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ENVIRONMENTAL RISKS FROM APPLYING SEWAGE SLUDGE COMPOST AS AN ORGANIC FERTILIZER TO CLAY SOILS

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ABSTRACT

A greenhouse crop experiment was conducted to identify the environmental consequences of applying compost as an organic fertilizer at different amounts and methods of application to a clay soil. The tested factor was the fate of heavy metals in terms of plant uptake, total recovery and accumulation in the soil surface layer. The results showed that compost application significantly increased the concentration of heavy metals in tomato fruits compared to the control. Crop recovery of compost-applied Zn and Cu was less than 0.45% at all compost application levels regardless to the method of application. It was significantly greater in compost surface applied plots than that in compost incorporated ones. Crop recovery of compost-applied Pb and Cd was less than 0.06% at all compost application levels.

A major consideration in recycling such compost on clay soils is the threat of heavy metals build-up. The amounts of heavy metal accumulated in the soil profile were more than 92% of the compost-applied heavy metals. These metals were present in the top 20 cm of soil plots, but these increased amounts were still far below the plant toxicity levels. Generally, no health problems could be expected to human or animals from food chain movement of these amounts of heavy metals. With regard to heavy metal concentrations in the soil, the data gave good assurance that the soil environment is protected. From this study, it could be concluded that the application of high loading levels of good quality compost to clay soils as organic fertilizer is agronomically valuable with a limited potential environmental risk associated with heavy metals.

INTRODUCTION

In Egypt, 18% of the agricultural wastes are used directly as fertilizers. Another 30% is used for animal feed. The remainder of these wastes is burnt directly on the fields or for heating in the small villages (El-Mashad, *et al.,* 2003). In addition, the increase in Egypt's population resulted in the production of large amounts of human wastes (sewage sludge). These various organic wastes that include animal and plant agricultural wastes as well as sewage sludge represent an important source of valuable macro and micro-nutrients that can be used more efficiently as a source of organic fertilizers for organic farming production (Awad, *et al*., 1993; Smith, 1996; Abdel-Sabour, 1997; Evanylo, *et. al.* 2008).However, the use of such wastes as organic fertilizers can be harmful because of the addition of heavy metals (Van den Berg, 1993 and ; Maynard, 2005). The contamination of soils with heavy metals can result in phytotoxic effects as well as the deterioration of surface and ground water (Heckman, *et al*., 1987). Furthermore, adverse effects on the soil microbial activity have been found even at very low concentrations of heavy metals in soils (McGrath, *et al*., 1995). Recently, the composting has been recognised as a cost-effective and environmentally sound process for the treatment of agricultural and human wastes, even for some of those that are contaminated with hazardous substances. The potential for metals to enter the food chain from the compost is much less than from the direct application of organic wastes to soils (Epstein, 1997and; Evanylo *et., al.* 2008). Furthermore, the compost generally has lower concentrations of heavy metals as a result of the use of bulk materials such as wood chips, sawdust and green wastes (Tambone, *et al*., 2007). The major biochemical processes which occur to the compost after soil application are the transformation of organic matter and the modifications of trace metals solubility.

These processes and the rates of the macro and micronutrients release influence the potential environmental consequences, specifically that of soil and groundwater degradation (Maynard, 1993 and; Stratton, *et al.*, 1995). The movement of heavy metals from the site of application is typically minimal.

Thus, the accumulation of heavy metals in the soil can be considered permanent, except for quantities taken up via harvested plant tissues (Schmidt, 1997). Soil application of compost to the organic farming systems for the beneficial use must take into account strategies to meet the nutrient agronomic levels and to minimize the environmental risks. Thus, the aim of this crop trial was to make practical recommendations for appropriate compost application levels and methods that could be used to minimize environmental consequences of applying compost to a clay soil in the organic farming systems and specifically, to examine the fate of heavy metals in terms of plant uptake, accumulation, movement and total recovery from compost by tomato crop grown on a clay soil under controlled conditions.

MATERIALS AND METHODS

A greenhouse crop trial was conducted at village 8 located west El-Minia Governorate in the period from June, 2004 to October, 2006. A clay soil that its properties are presented in Table 1 was collected from a stockpile at the Faculty of Agriculture farm. Prior to the initiation of the greenhouse study, the soil was air-dried, sieved to < 2.0 mm, and the moisture content was adjusted to 15 % before the addition of compost. Sub-samples of the dried and sieved soil were used to determine soil properties using the standard methods according to (Page, *et al.,* (1982) and MAFF (1986).

The compost with properties shown in Table 2 was made from sewage sludge (60%), farmyard manure (20%) and green wastes (include all types of agricultural residuals from rice straw to tree pruning and sugar beet wastes).

Samples of the dried, ground, and sieved compost were used to determine some physical and chemical properties such as moisture content, heavy metals and total nutrients. The compost was then added to clay soil at levels of 0.0, 120, 240, 360 t/ha (Mohamed, *et al.*, 2008) (dry weight basis) by two methods of application (surface and mix addition).

Table 1: Some physical and chemical properties of the investigated soil.

Field capacity (%)	18.26
Permanent welting point (%)	5.67
Available water (%)	12.59
Bulk Density (g/cm^3)	1.55
Particle Density (g/cm^3)	2.61
Porosity (%)	40.61
pH (1 : 2.5 suspension)	7.32
CEC ($cmol_c$/kg soil)	22.6
O.M (%)	1.59
EC (dS/m at 25 ^{0}C and 1:5 extract)	0.49
Total N, P and K (%)	0.091, 0.039 and 0.55, respectively.
Total Zn, Cu, Pb and Cd (mg/kg)	82, 45, 15 and 7, respectively.
Particle size distribution (%)	55.5% sand, 8.5% silt, and 36% clay
Texture	Clay

- Each value represents the mean of three replications.

Table 2: Some physical and chemical properties of the studied compost.

pH (1 : 2.5 suspension)	8.25
EC (mS/cm at 25 ^{0}C and 1:5)	8.21
CEC ($cmol_c$/kg compost)	52.5
Moisture content (%)	27.5
Dry matter (%)	72.5
Ash (%)	39.8
Total organic carbon (%)	36.1
Total N, P and K (%)	2.25, 0.95 and 1.64 ,respectively
C/N Ratio	16.04
Ammonia (mg/kg)	454
Nitrates (mg/kg)	57
Zn, Cu, Pb and Cd (mg/kg)	985, 487, 380 and 6, respectively.

- Each value represents the mean of three replications.

- **Experimental Design and Materials**

The trial was composed of 24 trenches; each trench was dug inside the greenhouse (length of 100 cm, width of 30 cm and depth of 30 cm) and covered with black polyethylene to maintain a high temperature environment. In June 2004, the trenches were filled with 140 kg soil and the weights of air dried-compost corresponding to the equivalent application levels were added by two methods. (surface or mixed by hand with the soil material to a depth of 20 cm. In the case of mixed application compost-soil, each trench was filled with soil to a depth of 10 cm and then the rest of 140 kg of the compost treated soil mixture was added. In the case of the surface application of compost, the trenches were filled with 140 kg soil and compost was added at the above mentioned levels. The trenches were watered by drip irrigation and left bare and undisturbed for 30 days to get the soil settled down. In June 2004, the tomato trial commenced and ran for two seasons. In the first season, three seedlings of a greenhouse cultivar of tomato were planted 30 cm apart in each trench and thinned for two after vigorous growth.

