Temporal dynamic of trace elements in soils amended with contaminated organic wastes

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Abstract

Applications of so-called organic wastes are recommended in agriculture where the organic matter content of soil is low. However, before applying organic wastes to soil it is essential to assess that these materials do not pose any hazard to humans, animals, or to the environment. This study aims at evaluating the dynamic of trace elements in a soil amended with various organic wastes combining incubation and DGT techniques. Soil/waste samples were incubated to evaluate the impact of organic waste application on trace elements exchangeable fractions by exploring the DGT response. Organic wastes were incorporated at 80 t ha^{-1} of dry matter. During organic waste mineralization, we have detected increase in the exchangeable fractions of trace elements, which was more noticeable for Zn and Pb than for Cu, Cd, Ni and Cr.

Introduction

Agricultural recycling is recognized as an alternative to stockpiling or incineration. However, benefits of the use organic wastes as soil amendment should be assessed together with the potential environmental and toxicological effects of trace elements (Hargreaves et al., 2008). The chemical and biological conditions of the medium are substantially altered during organic waste mineralization through changes in the organic matter stock and dynamics and in the physicochemical properties (pH, Eh, etc.) of the soil solution. The main challenge in organic wastes recycling is to ensure that there is no transient or disseminated pollution to natural environment. It is thus essential to gain insight into how these wastes change when they come in contact with the receiving medium. Among methods proposed to assess metals dynamic in soils after amendment most of them rely on chemical extractions using a series of more or less selective reagents (e.g., Santos et al., 2010; Doelsch et al., 2010). However, reagents are not completely selective and usually substantially modify the physicochemical properties of soil. Alternatively, the potential resupply of trace elements from soil to solution could be measured by the DGT technique (diffusive gradients in thin films; Zhang et al., 1998). It is noteworthy that this technique, which not disrupts the physicochemical equilibrium, would not affect the distribution of species in solution and enables an in situ investigation of trace element dynamic in soil. In addition, DIFS model could lead to quantitative interpretation of DGT measurements in terms of fundamental kinetic and equilibrium resupply parameters.

This study aimed at exploring the consequences of amendment with various organic wastes on dynamic of trace elements. The challenge was to assess to effects of amendments on metals dynamic in soil exploring the DGT response as a function of incubation time of soil.

Materials and Methods

The soil selected for the present study was sampled in the 0–25 cm horizon (La Réunion, France). This soil exhibits a fairly low concentration in total trace elements compared to contaminated organic wastes (Table 1).

	Soil	Mould of MSWC	Mould of MSWC	MSWC	MSWC	SS	PSC
		Madagascar	Senegal	Madagascar	Senegal	Senegal	France
Cu	34	270	310	80	20	390	180
Zn	170	3200	1740	440	75	1190	800
Cd	0.3	9.7	2.8	0.4	0.1	4.3	0.4
Pb	15	1800	2500	150	14	72	20
Ni	100	35	20	185	80	65	30
Cr	106	100	50	450	190	170	50

Table 1. Trace elements contents in investigated soil and organic wastes (mg kg^{-1} of dry matter).
MSWC = municipal solid waste compost; SS = sewage sludge; PSC = pig slurry compost

Incubation experiment was carried out with 80 t ha^{-1} DM of waste. Soil was equilibrated for 24 hours before mixing with organic waste. The moisture content was brought to 70% of the water-holding capacity and was controlled by weighting, and readjusted if necessary, during the experiments. The DGT units were inserted into the soil slurry. Three replicates were performed and study included a treatment without organic waste (control soil). The DGT devices were progressively retrieved at 6 times during 37 days. The calculated flux of metals from soil to the DGT device (F_{DGT}) provides information on the ability of the solid phase to resupply the soil solution with dissolved metals (for details, see Zhang et al., 1998). In addition, soil solution was extracted by centrifugation to measure some physicochemical parameters: pH, trace elements total concentrations and dissolved organic carbon.

Results and discussion

The organic wastes applied in this study are characterized by their contamination in trace elements (Table 1). Two groups of trace elements could be distinguished: (i) those with a predominantly geogenic distribution (Cr and Ni) and (ii) those with an anthropogenic one (Pb, Cd, Cu and Zn). We studied the resupply fluxes of these elements by plotting the relation of F_{DGT} with time. Results with mould from MSWC (Madagascar) showed that fluxes accumulated on resin are greater in presence of organic waste than in control soil for all metals. Consequently, the percentage of labile metals increased in consequence of the application of this amendment (See Fig. 1 for Zn). The increase was greater for Zn and Pb than for others elements. For Cu, Cd, Ni and Cr fluxes of labile metals in presence of compost decreased more rapidly with incubation time and were not greater than soil control after few days.

Recently, Doelsch et al. (2010) have realized incubation of the same soil with pig slurry and green compost. Their results, from chemical extraction by 0.1 mol l^{-1} $NaNO_3$, led them to conclude that any increase in trace elements exchangeable fractions occurred. This would suggest that DGT technique is more efficient to assess metals dynamic in an agricultural soil than chemical extractions what disrupts the physical-chemical equilibrium.

In addition, physicochemical parameters acquired on soil solutions will enable us to achieve quantitative interpretations of DGT measurements in terms of fundamental kinetic and equilibrium resupply parameters.

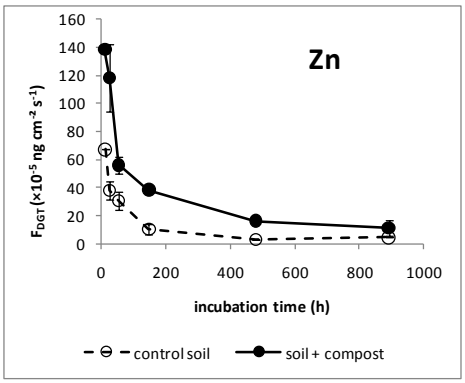

Figure 1. Flux of Zn resupply from the solid phase (F_{DGT}) for the experiment without organic waste (soil control) and with mould of MSWC (Madagascar).

Conclusion

The application of contaminated organic wastes on soil could increase the flux of trace elements measure by DGT. Consequently, a dynamic remobilization of trace elements occurs after organic amendment and potential available fraction to be taken by the biota or leached from the soil to ground water increases. Thus, these results demonstrate the potential risk of increasing metals mobility in soil, mainly Zn and Pb, associated to the use of contaminated organic amendments. In addition, we have demonstrated that this mobility could be easily and unambiguously assess by the DGT technique.

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