate according to Eaton et al. (1995). Briefly, moisture was measured as the weight loss after heating the sample at 65 °C for 24 h. The pH and electrical conductivity (EC) were measured directly on the sample by a pHmeter and a conductimeter, respectively. The CaCO₃ content was determined by gas-volumetry. Total organic carbon and total N contents were determined by the Walkley and Black and Kjeldhal methods, respectively. The contents of P, K, Ca, Mg, and S were determined on (HNO₃ + HClO₄)-digested extracts of the dry SS sample by colorimetry (P), photometry (K), atomic absorption spectrometry (AAS) (Ca and Mg), and 10% BaCl₂ precipitation (S). The contents of Cu, Zn, Ni, Cr, Pb, and Cd were measured by AAS on (HNO₃ + HClO₄ + HF)-digested extracts of the dry SS sample.

Soil analyses were made in triplicate according to the methods of EMBRAPA (1997). Texture was measured by the pipette method. Total contents of Al and Fe (expressed as Al₂O₃ and Fe₂O₃) were determined by AAS on concentrated H₂SO₄ soil extracts. Amorphous Al₂O₃ was measured by AAS on (0.1 M ammonium oxalate + 0.01 M oxalic acid) extracts at pH 3. Kaolinite and gibbsite contents were determined in the deferrified soil clay fraction by differential thermal analysis. The pH in water was measured on a soil:water (1:2.5) suspension. The H + Al content (potential acidity) was measured by 0.05 M NaOH titration of 0.5 M Ca acetate extracts at pH 7. The EC was measured on a soil saturated extract and the cation exchange capacity (CEC) was determined by the BaCl₂ method. The CaCO₃ content was measured by gas-volumetry. Organic C (C_{org}) was determined by the dichromate method. Total N (N_{tot}) content was measured by the Kjeldhal method. Available P (P_{ava}) and K (K_{ava}) were determined by colorimetric (P) and photometric (K) methods in 0.1 M H₂SO₄ soil extracts. Exchangeable Ca (Ca_{ex})

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