Depth-Wise Distribution of Extracted Cu and Zn in Cultivated Field-Plots Three Years After Treatment with A Cu- and Zn-Containing Waste, Lime, and Cassava-Leaf Compost

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ABSTRACT

Depth-Wise Distribution of Extracted Cu and Zn in Cultivated Field Plots Three Years After Treatment with A Cu-and Zn-Containing Waste, Lime, and Cassava-Leaf Compost (A.K. Salam, S. Bakri, F. Prihatin): Cation retention by soil colloid adsorptive surfaces is believed to inhibit the movement of heavy metal cations in soils. This research was to investigate the movement of Cu and Zn in cultivated field-plots 3 years after treatment with an industrial waste containing considerable Cu and Zn, lime, and organic compost. Three levels of industrial waste (0, 15, and 60 ton ha^{-1}) were mixed with field topsoils of 0-15 cm one week after treatment with lime and organic compost. Extracted Cu and Zn were measured in soil samples collected depth-wise from 0 to 75 cm in field-plots 3 years after treatments. Copper and Zn only from high-level waste-treatments were observed to have significantly moved from topsoils to subsoils of 30 – 75 cm. Unlike that of Zn, the movement of Cu was also shown to be significantly lowered by topsoil treatment with lime and/or compost, suggesting that the increase in soil adsorption capacity inhibited the movement of Cu cations. Most Cu and Zn were retained in topsoils.

Keywords: Copper, heavy metals, lime, movement, organic compost, retention, waste, zinc

INTRODUCTION

Heavy metal inputs into soil system will probably be distributed into several important components, i.e. into soil adsorptive sites and precipitates that are not mobile and not readily washed out and into soil water that are readily washed out by percolating water and readily contaminates ground water. Incorporation of particular ameliorants such as lime and organic compost, that may enhance the soil adsorption capacity (Salam and Helmke, 1998; Salam *et al.*, 1997), may presumably increase the adsorbed and lower the water soluble portion, and thereby may inhibit the movement of heavy metals in soil body and, therefore, may limit the extent of ground water contamination by heavy metals emitted by the presence of industrial waste.

As pointed out previously, addition of 15 and 60 ton ha^{-1} of industrial waste containing Cu and Zn was proved to significantly increase the soil labile Cu and Zn, including those classified as available, exchangeable, and water soluble. However, the presence of 5 ton ha^{-1} $CaCO_3$ significantly decreased water soluble, exchangeable, and available Cu and Zn (Salam, 2000; Salam *et al.*, 1998c; 1998e; 1998f; Salam *et al.*, 1997), which was suggested to be related to the increase in the soil adsorptive capacity induced by the increase in soil pH. A great deal of research works have previously revealed that the increase in soil pH enhanced the soil surface charges that may, eventually, decrease the soluble metal cations (Choi *et al.*, 1999; Salam and Helmke, 1998).

To a lesser extent, the presence of organic compost also increased the retention of Cu by soil, related to the increase in the soil adsorptive capacity originated from compost functional groups (Salam, 2000; Salam *et al.*, 1997). As pointed out previously (Shenker and Chen, 2005; Salam and Helmke, 1998; Parfitt *et al.*, 1995; Rodella *et al.*, 1995; Alloway, 1990; McGrath *et al.*, 1988), some researchers were convinced that heavy metal cation concentrations in soils may be lowered by manipulating some soil chemical properties such as pH, organic matter contents, and CEC, that directly or indirectly control heavy metal solubilities in soils. This relationship may eventually lower heavy metal cation movements in soils (Salam *et al.*, 1998a; 1998b; 1998d).

This research was to investigate the depth-wise distribution of Cu and Zn in soil three years after

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treatment with industrial waste containing Cu and Zn, lime, and cassava-leaf compost.