The plant density was 5.6 (60 × 30 cm) plants / m^2. Plants were staked and the side shoots removed to increase the early yield of fruits and to support the upright growth. Each trench (plot) was watered each third day to compensate the losses of water using the drip irrigation system which maintained the moisture content at the field capacity during the period of the experiment. In each plot, soil moisture content was determined weekly at 10 cm depth by weighing soil samples dried in an oven for 24 h at 105°C. The tomato plants were not fertilized other than compost application during the growth period (120 days) and weed control was maintained by hand.

Tomato was first harvested in August and the harvesting was continued for two months. Leaf, fruit and soil samples were collected at the time of first harvest for heavy metal analyses. On October at the last harvest, tomato plants were cut above the ground, washed with distilled water, oven dried at 65°C for 96 h, and weighed to determine dry weight.

After the tomato experiment, the plots were left for five months covered with black polyethylene and watered once a week for tomato roots to decompose before the second season. On late October 2005, the compost was added at the same levels as in the first year to each plot using the same two methods of application. On January 2006, the second year crop experiment commenced with the same procedures used in the first year.

To verify the effect of the studied compost on the uptake and the recovery of heavy metals, samples of tomato fruits and plant leaves were taken from plants of similar sizes and growth stages from each plot after sixty days from planting. Analyses of heavy metals in the compost, compost treated soils and plant tissues were determined by the digestion in the boiling aqua regia prepared in accordance with ISO 11466 (1995), using Atomic Absorption Spectrometry ISO 11047 (1998).

The recovery of heavy metals was based on their total concentrations in the 30-cm depth of the compost treated soil plots and their uptakes by tomato leaves. The heavy metal concentration in the compost treated soil plots was multiplied by soil mass (140 kg) and compost mass (equivalent to application levels), respectively, to determine the total metal mass in each plot (Table 3). The heavy metal recovery (HMR) was calculated as the percentage of the heavy metal applied for each treatment where: HMR% = [(Plant heavy metal uptake for each treatment (g/plot) - Plant heavy metal uptake for control (g/plot)) / Total heavy metal applied for each treatment (g/plot)] × 100. Removal of heavy metals by tomato fruits was negligible and its value was not included in the recovery calculation.

Table 3: Application levels of the studied compost (kg) and total heavy metal applied (g/plot).

Applied compost		Total applied heavy metals (g/plot)			
t ha^{-1}	kg/plot	Zn	Cu	Pb	Cd
0.0	0.0	11.5*	6.3*	2.11*	0.98*
120	3.7	15.1	8.1	3.47	1.01
240	7.3	18.7	10.1	4.94	1.03
360	10.7	22.1	11.57	6.21	1.05

- Each value represents the mean of three replications.
- Total Zn, Cu, Pb and Cd in the control soil.

All crop experimental data for all parameters were analyzed as a completely randomised block design with three replications. The experimental data were computed using the procedures available in the version 6.11 package (SAS Institute, 1996). The means of three samples of each treatment were compared using the Least Significant Difference (LSD) test at the 0.05 probability level.

RESULTS AND DISCUSSION

- **Heavy metals in Tomato Plants:**

The application of compost significantly ($P \leq 0.05$) increased the concentration of heavy metals in tomato fruit compared to the control. After one compost application (first season), heavy metal concentrations in tomato fruit increased with increasing compost application amount but with no significant differences. After two compost applications (second season), heavy metal concentrations in tomato fruit increased at the lower application levels of 120 and 240 t/ha with no significant differences and then decreased significantly at the higher level of 360 t/ha.

The decrease in heavy metals concentrations in tomato fruit at the higher application level could be due to a combined effect of increased pH and organic matter in the soil. The concentrations of heavy metals in tomato fruits for both seasons were in the order of Zn > Cu > Pb > Cd. After one compost application, concentrations of Zn, Cu, Pb and Cd were higher in tomato fruits grown on the compost-surface applied plots than the compost-mixed ones. After two compost applications, however, the reverse was true in most cases with slight concentration differences.

After one compost application, one plausible reason might explain this occurrence. The noticeable effect is that mixing the compost with the soil resulted in an increase in pH (from 7.3 to 7.6) of the soil at all application levels compared with the mulched (surface applied) plots. This increase probably caused tomato fruits grown on the compost-mixed plots to have lower concentrations of heavy metals, where there is an inverse relationship between soil pH and the solubility of most metal cations (Alloway, 1990). After two compost applications, the difference in heavy metal concentrations between tomato fruit taken from compost-surface applied and compost-mixed plots was not significant at all application levels, illustrating that the heavy metal bio-availability and solubility patterns were very similar.

The amounts of Zn in tomato fruit ranged from 5.13 to 37.50 mg/kg and from 3.51 to 35.62 mg/kg in the first season and second season, respectively (Fig. 1). In general, the concentration of Zn in tomato fruit grown on the compost-surface applied plots exhibited higher levels than those grown on the compost-mixed ones in the first season. However, the reverse was true in the second season. This could be a result of the combined effect of both high pH and organic matter in the thick mulching layer of compost.

Concentrations of Zn in tomato fruits were relatively high in comparison with other elements, although they were within the normal range reported in the literature. Plant tissue concentrations of Zn between 100 and 900 mg/kg have been known to induce phytotoxicity in plants (Basta and Sloan, 1999). The results indicated that plant Zn was in the range of 0.98 to 3.88 mg/kg and 0.65 to 5.32 mg/kg in the first and second seasons, respectively.

Copper concentrations in tomato fruit decreased with increasing the compost application level in both first and second seasons with no significant differences between treatments (Fig. 2). Concentrations of Cu in tomato fruit were relatively low in all compost treatments. This finding is consistent with the literature date which showed that Cu is not readily accumulated in tomato fruit (Basta and Sloan, 1999). McBride (1995) suggested that Cu bound primarily to organic matter in materials like organic compost and that Cu bioavailability increase as organic matter decomposes.

Lead and Cd concentrations in tomato fruit were generally very low (all were < 0.12-mg/kg dry matter) and were not correlated with increasing compost application rates (Figs. 3 and 4). This was not surprising since concentrations of these heavy metals in compost were not much higher than the soil levels. This finding is consistent with the literature which reported that these heavy metals are relatively immobile in soils and not readily accumulated in the aboveground tissue of plants (Page *et al.*, 1987).

These heavy metal concentrations in the tomato fruit increased in the first season after one compost application at higher application amounts. In the second season after two compost applications, heavy metals concentrations reached a plateau at all application amounts and they were relatively invariant with different methods of application.

