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# Short-term usage of sewage sludge as organic fertilizer to sugarcane in a tropical soil bears little threat of heavy metal contamination

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ABSTRACT

A field experiment was carried out to study the effect of application rates of sewage sludge and mineral nitrogen and phosphate fertilizers on As, Ba, Cd, Cr, Cu, Ni, Pb, Se, and Zn concentration in soil, cane plant, and first ratoon (residual effect) in a Typic Hapludult soil. To allow an analysis by means of response surface modeling, four rates of sewage sludge (0, 3.6, 7.2 and 10.8 t $ha^{-1}$, dry base), of N (0, 30, 60 and 90 kg $ha^{-1}$) and of $P_2O_5$ (0, 60, 120 and 180 kg $ha^{-1}$) were applied in randomized block design, in a 4 × 4 × 4 factorial scheme, with confounded degrees of freedom for triple interaction, with two replications. To evaluate the residual effect of the sludge applied to cane plant on the cane ratoon growth, mineral NK fertilizers were applied at the rates of 120 kg $ha^{-1}$ N and 140 kg $ha^{-1}$ of $K_2O$, on all treatments. The application rates of mineral nitrogen and phosphate fertilizers did not affect statistically the heavy metal concentration in the soil and in the sugarcane plants. Sewage sludge application increased As, Cd, Cu, Ni, Pb, and Zn concentrations in soil, but values did not exceed the quality standard established by legislation for agricultural soils. Although the concentrations of metals in the plants were very low, the uptake of heavy metal by sugarcane plants was generally increased by sewage sludge doses. The use of sewage sludge based on N criteria introduces a small amount of heavy metal into the agricultural system, however it poses no hazard to the environment.



## 1. Introduction

Sewage sludge is a residue from domestic wastewater treatment. Increasing costs of commercial fertilizers and large amounts of sewage sludge produced worldwide have made land application of this residue an attractive disposal option (Melo et al., 2007).

Sludge application to agricultural soils improves soil physical and chemical properties, such as porosity, aggregate stability, bulk density, water movement and retention (Silveira et al., 2003), and soil fertility by increasing organic matter and nutrients content (Chiba et al., 2008; Alcantara et al., 2009; Franco et al., 2010). The use of sewage sludge in Brazilian agriculture is controlled by Resolution 375, issued in 2006 by the Brazilian National Environment Council (CONAMA, 2006).

The use of sewage sludge in agriculture represents one of the most viable alternatives for its final disposal. However, the presence of heavy metals may limit its application because of the risk of soil contamination and metal transfer via the food chain potentially causing metabolic disorders and chronic diseases in humans (Nogueira et al., 2009). "Heavy metal" is a general collective term, which applies to the group of metals and metalloids with high specific weight and they are natural components of the earth's crust (Hashima et al., 2011). This definition is not acceptable and also inconsistent in use as already stressed in literature. However, in Plant Sciences, the term is so widely used that it is hardly possible to eliminate it (Appenroth, 2010). In the present study, the heavy metal term indicates metals and metalloids.

Heavy metals most commonly found in sewage sludge are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn), and the metal concentrations are governed by the nature and the intensity of the industrial activity, as well as the type of process employed during the sewage sludge treatment (Basta et al., 2005; Alvarez et al., 2008). Longer-term field studies have demonstrated consistent evidence that sewage sludge application increases heavy metal concentrations in soil (Udom et al., 2004; Melo et al., 2007; Nogueira et al., 2008, 2010). The

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levels of heavy metal in tropical soils may increase considerably even in a short-time after sewage sludge application (Oliveira and Matiazzo, 2001; Marques et al., 2007).

Heavy metal uptake by plants depends on the form in the soil and on the plant species. Moreover, most of vegetative parts of plants, especially leaves, have higher heavy metal contents than seeds, nuts and fruits. However, the accumulation of heavy metals is potentially most harmful in cereals and vegetables rather than to sugarcane which is not used for immediate human consumption, reducing the risk to human health. Consequently, sewage sludge has already been applied on sugarcane fields in the state of São Paulo (Brazil's leading cane-growing state). Studies have been conducted to investigate the effects of sewage sludge application on uptake of heavy metals by sugarcane (Marques et al., 2007; Nogueira et al., 2007; Camilotti et al., 2009), but most of them focused on the rates above those permitted by the technical criteria of Resolution 375 (CONAMA, 2006).

With increasing disposal of sewage sludge on agricultural land, the risk of soil and food contamination by heavy metals must be considered. However, field studies under tropical conditions to evaluate the effect of sewage sludge on the accumulation and availability of heavy metals in soils and uptake by sugarcane plants are inconclusive (Abreu Junior et al., 2008). Considering that Brazilian soils are quite different from temperate soils, the objective of this research was to evaluate the effect of application rates of sewage sludge and mineral nitrogen and phosphate fertilizers on heavy metal concentration in a tropical soil and its potential availability to sugarcane plants using a field experiment.

