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Reduction of heavy metal contents in liquid effluents by vermicomposts and the use of the metal-enriched vermicomposts in lettuce cultivation

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Abstract

The removal of Cu, Ni and Zn from electroplating effluents by adsorption in cattle manure vermicompost has been discussed. A glass column 38 cm long and 7 cm i.d. was loaded with cattle manure vermicompost and effluents were passed through it. The metal concentrations were measured in the elutant. The experiments on adding effluent aliquots into the columns were continued until the metal concentrations in the elutant reached the maximum values established for effluent discharges in water courses by the Brazilian quality criteria, i.e., Cu = 1.0 mg L^{-1}, Ni = 2.0 mg L^{-1}, and Zn = 5.0 mg L^{-1}. The amount of Cu retention by the vermicompost was determined at the natural effluent pH (2.0). The Zn and Ni retentions were evaluated at the natural effluent pH (6.9 and 7.4, respectively) as well pH 2.0. Vermicompost residues obtained from this process were used for lettuce cultivation. The vermicompost was found to be efficient in removing metals from the electroplating wastes, as well as in the increase of its pH values. Metal retention values were close to 100%. The Cu concentrations in lettuce leaves from the treatment with vermicompost enriched with this metal were below the range of critical toxicity level to plants, i.e., from 20 to 100 mg L^{-1}. However, the estimated Cu concentrations in the roots from the treatment with vermicompost enriched with Cu were much larger than that of the treatment with the natural vermicompost, reaching 246.3 mg L^{-1}. The Ni and Zn concentrations in lettuce leaves from the treatments, with vermicomposts enriched with the respective metals, were above the range of critical toxicity levels to plants, i.e., from 10 to 50 mg kg^{-1} and from 15 to 30 mg kg^{-1}, respectively. However, no symptom of toxicity was found visually. Larger accumulations of Cu, Ni and Zn were found in the lettuce leaves than in the roots after the treatments with the uncontaminated vermicompost. A greater absorption of Cu and Ni by roots was found in treatments with vermicompost enriched with these elements, whereas Zn was found preferentially in the leaves. The statistical analysis was done by analyses of variance and regression.

Keywords: Vermicompost; Absorption of heavy metals; Electroplating effluents; Lettuce

1. Introduction

One of the most important sources of pollution is the discharge of industrial effluents into soil and surface waters. Electrochemical methods are employed in metal finishing for protection and/or decoration of a variety of metal surfaces (Förstner and Wittmann, 1981). In the electroplating process, the rinsing operation to remove excess chemicals from the treated surfaces produces effluents containing high metal concentrations. Currently, most of the electroplating wastes in Brazil are discharged into water courses without a suitable treatment. The presence of heavy metals such as Cu, Ni and Zn in waste materials dis-

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charged into water courses may be toxic to the flora and fauna (Gigliotti et al., 1996). This requires controlled discharge of effluents to avoid hazardous situations. Significant reductions of metal concentrations in liquid effluents can be achieved by the humic substances in vermicomposts (Jordão et al., 2002; Pereira and Arruda, 2003). These materials contain a great number of sorption sites that interact with the metals. The organic fraction of vermicompost represents about 50% of its weight (Senesi et al., 1989).

Different organic wastes can be used in vermicompost production, such as urban solid waste (Alves and Passoni, 1997), swine manure (Atiyeh et al., 1999), residues of plant decomposition (Kamergam et al., 1999), sewage sludge and sugarcane pulp (da Silva et al., 2002), among others. The vermicompost can also be produced from cattle manure (Kiehl, 2001). Animal manures contain significant quantities of plant-available nutrients which could increase crop yields (Eneji et al., 2001). Waste reduction by recycling is an important part of any integrated liquid waste-management system.

The use of vermicompost seems to be a good alternative for reducing heavy metal contents in liquid effluents. The vermicompost residues obtained after the purification of effluents might be used in agriculture. Lettuce is a vegetable that accumulates relatively large amounts of heavy metals such as Cu, Zn and Pb (Hue et al., 1988; Boon and Soltanpour, 1972). This characteristic allows the use of lettuce as an indicator of soil metal contamination.