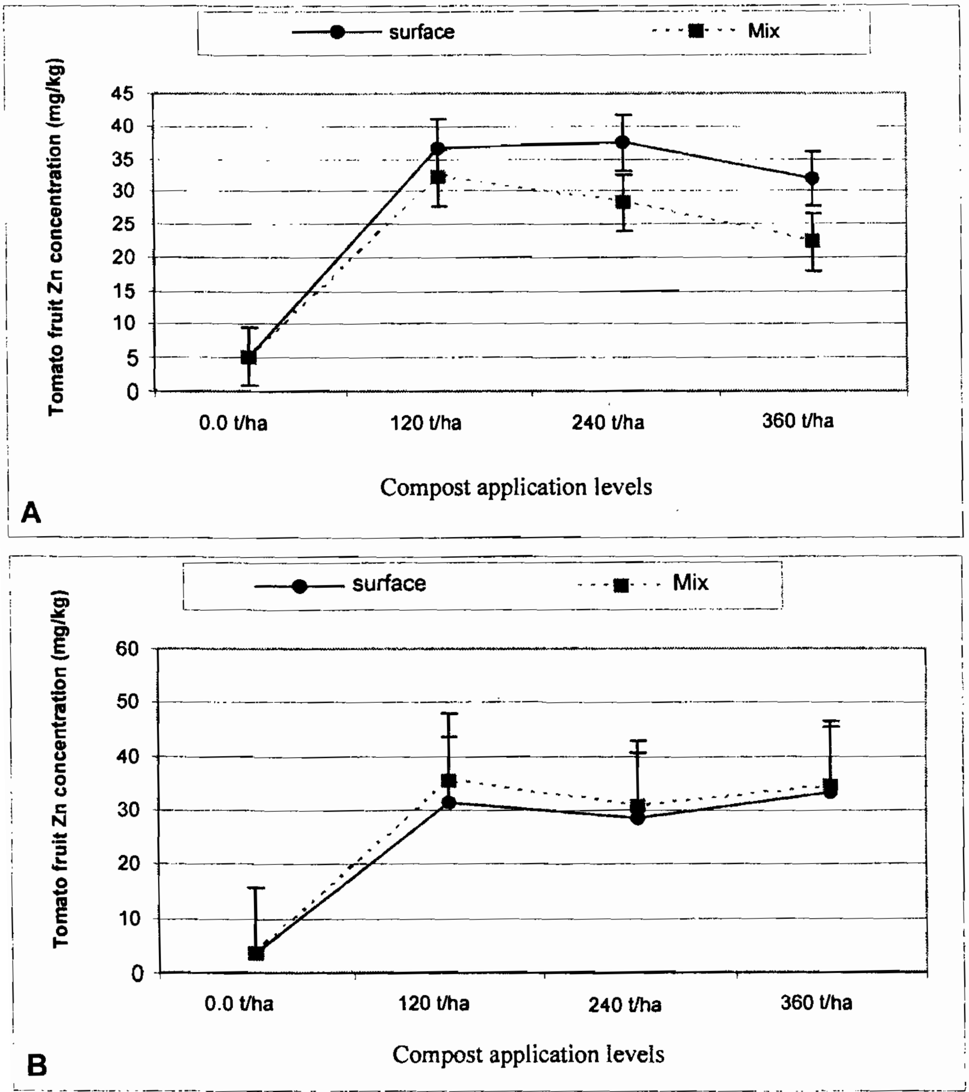


Fig. 1: Zinc concentration in tomato fruit, vertical bars represent a fixed value (L.S.D value) for the compost application method.

(A) After one compost application (First season).

(B) After two compost applications (Second season).

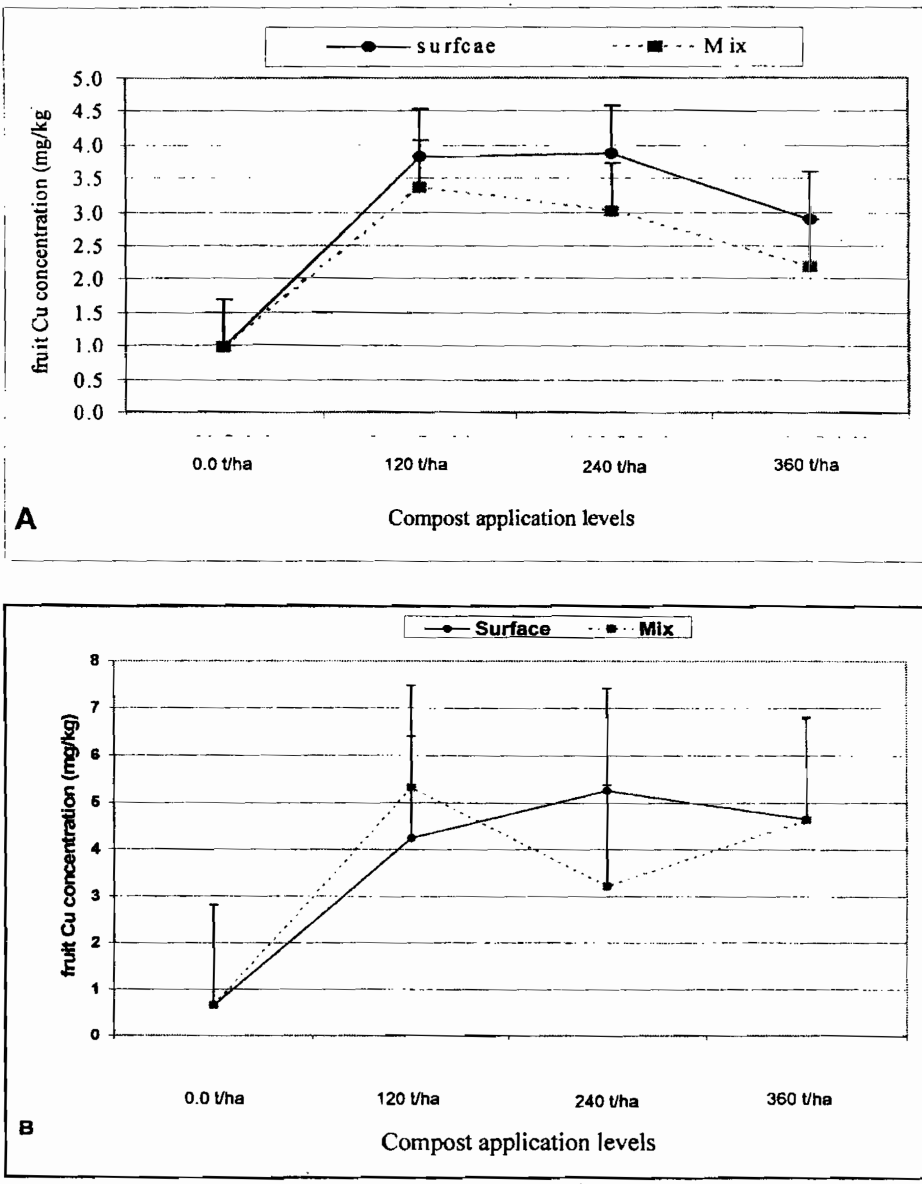
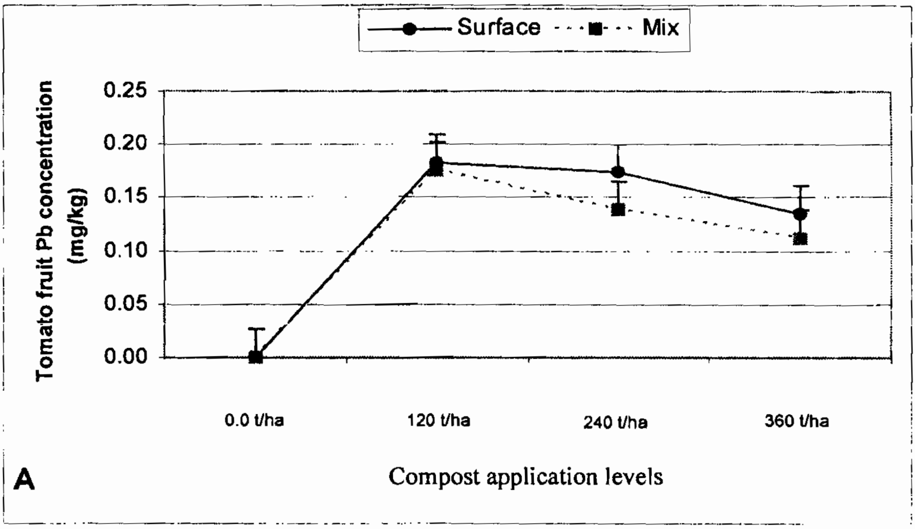


