

Composted municipal waste effects on chemical properties of a Brazilian soil

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Abstract

The spread of composted municipal waste (CMW) on land can be used for sustainable crop production. Nevertheless, heavy metals availability may be a problem. Therefore, the main objective of this study was to assess the impact of CMW disposal on heavy metal accumulation in soil and plants. The treatments consisted of an untreated plot (control) and four rates of CMW application. All plots were cultivated in succession of carrot, cauliflower, sweet corn, and radish. Cu and Pb significantly accumulated in the topsoil (0–5 cm) with a similar pattern in the depths of 5–10 cm and 10–20 cm. Cauliflower, for Fe and Cu, and radish, for Pb and Cu, had their tissue analysis significantly affected due to the increasing rates of application of CMW. Nevertheless, the levels of accumulation in both, soil and plant, are within permissible limits. The evidences provided by this experiment indicated that heavy metals are less likely to cause problems for the estimation of CMW loadings to Brazilian agricultural land.

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1. Introduction

Municipal solid waste has been a serious environmental problem for many cities in developing countries (Abdel-Sabour and Abo El-Seoud, 1996; Soumaré et al., 2003). For instance, Rio de Janeiro, the second largest city in Brazil, has shown over the last years a significant increase of solid waste handling. From 1995 to 2002, the total waste collected and the average waste collected per day increased from 2.6 to 3.6 million tons and 7.0 to 9.9 thousand tons, respectively.

In spite of the fact that there are many kinds of final disposal available, the agricultural practice of amending soils with composted municipal waste (CMW) has received worldwide attention. This compost is rich in organic matter and its use may improve soil fertility and physical properties (He et al., 1992; Oshins, 1995; Anikwe and Nwobodo, 2002). However, repeated compost application can lead to accumulation of trace metals in soils that could eventually contaminate human and other animal food chains (Garcia et al., 1992; Pinamonti et al., 1997; National Research Council, 2003).

There are currently no standards to evaluate compost quality in Brazil. Only Paraná and São Paulo states have set up guidelines based on the criteria for sludge (Sanepar, 1997; CETESB, 2001). Hence, there is a need to develop

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general standards for land application of urban waste. Our objectives were to determine: (i) the effect of CMW application on the heavy metal composition of four vegetable crops and (ii) the residual effects of this soil amendment on chemical properties of a Brazilian soil.

2. Methods

All the composted municipal waste used during this study was taken from the largest treatment plant (Caju) of Rio de Janeiro State, and it was applied from 1995 to 1997 to a soil (Dystrochrept) located in Nova Friburgo County (22°15'S and 42°45'W), a representative mountain area of intensive vegetable production. The Köppen climate classification is Cwb with mean annual temperature of 18 °C and mean annual precipitation of 1431 mm. In Caju plant, recyclable materials such as paper, glass and aluminum cans are manually removed early in the composting process. The remaining material is ground and the ferrous materials are separated using an electromagnet. The remaining organic waste is sieved and arranged into rows of long piles, and aerated by turning the pile periodically with mechanical means. Generally, 77–90 days are necessary to complete the composting.

Some characteristics of the soil used in this study are presented in Table 1. The experimental field design was a randomized complete block, consisting of an untreated plot (control) and four rates of CMW surface application (12.5, 25, 50, 100 t ha⁻¹, wet basis) and four blocks. No inorganic fertilizer was applied. Irrigation was also applied so as to keep soil moisture in the range of field capacity. Each plot had a total area of 4.0 × 2.4 m² separated in all directions by a border of 1 m. All plots were cultivated with the following crop succession: carrot, planted on November 22nd 1995 and harvested on April 2nd 1996; cauliflower, planted on May 23rd 1996 and harvested on September 5th 1996; sweet corn, planted on December 10th 1996 and harvested on April 10th 1997; and radish, planted on August 20th 1997 and harvested on October 21st 1997. These species were selected due to the fact that they present different edible plant parts (root, flower, seed) and, consequently, different nutrient uptake paths (Farago, 1994). They are also sensitive crops for different metal toxicities (Alloway, 1990; Fergusson, 1990; Kabata-Pendias and Pendias, 1992). Rotary tilling was used in order to prepare the soil since it mixes the upper layers of soil rather than completely turning the soil over. In the present study, tillage went to the first 15 cm of the soil. Moreover, the direction of the rotary tilling was inverted after each cultivation so as to avoid

