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REMEDIATION OF SOILS POLLUTED WITH HEAVY METALS

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ABSTRACT: A pot experiment was performed in a greenhouse to study the remediation of soil polluted with Cd and Pb using some chemical and organic soil amendments such as gypsum, lime, organic compost, Fe and Zn chelates. Also, phytoremediation by growing some crops, i.e., kenaf plants as a fibre crop and comparing with red radish plants as an edible crop was taken into consideration. The soil was collected from El–Gabal El-Asfar farm, El-Qalyobiya Governorate which irrigated with sewage effluent for long time.

The treatments of soil amendments were mixed thoroughly with the experimental soil. Gypsum treatments were added at rates of 0, 5, 10 and 20 ton/fed; lime at rates of 0, 1, 2 and 4 ton/fed; compost at rates of 0, 7, 14 and 21 ton/fed. For Fe-EDDHA and Zn-EDTA, the treatments were added at rates 0, 1, 2 and 4 kg/fed. Red radish (*Raphanus sativus*, L.) and kenaf (*Hibiscus cannabinus*, L.) were planted and harvested after 56 and 60 days, respectively.

Data showed that the values of the dry matter yields of shoots, roots and whole plants for both two species increased gradually with increasing applied rates of different soil amendments, being compost treatment was most effective. Generally, application of the used soil amendments at different rates decreased Cd and Pb concentrations and uptake by shoots and roots of red radish and kenaf plants as compared with the control, the decrease was progressive and significant with increasing rate. The compost treatment under different rates was the most efficient amendment in decreasing Cd and Pb concentrations and uptake by shoots and roots.

Most of Cd and Pb taken up by red radish plants were retained in the roots and consequently less amount of Cd and Pb were translocated to shoots. On the contrary, most of Cd and Pb taken up by kenaf plants were accumulated in the above ground parts.

Available and availability index of Cd and Pb in the soil after cultivation with both plants were reduced under different sources of soil amendments. The highest reduction of available and availability index of Cd and Pb was obtained under application of compost at a rate of 21 ton/fed. Accordingly, these soil amendments (gypsum, liming, compost, Fe-EDDHA and Zn-EDTA) have ability to minimize the immediate risk of the presented heavy metals through decreasing its mobility, hence reducing phytoavailability.

Keywords: Remediation, cadmium, lead, soil amendments, red radish, kenaf.

INTRODUCTION

Soil pollution with heavy metals, particularly Cd and Pb, is widespread on a large scale due to the human activities, i.e., industrial mining, industries, fuel burning, fuel production and sewage sludge (McGrath *et al.*, 1995; Reeves and Baker, 2000; Yang *et al.*, 2002). Remediation of polluted soils is essential for sustainable use of agricultural land, however, if no remediation action is undertaken, the availability of arable land will decrease due to stricter environmental laws limiting food production on contaminated lands. In this concern, two methods were used: (1) some chemical treatments such as addition of immobilizing agents to fix the metal pollutants in immobile forms; and (2) using certain species of higher plants having the ability to live in highly polluted soils or to absorb high amounts of the metals. These two methods were being developed to treat such as immobilization and phytoremediation (Vangronsveld and Cunningham, 1998).

Application of some materials to contaminated soils were studied by many investigators such as Escrig and Morell (1998) who studied the effect of applied calcium on the soil adsorption of Cd in some Spanish sandy soils. They found that a tenfold increase in Ca concentration reduced the Cd adsorption capacity approximately by one third. Oste *et al.* (2001) showed that the addition of lime (pH increase) could decrease the free Cd concentration in soil pore water. Scherer *et al.* (1997) found that Cd concentration of the plant material was mainly reduced after compost application. Geebelen *et al.* (2003) mentioned that the uptake of Pb by plants is often decreased with liming.

Lombi *et al.* (2001) mentioned that, in the contaminated soils used, virtually all EDTA added formed complexes with metals of high stability constants, and this may contribute to the slow degradation and the persistent mobility of metals.

Moreover, some plants were able to take up large amounts of toxic elements without any visible toxicity effect, i.e., hyperaccumulators (Baker and Brooks, 1989). Tolerance to heavy metals in plants may be defined as the ability to survive in a soil that is toxic to other plants, and is manifested by an interaction between genotype and its environment (Macnair *et al.*, 2000). Ghosh and Singh (2005) reported that plants like sunflower and maize have been studied for their ability to remove Pb from effluent, with sunflower having the greatest ability.

Therefore, the current work is a trial towards heavy metals, especially Cd and Pb, immobilization in the contaminated soil by using chemical techniques, i.e., application of chemical and organic amendments such as gypsum ($CaSO_4.2H_2O$), lime ($CaCO_3$), organic compost, chelating agents (Zn-EDTA and Fe-EDDHA) for their ability to immobilize such metals, and in turn reducing their uptake and accumulation by different plant species. Moreover, this work involved phytoremediation technology by growing some crops, i.e., kenaf plants as a fibre crop and comparing with red radish plants as an edible crop.