Fig. 2: Copper concentration in tomato fruit, vertical bars represent a fixed value (L.S.D value) for compost application method.

(A) After one compost application. (B) After two compost applications.



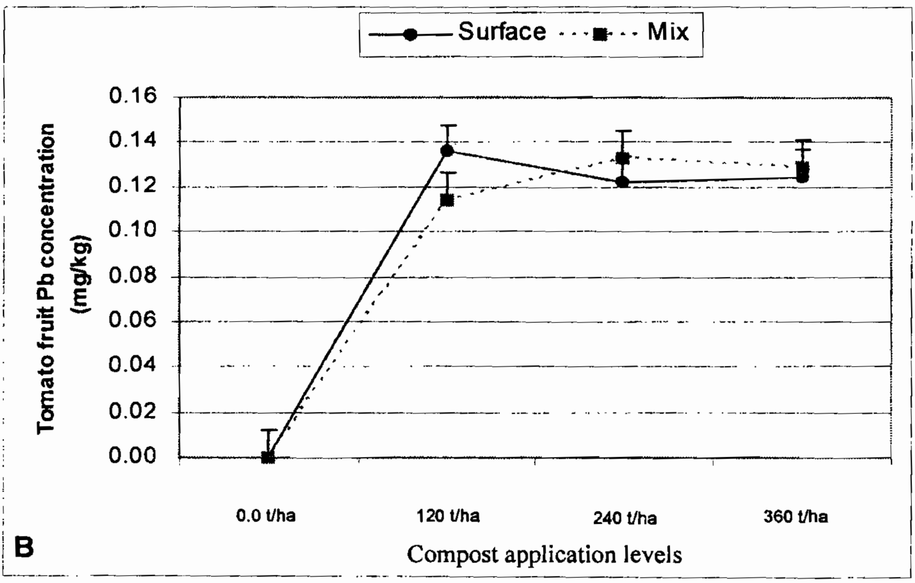
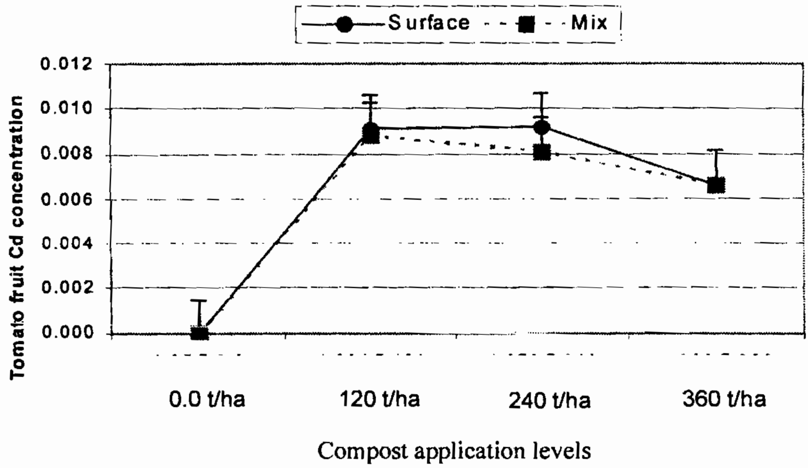
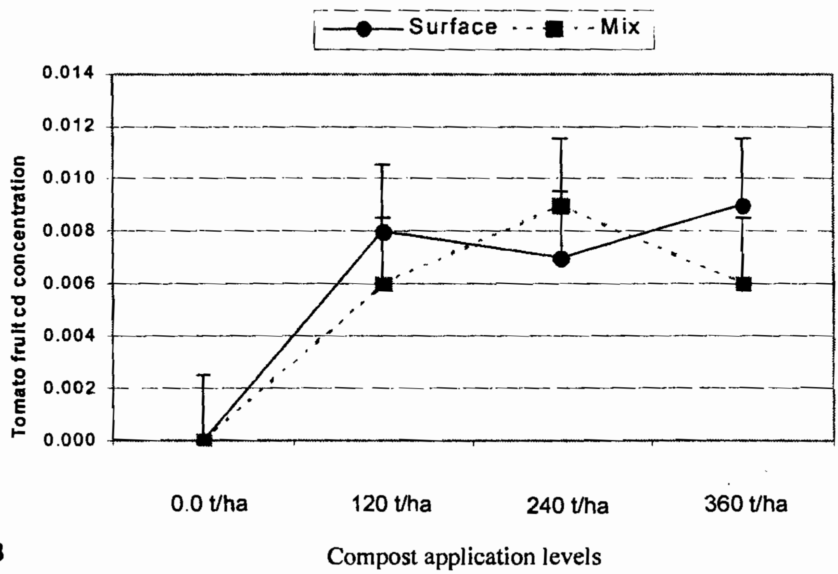


Fig. 3: Lead concentration in tomato fruit. Vertical bars represent a fixed value (L.S.D value) for compost application method.

A. After one compost application. B. After two compost applications.



A



B

Fig. 4: Cadmium concentration in tomato fruit. Vertical bars represent a fixed value (L.S.D value) for compost application method.

A. After one compost application. B. After two compost applications.

The literature assumed a plausible mechanism that might explain this phenomenon. Logan *et al.,* (1997) reported that the plateau concept suggested that compost is both a source and a sink for trace elements applied to soil. At low compost application amounts, soil binding of trace elements would predominate and plant uptake would increase in a generally linear manner. At a very high application amount, the compost matrix would begin to exert an influence on trace element binding. In the limit, as the soil matrix approached that of pure compost, trace element uptake would be essentially that from pure compost, and would be determined by the binding of the sludge matrix for the individual trace element (Logan *et al.,* 1997).

