

SOIL ORGANIC MATTER AND SALINITY MODIFY CADMIUM MOBILITY IN SOIL

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Introduction

There is a special interest in understanding the processes which control the mobility, transformation and toxicity of cadmium (Cd) at the soil–plant interface. The mobility of Cd in soil ultimately depends on its chemical speciation, which is mainly a function of soil pH and the presence of organic and inorganic ligands in the soil solution (McLaughlin et al., 1997; Smolders et al., 1998). Soil organic matter (SOM) plays a two-sided role in metal mobility in soil: (i) particulate SOM retains metals through the formation of metal-SOM complexes, decreasing thus their mobility in soil (Matijevic et al., 2014), and (ii) dissolved organic matter (DOM) may increase the metal mobility due to formation of metal-DOM complexes (Kirchmann and Eriksson, 2011). Similarly, increased soil salinity may affect the mobility of Cd in the soil by the formation of $CdCl_n^{2-n}$ complexes. Formation of such complexes reduces the activity of free Cd^{2+} in soil solution, considered to be the most available Cd species to soil biota, but at the same time they are more loosely bound to soil particles and therefore may result in metal mobilization in soil. Because the mobility of Cd in soil is a main factor controlling its bioavailability, the present study is focused on the effects of soil Cd contamination, increased SOM and raised soil (NaCl) salinity on Cd mobility in soil.

Methods

A greenhouse pot experiment was carried out. Pots were containing (i) alluvial soil and (ii) the same soil with added peat (4:1, v/v) to increase SOM content. Two SOM levels, unmodified (SOM₀) and increased (SOM₁), were investigated. The soil (SOM₀ and SOM₁) was spiked with Cd at two levels: 5 mg kg⁻¹ (Cd₅) and 10 mg kg⁻¹ (Cd₁₀); with the control soil (Cd₀ – without added Cd) also used in the experiment. NaCl salinity was applied to pots: NaCl₀ – control (without added NaCl), NaCl₅₀ (control + 50 mM NaCl) and NaCl₁₀₀ (control + 100 mM NaCl). Split–split–plot experimental design with three blocks was used. Five weeks after salinity treatment started, soil samples were taken, air–dried, passed through a 0.5 mm mesh and digested in aqua regia. Element concentrations in soil digests were determined by ICP – OES and AAS. Calcium chloride extraction (Houba et al., 1999) was used for the estimation of the Cd availability in soil. Distribution (%) of different Cd species in soil solution was estimated by Visual MINTEQ version 3.0 chemical equilibrium software (NICA–Donnan model) (Kinniburgh et al., 1996). Data processing was done using the Statistical Analysis Software (MIXED procedure).

Results

Increase of SOM resulted in statistically significant increase of total soil Cd concentration, implying that the mobility of Cd was reduced by the SOM addition. Complexation of Cd with DOC in the soil solution lowered the percentage of free Cd^{2+} in soil solution. Increased soil salinity had a significant effect on soil total Cd concentration, but without a consistent trend in regard to salinity treatments. Also, salinity affected $CaCl_2$ extractable Cd concentrations, with the highest concentration recorded in control soil, and without difference between the salinity treatments. Furthermore, data confirm that increased (NaCl) soil salinity affects the Cd speciation in soil solution by promoting the formation of $CdCl_n^{2-n}$ complexes, with the $CdCl^+$ as the dominant species. We explain the results by the possibility that, at studied NaCl levels, $CdCl^+$ operated just as a carrier of Cd between different fractions in soil. Presumably, it could have caused an initial increase of Cd mobility in soil, but resulted only in transfer between solid phases and not in increased availability.

Conclusion

This study has confirmed that Cd is highly mobile between different soil fractions and Cd speciation in the soil solution was greatly affected by all investigated trial factors: soil Cd contamination enhanced the proportion of the free Cd²⁺ ion, raised SOM induced complexation of Cd with DOC, and increased soil salinity promoted the formation of CdCl_n²⁻ⁿ complexes in soil solution, all of which consequently modified the mobility of Cd in soil. However, results are also indicating that, if a soil adsorption capacity for Cd has not been exceeded, increased Cd mobility in soil does not always result in its increased availability, but only in transfer between soil solid phases.

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