

Chemical fractionation of trace elements in an amphibolite soil amended with municipal solid waste composts

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Abstract

An agricultural acid soil developed on amphibolites was amended with 5% of five commercial composts (produced mainly from municipal solid wastes) and incubated in the laboratory during 90 days, with the objective of studying the fate of trace elements in soil after compost addition by means of chemical analyses based on BCR fractionation schemes. In general, the addition of the composts had little effect on the distribution of trace elements, because of their high previous contents in the soil. Compost addition increased the oxidizable (organic matter) and reducible (iron oxides) fractions of soil Cu, and the soluble and reducible fractions of soil Zn. None of the composts modified Pb distribution, which was mostly found in the reducible fraction, nor that for Cr or Ni, present in more than 80% in the residual non-extractable fraction. Among the elements studied, Zn was that of most concern, since the addition of some composts increased the soluble forms of this element.

Introduction

The recycling of the organic matter contained in wastes as an amendment for agricultural soils after composting is a feasible option for maintaining the organic matter levels in soil and also for improving soil quality and productivity. However, the use of certain composts produced from municipal solid wastes (MSW) can raise serious concerns about the environmental impact of this practice. These composts may present high concentrations of potentially toxic trace elements such as Cu, Zn or Cr, especially when mechanically-sorted organic fraction is used for their production, instead of the separately collected waste [1].

The environmental risk derived from the agricultural use of compost relies to a great extent on the behaviour of trace elements once they reach the soil, which is a function of (i) their concentrations and chemical forms in compost, and (ii) their interactions with soil components. Here, we studied trace element distribution in chemical fractions after compost addition to an agricultural soil developed over amphibolites (a geological material which is rich in iron oxides and trace elements).

Material and Methods

Soil

The soil used in the experiment was a cropped soil developed over amphibolites, located in Santiago de Compostela (NW Spain, 43° N and 8° W), 180 m above the sea, under an oceanic climate (mean annual temperature 12.3°C; mean annual rainfall 1900 mm). Similar soils in the area are classified as Ferrali-Humic Umbrisols or Oxic Dystrudepts [2]. For the experiment, a composite sample was taken from the top 10 cm of the Ap horizon of the soil. For the analysis of soil pH, texture and total organic carbon (TOC) the methods described by Guitián and Carballas [3] were followed. Total Cu, Pb, Zn, Cr, Ni and Cd were determined after microwave digestion with HF, HNO₃ and HCl at 120°C.

Composts

Four municipal solid waste composts and a manure vermicompost were used: MSWC1 was obtained by anaerobic fermentation of the biodegradable fraction of municipal solid waste (MSW), separated before collection, followed by an aerobic composting step, to stabilize the incompletely digested residue. MSWC2 was obtained by composting the source separated organic fraction of MSW. Both MSWC1 and MSWC2 were provided by industrial composting facilities located in Galicia (Spain). MSGW is a commercial compost obtained from source separated biodegradable MSW mixed with

green waste, and MGSS is compost obtained from municipal garden trimmings mixed with sewage sludge; they both were supplied by an industrial composting facility located in Catalunya (Spain). Finally, MV is a mixed manure vermicompost supplied by a local producer in Galicia (Spain). For their analysis, the Spanish version of the European methods for the characterization of soil amendments and substrates [4-6] was followed.

Incubation experiment

The soil was amended with a 5% (dry weight) of each one of five commercial composts. Three replicates of each treatment and a control consisting of non-amended soil were placed on 0.5-L plastic pots and incubated at 23°C in the laboratory during 90 days. Moisture was maintained throughout the experiment around 60% of their field capacity, replacing weight losses with distilled water. Composite samples were taken monthly at random from each pot, and air-dried for analysis. For the determination of immediately available trace elements (Cu, Pb, Zn, Cr, Ni, Cd), 2 g of air-dry soil were extracted with 20 mL of 0.01N CaCl₂, shaken for 3 h, and filtered [7]. Cu, Pb, Zn, Ni and Cr distribution in chemical fractions was analysed monthly following the BCR sequential extraction procedure as described by Rauret et al. [8]. This method consists of three steps and a residual extraction, and defines four fractions: an acid-soluble fraction, a reducible fraction that is mainly associated to iron and manganese oxides, an oxidizable fraction associated to organic matter, and a non-extractable fraction which is associated to silicates and other mineral material.

Results

The soil presented a slightly acidic pH and a loamy texture; it was rich in organic matter and iron oxides, with high trace element contents (Table 1). The composts had pH values from neutral (MGSS) to alkaline (MSGW), and similar TOC contents, the organic matter representing approximately half of the compost by weight. Considering total trace element contents, Zn and Cu were the most abundant in all the composts, followed by Pb, Cr and Ni, and last, Cd. It has to be highlighted the higher Cr and Ni contents of the soil with respect to the composts, which is related to their abundance in the rock.