Data of the heavy metal content of tomato leaves are given in Table 4. The results revealed that heavy metal concentrations in tomato leaves were almost double those in tomato fruit and this trend was for all heavy metals uptake by tomato leaves except for Zn. The concentration of Zn in tomato leaves grown on compost-surfaced plots exhibited higher levels than those grown on compost-mixed in both first and second season.

Heavy metal uptake differs among plant species and among cultivars within species, and accumulation varies in different plant organs (leaves > storage roots > fruit and grain). Keefer *et al.,* (1986) found that heavy metals in edible parts of plants (fruit and grain) were lower than in the non-consumable parts (i.e., the leaves).

Table 4: The effect of compost on the heavy metal contents (mg/kg) in tomato leaves.

Application amounts & Methods		First season				Second season			
		Zn	**Cu**	**Pb**	**Cd**	**Zn**	**Cu**	**Pb**	**Cd**
Control. 0.0 t/ha		25.33	5.11	0.21	0.05	18.77	5.66	0.05	N/A*
Surface. 120 t/ha		65.3	19.21	0.69	0.16	73.23	14.99	0.37	0.11
Surface. 240 t/ha		68.11	18.12	0.88	0.15	74.55	13.11	0.45	0.11
Surface. 360 t/ha		64.15	12.13	0.63	0.16	64.59	13.99	0.44	0.12
Mix. 120 t/ha		45.36	11.98	0.57	0.10	65.66	19.36	0.82	0.12
Mix. 240 t/ha		57.13	15.95	0.77	0.11	59.55	19.78	0.87	0.11
Mix. 360 t/ha		49.63	1566	0.68	0.11	61.55	16.11	0.91	0.13
$L.S.D_{0.05}$	Levels	11.96	2.89	0.37	0.02	6.66	2.38	0.25	N/A*
	Methods	15.11	1.79	0.29	0.03	4.99	1.92	0.17	

* N/A = not applicable. - Each value represents the mean of three replications.

Data of the heavy metal recovery (HMR%) of each plot by tomato plants are illustrated in Figs. 5, 6, 7 and 8. Percentage recovery of compost-applied Zn was less than 1% at all compost application amounts regardless to the method of application and was significantly greater for plants grown on compost-surfaced plots than on compost-mixed. Copper recovered with compost-surfaced plots peaked at 0.36% in the first season and 0.32% in the second season. Similarly, Cu recovered in the compost-mixed plots was 0.24% in the first season, and 0.33% in the second season.

Percent recovery of compost-applied Pb and Cd by plants was less than 0.05% at all compost application amounts regardless of the method of application, and was significantly greater in compost-mulched plots than on compost-incorporated. Short-term field experiments have shown that the adsorptive properties of compost itself often prevent excessive uptake of many of these metals into crops, a protection attributable largely to the added organic matter.

This could be termed the compost protection hypothesis (Ryan and Chaney, 1993). The importance of organic matter has been discussed both in relation to the formation of complexes that prevent movement and uptake of heavy metals (Tyler and McBride, 1982) as well as the formation of complexes that solubilize heavy metals as organo-metal complexes at higher levels (Kou and Baker, 1980). Several factors are proposed to explain why heavy metal recovery and uptake by tomato plants grown on surface-applied compost were higher than mix-applied compost. These include soil pH, CEC, soil structure and organic matter content. For surface-applied compost, heavy metals recovery and uptake by tomato plants increased as a result of high pH of the thick mulching layer. At the higher pH levels of the thick mulching layer, the formation of complexes that solubilize heavy metals as organo-metal complexes increased and then the soil underneath maybe facilitated the movement of heavy metals complexes through soil plot without being adsorbed. This may have enhanced plant uptake and recovery of heavy metals by plants grown on compost-surfaced plots once these organo-metal complexes diffuse to the roots of plants.

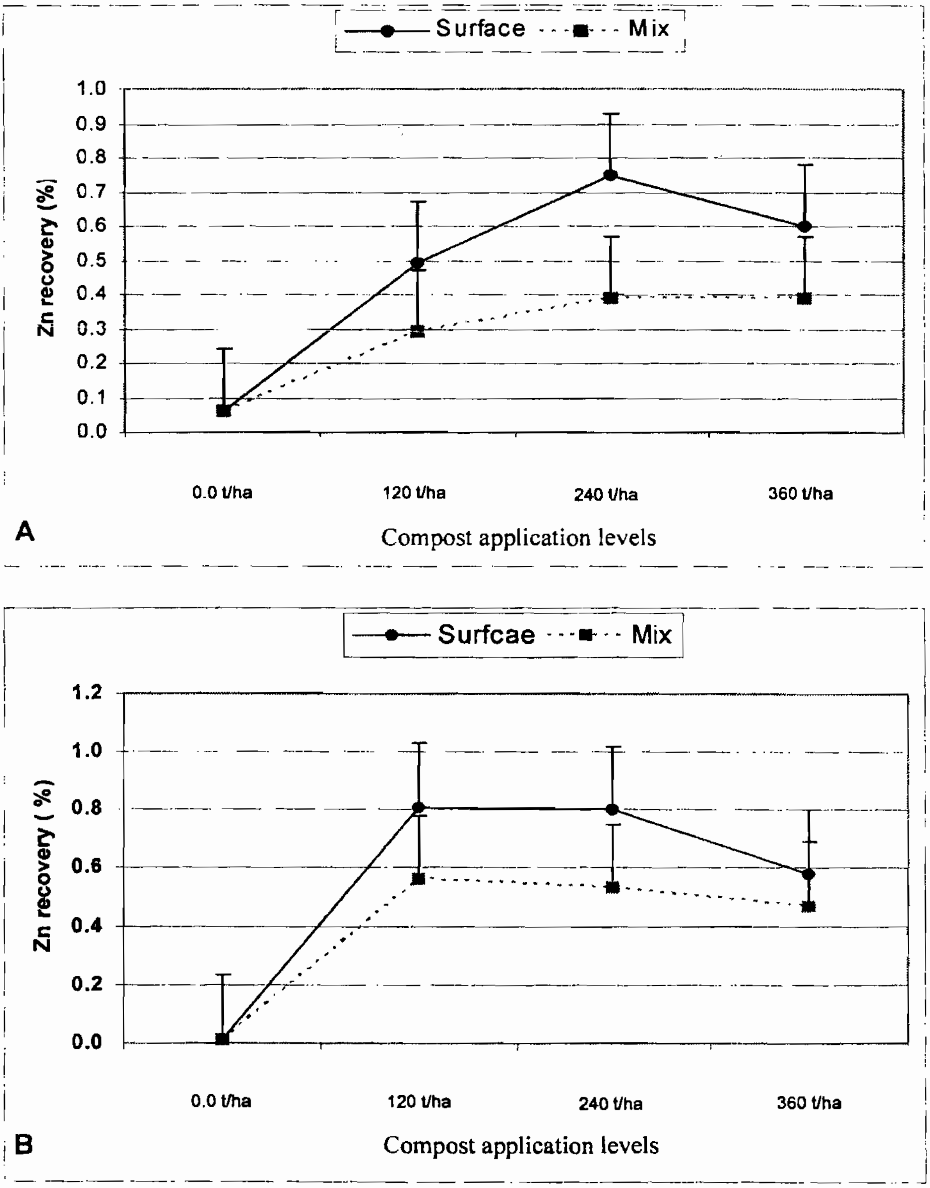
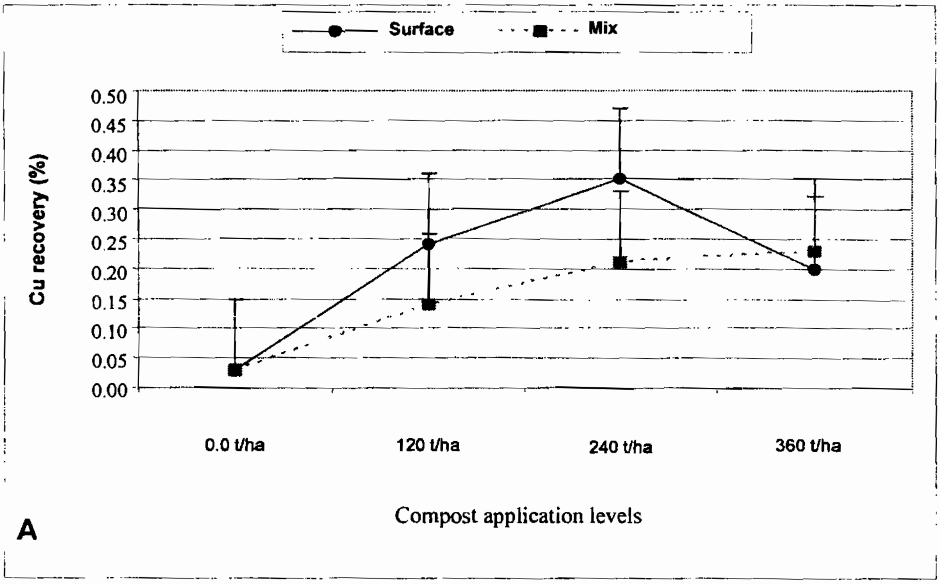