This paper reports the use of vermicomposts for purifying effluents containing Cu, Ni and Zn collected from an electroplating plant. The effluents were passed through a glass column containing vermicompost and the metal concentrations in the elutant were measured to verify if they were within the guidelines for effluent discharges into water courses by the Brazilian legislation. For the purpose of using vermicompost residues for lettuce nutrition, vermicompost was used together with lettuce in pots for metal evaluation in leaves and roots.

2. Methods

2.1. Sample collection and pre-treatment

Five kg of commercial cattle manure vermicompost (Super Húmus), produced in the Vista Alegre farm in the city of Ubá (State of Minas Gerais, Brazil) was used as the sorptive material of Cu, Ni and Zn from electroplating effluents. The raw vermicompost was air-dried for 72 h and passed through a 2 mm sieve. Samples of 10 L of electroplating effluents containing Cu, Ni or Zn were obtained from a factory located in Ubá. The zinc effluents were collected twice, the second collection being 6 months latter the first one. Two hundred kg of an oxisol were collected from the soil surface (0–20 cm depth) in Viçosa, State of Minas Gerais, Brazil. Subsamples of the oxisol were air-dried, ground to pass through a 4 mm sieve and used in the determination of the oxisol characteristics as well as in the lettuce cultivation experiments in soil amended with vermicompost enriched with Cu, Ni or Zn. The oxisol characteristics are summarized in Table 1.

Table 1
Soil characteristics[a]

pH in H_2O (1:2.5)	4.15
Organic matter (%, w/w)	1.25
CEC ($cmol_c\ dm^{-3}$)	11.60
Available P ($mg\ dm^{-3}$)	1.60
Available K ($mg\ dm^{-3}$)	14.00
Exchangeable Al ($cmol_c\ dm^{-3}$)	2.3
Exchangeable Ca ($cmol_c\ dm^{-3}$)	0.12
Exchangeable Mg ($cmol_c\ dm^{-3}$)	0.03
H + Al ($cmol_c\ dm^{-3}$)	11.4
Total metal ($mg\ kg^{-1}$)	
Cu	17.4
Ni	33.9
Zn	34.5
Al	72,700
Fe	49,400
Ca	37.1
Cd	3.4
Pb	<1
Mg	76.1
Na	93.7
K	15.2
Mn	65.1
Clay (%, w/w)	60
Silt (%, w/w)	12
Sand (%, w/w)	28
Textural class	Clay

[a] Value preceded by < symbol indicate detection limit.

2.2. Natural vermicompost characterization

The vermicompost pH was measured in deionised water (solid/solution ratio = 1:2.5) using a pH meter. Moisture content of the vermicompost was determined by the percentage loss in weight after drying the sample at 60 °C and at 110 °C for 24 h; organic matter content was measured by ignition in a furnace at 550 °C for 24 h, and ash content after heating at 800 °C for 2 h (Kiehl, 1985). The C and H contents were measured with an infrared detector and the N content was measured with a thermal conductivity detector.

The carboxylic group content was determined in approximately 0.1 g of vermicompost. This was added to 10 mL of 0.5 mol L^{-1} $Ca(OAc)_2$ solution. After agitation of the mixture for 24 h, the carboxylic groups were determined by titration with a 0.1 mol L^{-1} NaOH solution to pH 9.8 (Stevenson, 1994). To obtain titration curve, 1 g of the vermicompost, previously sieved to a particle size of less than 0.177 mm, was titrated potentiometrically with NaOH solution. A nonlinear regression equation was adjusted to the titration data to differentiate the acid groups. This allowed the determination of the pK_a values. The total concentrations of Cu, Ni, Zn, Mn, Fe, Pb, Cd, Ca, Mg, Na, and K were determined in the vermicompost using 0.5 g portions of air-dried samples. They were digested individually at 200 °C with 5 mL of 65% (w/v)