## 2. Materials and methods

### 2.1. Field procedures

The experiment was carried out in a commercial cane field in the municipality of Capivari, State of São Paulo, Brazil (22°55′45″ S and 47°33′58″ W, altitude 550 m). This area (Fig. 1) has been cultivated exclusively with sugarcane crop for near 30 years, and was chosen in this study because it was included in a project on sludge use on sugarcane, although the field had not been treated with sewage sludge until 2005.

The local climate is moist tropical (Cwa on the Köppen scale), with relatively dry winters and hot and humid summers. Annual rainfall was 1565 and 1615 mm, respectively, in the period from September 2005 to September 2006 (first growth, cane plant) and from September 2006 to October 2007 (second growth, cane ratoon).

The tropical soil (classified as a Typic Hapludult, sandy clay loam texture) was sampled at 0–20 cm deep (clay, 28%; silt, 12%; sand, 60%) before setting up the experiment for fertility analysis according to procedures described by van Raij et al. (2001) and characterizing potentially toxic elements by USEPA-3051A method (USEPA, 2007) (Table 1).

The sewage sludge (Table 2) was obtained from the Jundiaí Wastewater Treatment Plant, in the municipality of Jundiaí, State of São Paulo, Brazil. The sludge was generated in an aerated biological system, stabilized in the sedimentation ponds for about 12 months, treated with polymers, centrifuged and air-dried for at least 120 days.

The sugarcane cultivar used was RB 85-5536, which is a medium/late cycle variety, very responsive to the application of mineral fertilizers, with high stalk and sugar yields when grown under favorable conditions for its development. Prior to the experiment, in August 2005, lime was applied at the rate of 500 kg ha$^{-1}$ in the entire area, to raise base saturation to 60% (Spironello et al., 1997).

In September 2005, the sludge was applied in the furrows, just before cane planting, at the rates of 0, 3.6, 7.2, and 10.8 t ha$^{-1}$ (dry basis), equivalent to 0, 33, 66, and 100% of the recommended N supply (CONAMA, 2006). Nitrogen (as urea, 45% N) was applied at the rates of 0, 30, 60, and 90 kg ha$^{-1}$ of N, equivalent to 0, 33, 66, and 100% of the recommendation for the experimental area (Spironello et al., 1997), in proportions of 1/3 applied at planting and 2/3 applied 30 days later as side dressing. Phosphorous (as triple superphosphate, 45% $P_2 0_5$) was applied, at planting only, at the rates of 0, 45, 90, and 180 kg ha$^{-1}$ of $P_2O_5$, equivalent to 0, 33, 66, and 100% of the recommended supply. Since sewage sludge is poor in potassium (Table 2), this nutrient was supplied at 160 kg ha$^{-1}$ of $K_2O$ at planting (as potassium chloride, 58% $K_2O$), on all plots. To evaluate the residual effect of the sludge applied to cane

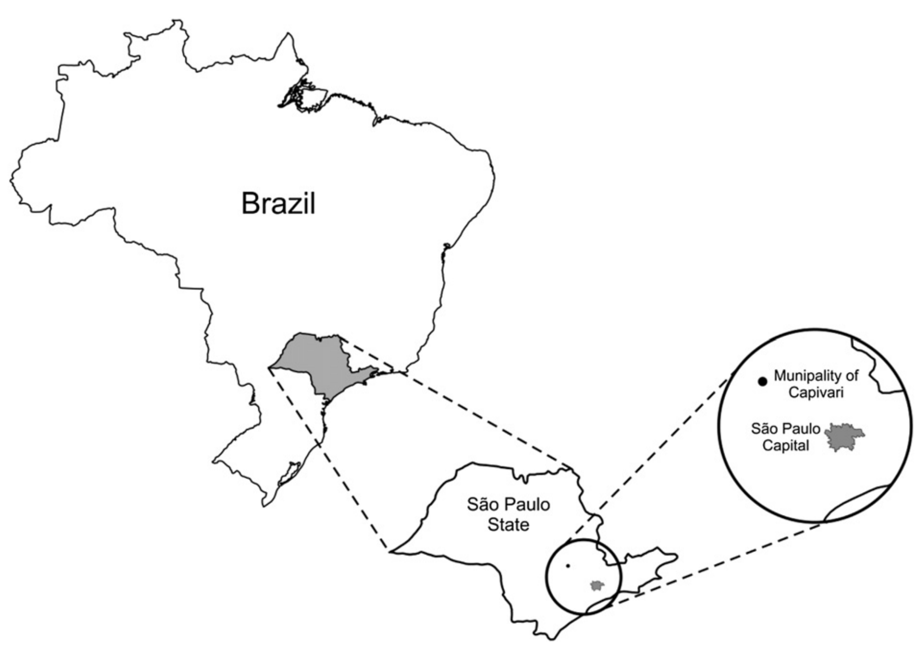


**Fig. 1.** Location of experimental site (not in scale), in the State of São Paulo, Brazil.