Fig. 5: Zinc recovered by tomato plants, vertical bars represent a fixed value (L.S.D value) for compost application method.
A. After one compost application. B. After two compost applications.



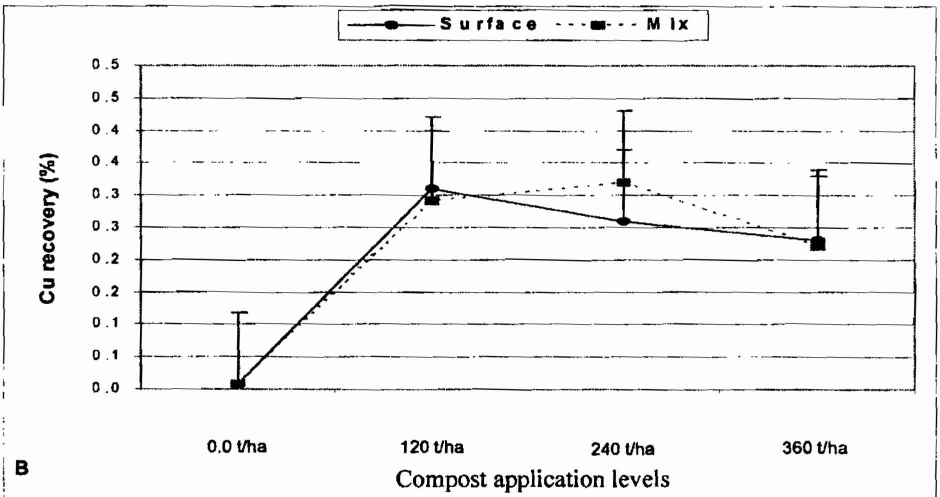


Fig. 6: Copper recovered by tomato plants, vertical bars represent a fixed value (L.S.D value) for compost application method.

A. After one compost application. B. After two compost applications.

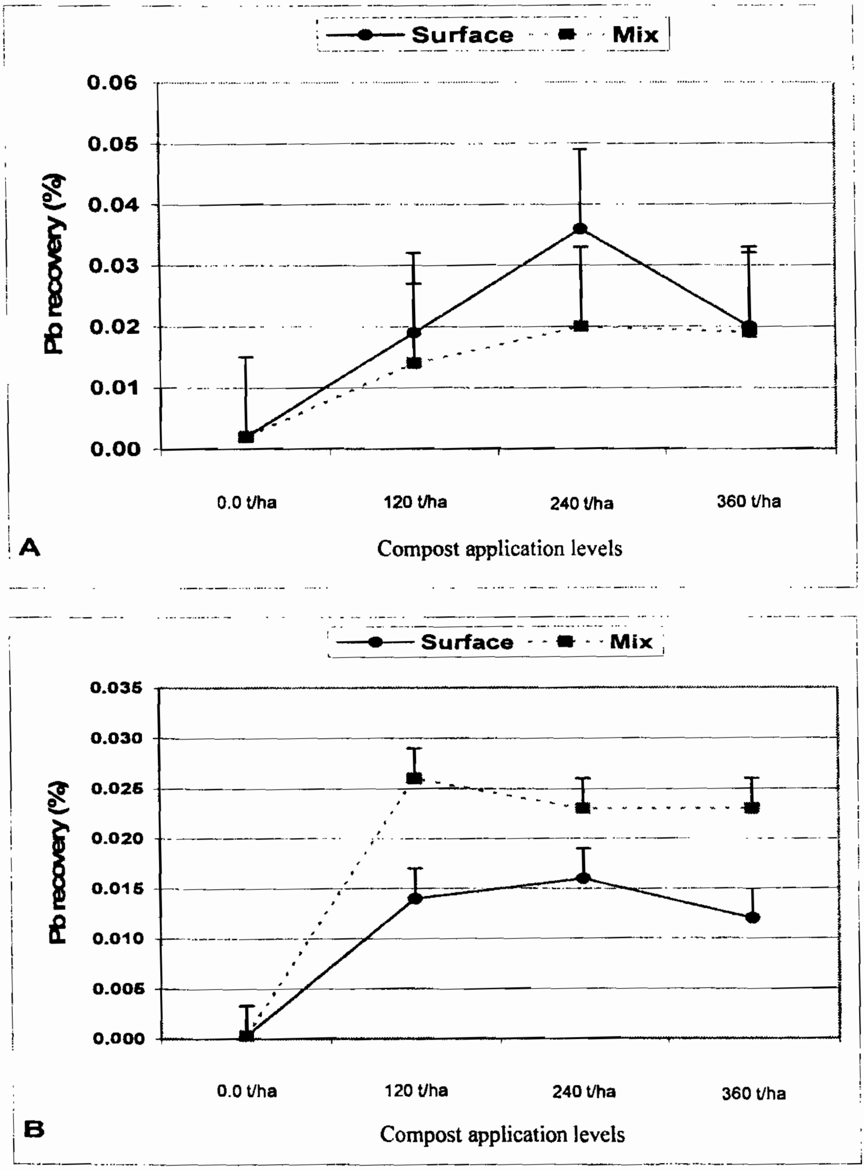


Fig. 7: Lead recovered by tomato plants, vertical bars represent a fixed value (L.S.D value) for compost application method.