Table 1. Properties of soil and composts. TOC: total organic carbon.

	pH	Texture	TOC g kg ⁻¹	Cu	Zn	Pb	Cr	Ni	Cd
				----- mg kg ⁻¹ -----					
Soil	6.0	Loamy	67	97	151	63	190	73	1.7
<i>Composts</i>									
MSWC1	8.4	-	280	325	608	188	80	57	3.5
MSWC2	8.2	-	230	829	1149	223	77	75	3.1
MSGW	9.2	-	248	52	200	62	17	25	2.1
MGSS	7.3	-	298	688	896	180	68	71	2.7
MV	7.9	-	217	144	689	33	23	27	2.0

Compost addition did not have a strong impact on total trace element contents of the mixtures (data not shown), due to the high previous contents in the amphibolite soil and the low dose of compost added. Regarding the immediate environmental risk, assessed by the CaCl₂ extraction, different trends were observed for each element considered. Compost addition did not modify the extractable Cu and Cr with respect to the control soil, but decreases of extractable Pb, Zn, Ni and Cd were observed (Figure 1). Overall, aside from a few cases of increasing CaCl₂ extractable Cu, Zn, Ni or Cd in control or amended soils observed between 60 and 90 days, most compost-amended soils showed a decreasing trend of extractable metals during the incubation.

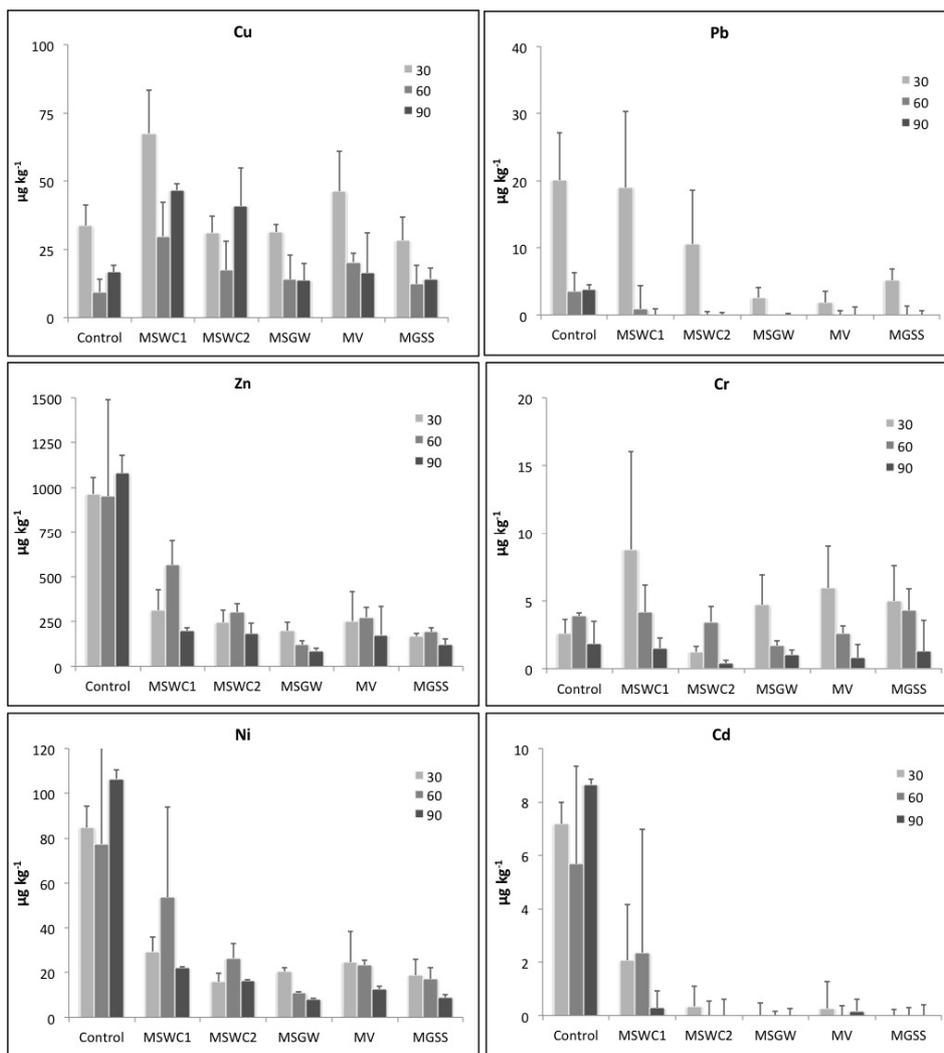


Figure 1. Evolution of trace element extractability in 0.01N CaCl₂ during the incubation after 30, 60 and 90 days.