MATERIALS AND METHODS

Field experimental plots were set up in Sidosari, Natar, South Lampung, in July 1998. Some initial soil characteristics were sand 41.2%, silt 26%, clay 32.8%, organic C 12.8 g kg^{-1}, total N 0.94 g kg^{-1}, C/N 13.6, pH 5.11, Cu 1.6 mg kg^{-1} and Zn 0.13 mg kg^{-1}. The experimental field consisted of 12 plots for one block, each measuring 4 m x 4.5 m with distances 50 cm between plots and 100 cm between blocks. Treatments were arranged in a completely randomized block design with 3 treatment factors, i.e. industrial waste, lime, and cassava-leaf compost. Industrial waste (with Cu 754 mg kg^{-1}, Zn 44.6 mg kg^{-1}, and pH 7.3) was given at 0 (W_0), 15 (W_1), and 60 ton ha^{-1} (W_2); lime ($CaCO_3$) at 0 (L_0)and 5 ton ha^{-1} (L_1); and cassava-leaf compost (C/N 6.85) at 0 (C_0) and 5 ton ha^{-1} (C_1). A complete report on the preparation of industrial waste, cassava-leaf compost, and experimental field plots was reported previously (Salam, 2000). All plots were planted with one time corn and one time upland paddy and were left bared until the time of soil sampling.

Soil sampling was conducted in July 2001. Soil samples were taken depth-wise: 0 – 15, 15 –30, 30 – 45, 45 – 60, and 60 – 75 cm in the exact middle of plots of two blocks. Sampling from the exact middle of the plots was considered very important to ensure representative soil samples because all sides of plots were prone to contamination from outside of plots (Liang, 1991). Soil samples were all ground, screened to pass a 2 mm sieve, and thoroughly mixed before chemical analysis.

Soil analysis included the availabilities of Cu and Zn by using the method of DTPA (Baker and Amacher, 1982) and soil pH by using a pH-electrode (soil-to-water 1:2). The significance of treatment factors was evaluated using analysis of variance (anova). Differences between treatments were evaluated using HSD Test at 5% and 1% significant level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Vertical Distribution of Cu

Significant effects of waste, lime, and/or compost on the extracted Cu were observed through the soil depths of 0 – 60 cm, shown by anova at 5% and 1% (Prihatin, 2002). This observation indicates that the effects of waste, lime, or compost and their interactions were still effective through the soil depth three years after treatments, suggesting that the use of these ameliorants were relatively long-lasting.

The movement of Cu in soil body was observed in high-level waste-treatments. The significant differences between treatments $W_2L_0C_0$ and $W_0L_0C_0$ at depth of 30 – 60 cm (Table 1) suggested that Cu treated at high-level waste (60 ton ha^{-1}) in topsoils (0 – 15 cm) moved to subsoils. At zero time, the extracted Cu both from $W_2L_0C_0$ and $W_0L_0C_0$ at 30 – 60 cm were assumed to be similar because the Cu-containing industrial waste was applied to topsoils (0 – 15 cm). The higher values in $W_2L_0C_0$ at depths of 30 – 60 cm must have been due to the movement of Cu cations from topsoils (0 – 15 cm).

Such movement was, however, not observed at low levels of waste treatment of 15 ton ha^{-1}, that increased the soil extracted Cu to much lower values than those treated with waste at the level of 60 ton ha^{-1}. This suggests that the soil adsorptive surfaces were not capable of adsorbing higher amounts of Cu from high-level wastes. However, after three years, significant amounts of added Cu were still retained at depths of 0 – 30 cm.

The treatment of lime and/or compost at topsoils (0 – 15 cm) lowered the extracted Cu, not only in the depth of 0 – 30 cm, but also those moved to the subsoils with the depths of 30 – 60 cm. This phenomenon is most probably associated with the increase in the soil adsorption capacity driven by the increase in soil pH (Fig. 1) and also by the presence of residue of organic compost. This suggests that these ameliorants can be utilized to inhibit the movement of Cu in soils.

Table 1. The effects of industrial waste, lime, and cassava-leaf compost on the depth-wise availability of Cu in soil three years after treatment[1].