A. After one compost application. B. After two compost applications.

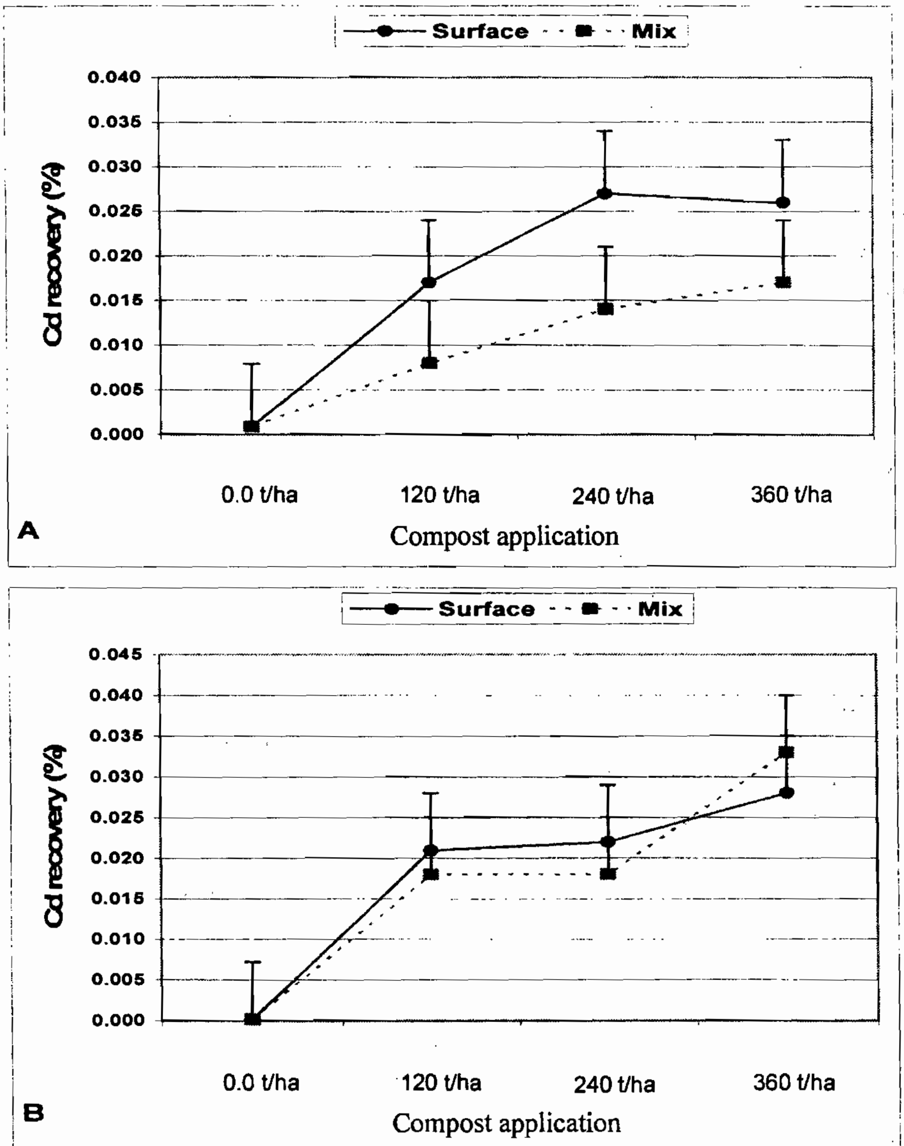


Fig. 8: Cadmium recovered by tomato plants, vertical bars represent a fixed value (L.S.D value) for compost application method.

A. After one compost application. B. After two compost applications.

Table 5 shows total and available heavy metals content (mg/kg) in the upper 20-cm soil plots treated with compost and cultivated with tomato for two seasons. Results revealed that one compost application caused a significant increase ($P \leq 0.05$) in surface accumulations (top 20 cm of soil) of total heavy metals at all application amounts andmethods. In general, more than 90% of the compost-applied heavy metals were present in the top 20 cm of soil plots.

Two annual applications of compost resulted in cumulative compost loadings of 0.0, 240, 480 and 720 t/ha. Cumulative metal loadings for the 720 t/ha compost amount were 728, 348, 275 and 2.88 kg/ha for Zn, Cu, Pb and Cd, respectively. The cumulative loading rate limit (established by the USEPA in 1993) of the investigated heavy metals in this study were 2800, 1500, 300, 39 kg/ha for Zn, Cu, Pb and Cd, respectively.

After two annual compost applications, compost addition caused a significant increase ($P \leq 0.05$) in surface accumulations (top 20 cm of soil) of total heavy metals at all application amounts and methods except for Zn, Pb and Cd at the amounts of 120 and 240 t/ha for surface-applied compost. The slight increase of Zn, Pb, and Cd for surface-applied compost was due to removing the compost-mulching layer before analysis (Copper was the exception to this trend). The significant increase of Cu in spite of removing the compost-mulching layer indicates that Cu migrated with the organic-metal complexes from the mulching layer into the soil profile and consequently, imposing a risk of high plant availability and groundwater contamination. These results agree with various studies that found approximately 95% of Zn, Cu, Pb and Cd were retained in the 0 to 30 cm depth after application of sewage sludge to soils (Sloan *et al.,* 1998).

Table 5: Total and DTPA-extractable heavy metals content (mg/kg) in the soil treated with compost and cultivated with tomatoes for two seasons (yr1 and yr2).