Regarding the distribution of the added metals in the fractions of the BCR procedure, we did not observe changes over time, so only the results at the end of the incubation are shown here. Compost addition slightly increased the oxidizable (organic matter) and reducible (iron oxides) fractions of soil Cu, and the soluble and reducible fractions of soil Zn, at the expense of the residual fraction. None of the composts modified the distribution of Pb, which was mostly found into the reducible fraction, nor that of Cr or nickel, present in more than 80% in the residual non-extractable fraction. In what concerns the trace element soluble fraction, which presents the highest environmental risk, it was only increased by compost addition in the case of Zn, which is a common feature in municipal solid waste composts. The distribution of each element in soil after compost addition agrees with the results of the BCR analyses of the composts [9], which suggests that compost analyses can adequately predict the behaviour of trace elements in soil.

Conclusion and perspectives

The addition of compost to an acid amphibolitic soil had little effect on the chemical fractionation of trace elements, which is in part due to their high previous concentrations in soil. Among the elements studied, Zn was of most concern, since the addition of some composts increased the soluble forms of this element.

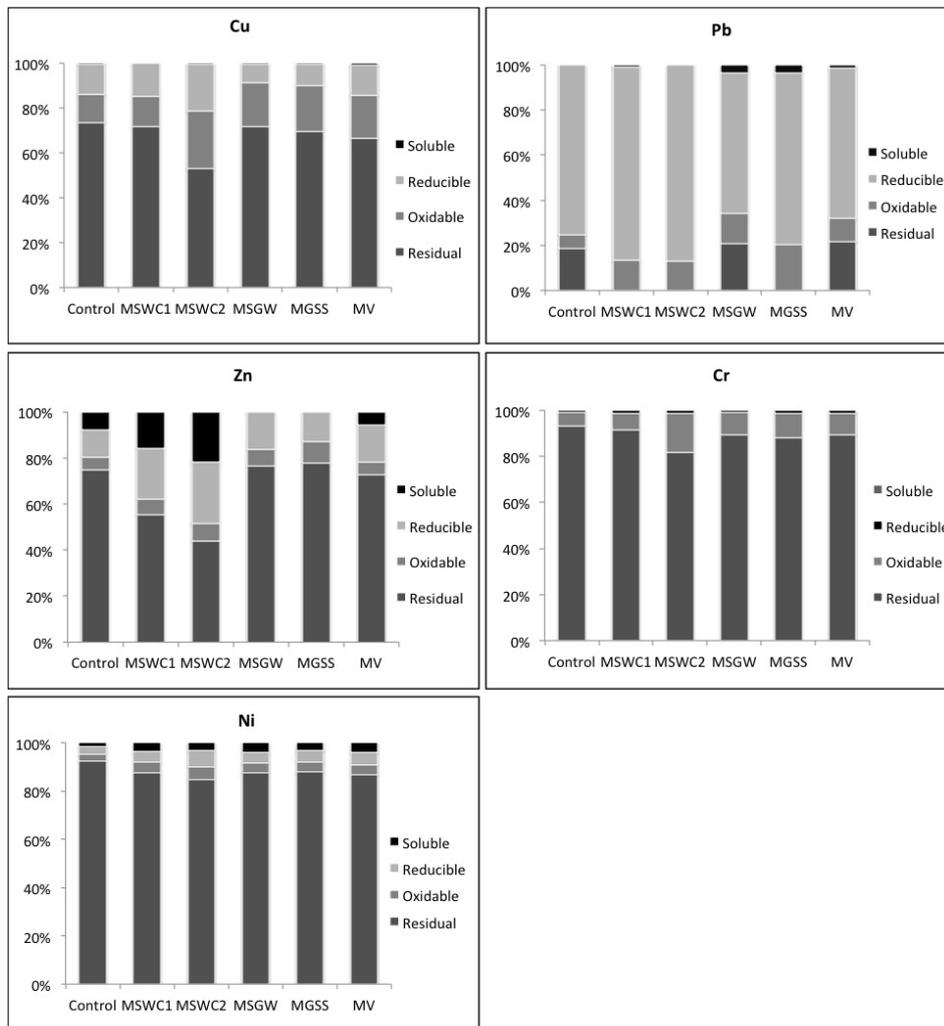


Figure 2. Relative distribution of trace elements in the BCR fractions after 90 days of incubation.

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