Soil Depth (cm)	W_0				W_1				W_2				HSD 5%
	L_0		L_1		L_0		L_1		L_0		L_1		
	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	
	mg kg^{-1}												
0 – 15	0.67	1.06	0.63	0.81	1.67	2.24	2.21	2.13	9.66	8.57	8.10	8.81	0.89
15 – 30	0.55	0.85	0.49	0.71	1.36	1.62	1.67	1.29	6.98	4.32	5.74	5.87	1.00
30 – 45	0.63	0.81	0.44	0.75	0.75	0.81	0.84	0.67	2.03	1.14	1.14	1.09	0.56
45 – 60	0.63	0.75	0.30	0.75	0.67	0.78	0.74	0.67	0.88	0.84	0.99	0.93	0.28

Note: [1] All values are in square root; W = waste, W_1 = 0, W_2 = 15, and W_3 = 60 ton ha^{-1}; L = lime, L_0 = 0 and L_1 = 5 ton ha^{-1}; and C = compost, C_0 = 0 and C_1 = 5 ton ha^{-1}; effect of W, L, and C was significant.

Table 2. The effects of industrial waste, lime, and cassava-leaf compost on the depth-wise availability of Zn in soil three years after treatment[1].

Soil Depth (cm)	W_0				W_1				W_2				HSD 5%
	L_0		L_1		L_0		L_1		L_0		L_1		
	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	
	mg kg^{-1}												
0 – 15	1.33	1.19	1.75	1.20	3.10	6.60	5.56	4.30	9.51	9.03	7.89	7.22	2.35
15 – 30	0.58	0.98	0.79	0.68	1.77	2.01	2.04	2.37	5.28	5.70	5.28	5.70	1.76
30 – 45	0.62	0.87	0.65	0.40	0.65	0.98	0.62	0.41	1.41	1.58	1.20	1.42	0.66
45 – 60	0.40	0.71	0.58	0.28	0.50	0.54	0.40	0.40	0.96	1.06	1.01	1.02	0.46
60 – 75	0.29	0.29	0.35	0.06	0.44	0.50	0.40	0.35	0.94	0.73	0.74	0.91	0.57

Note: [1] All values are in square root; W = waste, W_1 = 0, W_2 = 15, and W_3 = 60 ton ha^{-1}; L = lime, L_0 = 0 and L_1 = 5 ton ha^{-1}; and C = compost, C_0 = 0 and C_1 = 5 ton ha^{-1}.