Treatments	Zn^{2+}				Cu^{2+}				Pb^{2+}				Cd^{2+}			
	TOTAL		DTPA		TOTAL		DTPA		TOTAL		DTPA		TOTAL		DTPA	
	yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2
Control	84	80	19.1	14.9	45.2	42.3	15.9	12.9	17.5	15.3	1.3	0.9	6.5	6.25	0.75	0.61
Surface120 t/ha	103	85	25.5	20.5	56.3	55.1	26.1	14.9	22.9	18.9	1.9	1.4	7.3	6.5	1.6	0.65
Surface240 t/ha	121	88	30.1	16.3	67.3	55.9	28.6	17.9	26.3	19.5	2.2	1.3	7.5	6.5	1.9	0.78
Surface360 t/ha	132	95	30.9	16.9	73.1	60.9	30.2	15.6	31.3	19.5	2.2	1.5	7.8	6.6	1.9	0.75
Mix.120 t/ha	121	133	29.6	35.9	63.1	71.9	28.1	28.9	20.5	31.5	1.6	1.9	7.6	8.7	1.8	1.38
Mix.240 t/ha	131	146	31.2	31.1	66.1	78.9	30.5	27.6	32.1	42.9	2.1	2.3	7.4	8.9	1.7	1.85
Mix.360 t/ha	137	169	32.1	39.2	70.1	84.9	31.6	31.1	36.3	52.6	2.1	2.5	8.1	9.5	2.1	1.78
L.S.D for levels	14	16	9.2	9.96	9.9	8.8	6.4	7.1	3.7	5.6	0.31	0.6	0.4	0.9	0.61	0.53
Methods	18	19	7.1	4.96	5.7	9.5	8.2	5.5	2.9	11.2	1.2	0.7	0.7	0.11	1.15	2.37

- Each value represents the mean of three replications.

A gradual increase pattern with no significant difference was noticed for the DTPA-extractable heavy metals. DTPA-extractable concentrations of Zn, Cu, Pb and Cd in compost- amended plots did not correlate significantly with the total applied amounts of these heavy metals in compost. Concentrations of DTPA-extractable heavy metals were significantly higher for the compost-amended plots than for the control.

In most cases, there was no significant difference in DTPA-extractable heavy metals concentrations between all the compost treatments. As a result of increasing compost application amount, the organic matter, CEC and pH of this soil increased. Consequently, the adsorption and precipitation capacity of the soil increased and then a high correlation between DTPA-extractable heavy metals and total applied heavy metals is unlikely to occur.

Results of this study generally showed no significant difference ($P \leq 0.05$) in total heavy metal concentrations between compost-amended plots and control below the top 20-cm of the soil plots (table, 6). Zinc and cadmium were the exceptions to this pattern. Compost application significantly increased the Zn and Cd concentrations below the top 20-cm in the soil plot at all application levels of mixed-applied compost compared to control. This is not surprising in the case of Zn where the compost Zn concentration (985 mg/kg) was much greater than the other elements.

Table 6: Total heavy metals (mg/kg) moved below the top 20-cm of the soil treated with compost and cultivated with tomatoes for two seasons (yr1 and yr2).

Treatments (t/ha)		Zn^{2+}		Cu^{2+}		Pb^{2+}		Cd^{2+}	
		Total		Total		Total		Total	
		yr1	yr2	yr1	yr2	yr1	yr2	yr1	yr2
Control		83.5	82.3	47.5	44.9	17.5	15.2	6.2	5.9
Surface.120		84.3	85.4	48.7	45.5	18.3	18.3	6.5	6.4
Surface.240		85.2	83.6	47.7	48.9	17.1	18.6	7.1	7.1
Surface.360		84.3	85.3	46.1	46.9	17.9	18.2	7.1	7.3
Mix 120		88.7	88.3	51.2	51.8	18.5	20.6	8.6	8.3
Mix 240		87.4	88.5	52.3	53.1	19.7	20.9	8.3	8.5
Mix 360		87.6	91.9	52.1	52.6	19.8	21.6	8.2	8.5
LSD	levels	2.2	2.8	4.8	8.6	12.5	17.3	0.8	1.3
	Methods	1.9	2.3	3.4	11.5	11.3	14.5	0.5	1.5

- Each value represents the mean of three replications.

On the other hand, the compost Cd concentration (6 mg/kg) was far less than other elements. Berti and Jacobs (1996) showed that significant quantities of Cd and Zn resided in the water-soluble, exchangeable, and acid soluble forms, which are probably more plant available and more susceptible to leaching than the other soil fractions (Barbarick *et al.*, 1998). Column leaching studies have shown little or no short-term (<1 yr) movement of heavy metals through the soil as a result of compost applications (Dowdy and Volk, 1983; Emmerich *et al.,* 1982 and ; Sommers *et al.,* 1979).

CONCLUSIONS AND RECOMMENDATIONS

From the results of this study, it could be concluded that annual application of compost may result in soil surface accumulation of heavy metals, but this still far away from the annual accumulation limits rate of the studied heavy metals. Compost addition in most cases caused a significant increase ($P \leq 0.05$) in surface accumulations (top 20 cm of soil) of total heavy metals at all application amounts and method. However, the results of this study showed no significant difference in DTPA-extractable heavy metal concentrations between all the compost treatments.

In general, the heavy metals uptake, availability, recovery and accumulation seemed to increase at the lowest application level, and then leveled off or decrease at the highest application levels as pH and organic matter of this soil increased and consequently converting metals to non-available forms. These results revealed that the heavy metal availability in compost- amended plots did not depend on the total heavy metal content where the uptake of these heavy metals became less efficient at higher application levels.

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المخاطر البيئية لاستخدام كومبوست حمأة المجارى كسماد عضوي فى الأراضى الطينية

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تجربة محصولية أجريت فى الصوبة للتعرف علي المخاطر البيئية لإضافة كومبوست حمأة المجارى كسماد عضوي بكميات وطرق مختلفة إلي ارض طينية. العامل المختبر فى هده الدراسة هو حركة العناصر الثقيلة فيما يتعلق بامتصاص النبات والاسترجاع الكلى لها وكذلك التراكم فى التربه. نتائج هده الدراسه أوضحت أن استعمال الكومبوست أدى حدوث زيادة معنوية فى محتوى ثمار الطماطم من العناصر الثقيله بالمقارنه بالكنترول. استرداد الطماطم للزنك والنحاس كان أقل من ٠,٤٥% عند جميع مستويات الإضافة بصرف النظر عن اختلاف طرق الإضافة. استرداد الطماطم للخارصين والكادميوم كان أقل من ٠,٠٦% عند كل مستويات الإضافة.

يجب أن يؤخذ في الاعتبار خطر تراكم العناصر الثقيلة بالتربة عند تدوير هذه النوعية من الكومبوست في الأرض الطينية. كميات العناصر الثقيله التى تراكمت فى قطاع التربه تمثل أكثر من ٩٢% من محتوى الكومبوست للعناصر الثقيله. هده الكميات تراكمت فى العشرين سم الأولى لقطاع التربه ولكن هده الكميات المتزايده من العناصر الثقيله مازالت بمدى بعيد تحت مستوى السميه للنبات.

عامة لا توجد مخاطر صحية علي الإنسان أو الحيوان من حركة السلسلة الغذائية لهذه الكميات القليلة من العناصر الثقيلة. فيما يتعلق بتركيزات العناصر الثقيلة في التربة نتائج هذه الدراسة أثبتت أن بيئة التربة آمنة وليس هناك خطورة من تراكم هذه النسبة من العناصر الثقيلة. من هذه الدراسة يمكن استخلاص أن إضافة كميات كبيرة من الكومبوست الجيد كسماد عضوي إلي الأراضي الطينية أعطي نتائج محصولية جيدة مع وجود تأثير بيئي محدود فيما يتعلق بالعناصر الثقيلة.