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Heavy metal sequential extraction methods—A modification for tropical soils

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Abstract

Sequential extractions of metals can be useful to study metal distributions in various soil fractions. Although several sequential extraction procedures have been suggested in the literature, most were developed for temperate soils and may not be suitable for tropical soils with high contents of Mn and Fe oxides. The objective of this study was to develop a sequential fractionation procedure for Cu and Zn in tropical soils. Extractions were performed on surface (0–20 cm) samples of ten representative soils of Sao Paulo State, Brazil. Chemically reactive Mn forms were satisfactorily assessed by the new modified procedure. Amorphous and crystalline Fe oxides were more selectively extracted in a new two-step extraction. Soil-born Zn and Cu were primarily associated with recalcitrant soil fractions. The proposed procedure provided more detailed information on metal distribution in tropical soils and better characterization of the various components of the soil matrix. The new procedure is expected to be an important tool for predicting the potential effects of environmental changes and land application of metals on the redistribution of chemical forms of metals in tropical soils.

Keywords: Copper; Metals; Sequential fractionation; Tropical soils; Zinc

1. Introduction

Metals present in soils can be associated with several reactive components. Although total metal concentrations may indicate the overall level of metals in soils, they provide no information regarding the chemical nature or potential mobility and bioavailability of a particular element (Vijver et al., 2004; Jin et al., 2005; Powell et al., 2005). Sequential fractionation is a frequently used approach to evaluate metal distribution into different chemical forms present in a solid phase. Conceptually, sequential fractionation categorizes metals associated with chemically homogeneous fractions that, ultimately, affect metal availability. Although often criticized due to lack of specificity of extractants and possible readsorption of metals during extraction (Beckett, 1989), sequential fractionation can provide useful information to predict the fate of heavy metal in the environment.

Ideally, sequential extraction procedures selectively extract metals bound by specific soil fractions with minimal effect on the other soil components. In practice, sequential fractionation schemes have been suggested to identify element distribution with "operationally" defined soil pools. These chemical pools range from water soluble to recalcitrant forms immobilized in mineral lattices. Several single and sequential extraction methods have been proposed (Tessier et al., 1979; Ahnstrom and Parker, 1999; Qiao et al., 2003). Fractionation schemes have not been standardized and the results of different procedures are not always comparable due to the lack of uniformity in the experiment conditions (i.e., number of extractions, reagents, shaking time).

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Table 1
Soil chemical and physical properties

	Soils	pH	C (g kg^{-1})	Exchangeable cations				Total				Fe_{DCB}[a] (g kg^{-1})	Fe_{ox}[b] (g kg^{-1})	Clay (g kg^{-1})	Silt (g kg^{-1})	Sand (g kg^{-1})
				Ca (mmol$_c$ kg^{-1})	Mg (mmol$_c$ kg^{-1})	K (mmol$_c$ kg^{-1})	Al (mmol$_c$ kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Fe (g kg^{-1})					
LVA-1	Typic hapludox	4.5	12	1.3	0.7	0.5	9.8	2.6	6.6	19	13	10	1.7	181	40	779
LVA-2	Typic hapludox	4.2	30	1.8	1.0	0.6	12	3.8	9.3	18	16	14	0.9	221	20	759
LVA-3	Typic hapludox	4.3	16	1.5	0.6	0.6	8.6	5.0	9.3	37	27	21	1.6	202	60	738
LV-1	Rhodic eutrudox	6.4	19	16	9.6	1.5	1.2	15	33	130	66	53	3.1	201	81	718
LV-2	Rhodic hapludox	4.6	38	9.3	6.4	1.8	13	36	31	270	126	87	6.4	530	102	368
LVwf	Rhodic acrudox	4.7	67	10	4.9	2.9	5.9	130	120	1100	360	200	19	716	143	141
LAwf	Anionic acrudox	4.7	40	5.0	3.9	1.1	6.9	130	34	250	200	110	7.7	470	123	407
PVA-2	Arenic hapludalf	5.4	7.6	4.7	2.1	1.0	0.9	2.4	7.2	100	10	5.3	0.5	100	320	580
PV-1	Arenic hapludult	5.3	6.8	3.4	1.9	1.2	3.0	2.1	7.3	160	9.5	8.5	1.2	427	427	146
NVef	Kandiudalfic eutrudox	5.5	66	41	14	4.5	1.3	230	170	2500	320	190	15	658	267	75

[a] Cystalline Fe extracted by dithionite–citrate–bicarbonate.
[b] Amorphous Fe extracted by 0.2 M oxalic acid + ammonium oxalate solution.