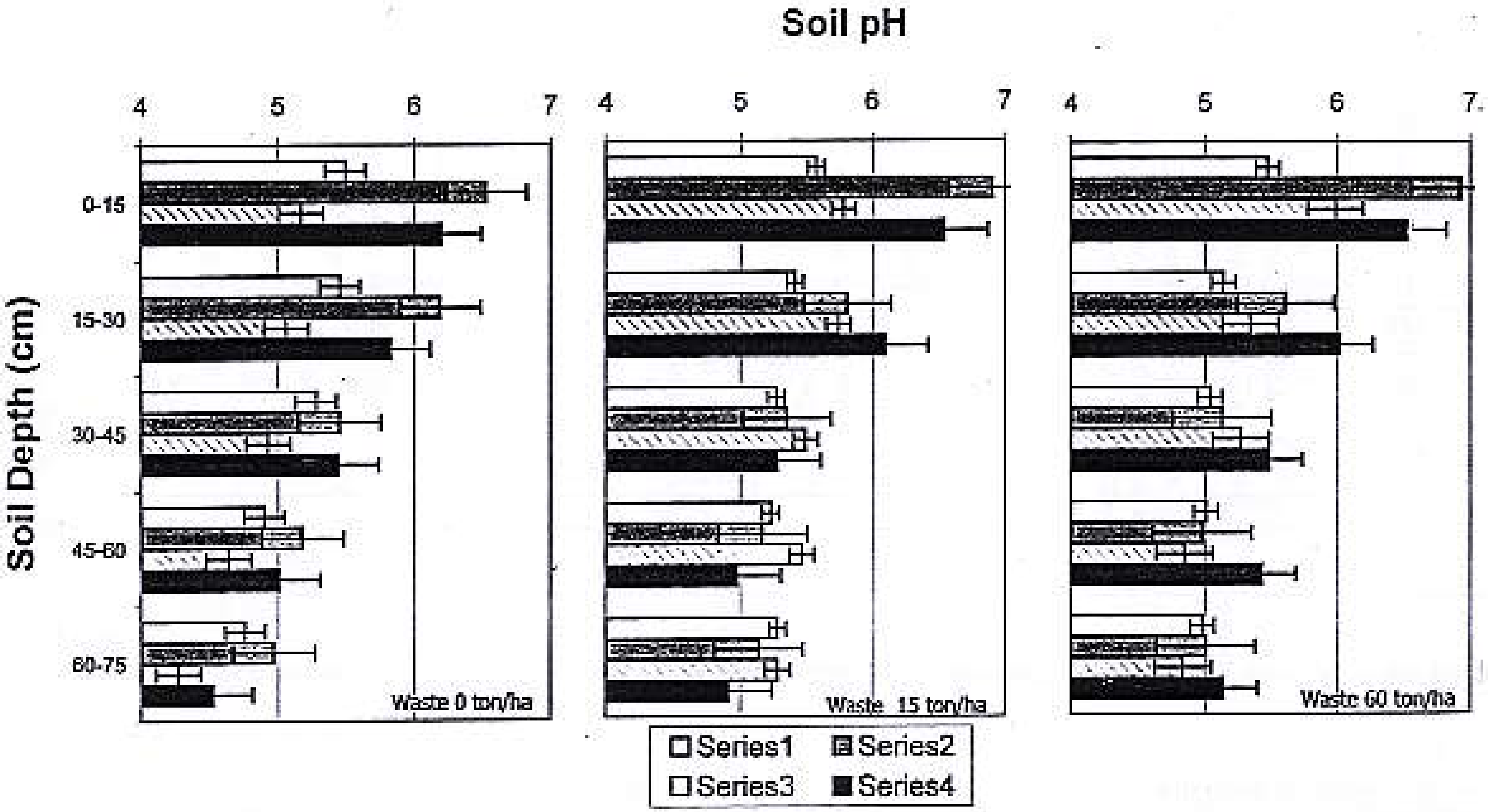

Figure 1. Effects of industrial waste, lime, and organic compost on depth-wise soil pH.
Series 1 = no lime - no compost, Series 2 = with lime - no compost, Series 3 = no lime - with compost, and Series 4 = with lime - with compost.

Vertical Distribution of Zn

Significant effects of waste, lime, and/or compost on the extracted Zn were also observed through the soil depths of 75 cm, shown by Anova at 5% and 1% (Prihatin, 2002). This observation also indicates that the effect of waste, lime, or compost and their interactions were still effective through soil depths three years after treatments, also suggesting that the use of these ameliorants were relatively long-lasting, particularly at low-level waste-treatments (Table 2).

Similar to that of Cu, Zn from waste of high-level treatment (60 ton ha^{-1}) moved from topsoils (0 –15 cm) to subsoils (30 – 60 cm), as indicated by significant differences between treatments of $W_2L_0C_0$ and $W_0L_0C_0$ for the respected depths (Table 2). For example, in soil depth of 60 – 75 cm, the square root value of extracted Zn with treatment of $W_2L_0C_0$ was 0.94 and that with treatment of $W_0L_0C_0$ was 0.29. The difference was 0.65, higher than the related HSD at 5%, i.e. 0.57. Similar to Cu, most Zn was still retained at depths of 0 – 30 cm, indicating that Zn was strongly held by topsoils.

However, unlike that with low level waste treatments, the effect of lime and/or compost at high-level waste did not significantly affect the extracted Zn from topsoils, and hence, the extent of Zn moving to subsoils (Table 2). This phenomenon suggests that Zn was less strongly adsorbed by soil colloids than was Cu.

The above observation and discussion obviously show that Cu and Zn only from high-level treatments of waste were observed to have significantly moved to subsoils of 30 – 75 cm. Unlike that of Zn, the movement of Cu was shown to be significantly lowered by topsoil treatments with lime and/or compost. Most Cu and Zn were retained in top soils.

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