Table 2

Procedure of the sequential extraction scheme used to fractionate heavy metals in soil samples

Fraction	Sequence of extraction
(F1) Exchangeable + carbonate bound	HAc (2 M) + NaAc (2 M) 1:1; pH 4.7 Room temperature/16 h
(F2) Fe & Mn oxide bound	NH ₂ OH · HCl (0.1 M); pH 2 (HNO ₃) Room temperature/16 h
(F3) Organically bound	H ₂ O ₂ (30%) + HNO ₃ (0.02 M) + NH ₄ Ac (1 M) Room temperature/16 h
(F4) Al oxide + strong Fe & Mn oxide bound	NaOH (0.1 M); pH 12 Room temperature/16 h
(F5) Residual	Aqua regia (HNO ₃ /HCl; 1:3) 50 °C/30 min

plot-to-plot contamination. The compost treatments were superficially applied in the same day of planting. Hence, a total amount of 50, 100, 200, and 400 t ha⁻¹ CMW was applied during the experiment. After the first year of the last CMW spread (1998), soil samples were collected from four depths (0–5, 5–10, 10–20, 20–40 cm). The samples were dried in a forced air oven at 40 °C, passed thorough a 2-mm sieve and stored in a polyethylene bag. Vegetable edible parts were rinsed with distilled water, after that they were dried at 70 °C and ground in a stainless steel Wiley mill in order to pass a 1 mm sieve. Ground samples were stored at room temperature in acid-washed polyethylene containers.

Aqua regia (HCl/HNO₃, 3:1) extraction is used in order to evaluate anthropogenic inputs of heavy metals and it is rather efficient (Hani, 1996; Walter and Cuevas, 1999; Scancar et al., 2000). Hence, this method was applied for soil and compost evaluation of Fe, Mn, Zn, Cu, Cd, Cr, Pb, and Ni. Therefore, considering the accumulation of some metals observed in the 0–5 cm, a sequential extraction method (Wasserman et al., 2005; Table 2) was used in order to specify the types of metal associations in soil. Dried plant samples were digested with a nitric/perchloric acid mixture. The content of the selected metals was analyzed by ICP-OES (Perkin–Elmer OPTIMA 3000, Norwalk, CT, USA). Duplicate analyses of each soil and plant extractions were performed throughout the work as well.

The humic fractions of the soil were sequentially extracted according to Kononova and Bel'Chikova (Sastri-ques, 1982). In short, the free fulvic acids (not bound) were obtained by shaking 20–40 g of soil (air dried, 2 mm-sieved)

Table 1

Some physical and chemical characteristics^a of the soil used in the experiment

Horizon	Depth (cm)	Clay (g/kg)	pH (H ₂ O)	Ca ²⁺ + Mg ²⁺ (cmol _c /kg)	K ⁺ (cmol _c /kg)	Al ³⁺ (cmol _c /kg)	CEC (cmol _c /kg)	P (mg kg ⁻¹)	C (g/kg)	N (g/kg)	
Ap	0–20	330	6.0	3.6	1.1	0.84	0.0	11.1	251	14.8	0.22
Bi1	20–45	390	5.2	0.8		0.12	0.6	12.0	34	18.0	0.25
Bi2	45–70	380	5.1	0.7		0.07	0.6	9.0	34	18.4	0.25

^a Determined according to the procedures of EMBRAPA (1997).

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