MATERIALS AND METHODS

A pot experiment was performed under greenhouse conditions at January for red radish and June 2005 for kenaf to study the remediation of soil polluted with heavy metals especially Cd and Pb by using some chemical and organic soil amendments such as gypsum, lime, organic compost, Fe and Zn chelates. Also, phytoremediation by growing some crops, i.e., kenaf plants as a fibre crop and comparing with red radish plants as an edible crop was taken into consideration in this study. For this purpose, surface soil sample (0-30 cm) was selected from El-Gabal El-Asfar farm, El-Qalyobiya Governorate which irrigated with sewage effluent for long time. Soil sample was air-dried, crushed and sieved to pass through a 2 mm sieve and preserve for some physical and chemical analyses, their results given in Table (1-a). The soil analyses were determined according to the ordinary methods described by: particle size distribution using the international pipette method (Piper, 1950); calcium carbonate was estimated volumetrically using Collin's calcimeter (Nelson and sommers, 1982); organic matter by Walkley and Black (Black *et al.*, 1965); cation exchange capacity (CEC) using ammonium acetate (Richards, 1954); electrical conductivity (E.C., dSm^{-1}), soil pH, soluble cations and anions, (Jackson, 1973); available nitrogen, phosphorus and potassium (Jackson, 1973). Available micronutrients and heavy metals were extracted by ammonium bicarbonate-DTPA (AB-DTPA) according to Soltanpour and Schwab (1977); total Cd and Pb were extracted using aqua regia, as described by Cottenie *et al.* (1982), and determined by using plasma emission spectrometry (ICP400 Perkin Elmer). The used compost was obtained from Ismailia Agric. Res. Station and its analysis is shown in Table (1-b).

Polyethylene pots of 20 cm diameter and 18 cm depth were filled with 6 kg of soil sample (fine earth). Before filling the pots, the treatments of soil amendments were mixed thoroughly with the experimental soil. Gypsum treatments were added at rates of 0, 5, 10 and 20 tons/fed; lime at rates of 0, 1, 2 and 4 tons/fed; compost at rates of 0, 7, 14 and 21 tons/fed. For Fe-EDDHA and Zn-EDTA, the treatments were added at rates 0, 1, 2 and 4 kg/fed. The pots were arranged in a randomized complete block design, with three replicates.

All the pots received the recommended doses of nitrogen and potassium, which were dissolved in irrigation water at rates of 0.60 g ammonium sulphate/pot (20.60 % N), 0.30 g potassium sulphate/pot (48% K_2O) and 0.60 g superphosphate/pot (15% P_2O_5) and added before planting. Ten seeds from each of red radish (Raphanus sativus, L.) and kenaf (Hibiscus cannabinus, L.) were planted in each pot and thinned after complete germination to 5 plants per pot. The moisture content was always kept about 70 % from water holding capacity through growth period using tap water. After 56 and 60 days from planting for red radish and kenaf, respectively, the plants were harvested, then rinsed with

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Table 1-a. Some physical and chemical properties of El- Gabal El-Asfar soil

Properties	Value
Particle size distribution (%)	
Coarse sand	3.56
Fine sand	48.73
Silt	35.36
Clay	12.35
Textural class	Sandy loam
pH (1:2.5, soil:water suspension)	6.60
EC (dSm^{-1}, Sat. extr.)	0.83
Soluble cations (mq/L)	
Ca^{2+}	1.36
Mg^{2+}	0.82
Na^{+}	5.97
K^{+}	0.35
Soluble anions (mq/L)	
CO_3^{--}	0.00
HCO_3^{-}	1.47
Cl^{-}	3.92
SO_4^{--}	3.11
CEC ($cmol_c\ kg^{-1}$)	12.98
Organic matter (%)	5.87
Organic carbon (%)	3.41
Total-N (%)	0.21
C/N ratio	17.0
$CaCO_3$ (%)	1.20
Available N ($\mu g\ g^{-1}$)	
NH_4^{+}	17.00
NO_3^{-}	49.00
Total	66.00
Available P ($\mu g\ g^{-1}$)	14.00
Available K ($\mu g\ g^{-1}$)	134.55
Total heavy metals ($\mu g\ g^{-1}$)	
Cd	3.36
Pb	164.87
DTPA-extractable trace elements ($\mu g\ g^{-1}$)	
Fe	134.30
Mn	7.90
Zn	6.40
Cu	4.60
Cd	0.41
Pb	21.82

Table 1-b. Some chemical analysis of the used compost

Property	Value
Organic matter (%)	23.20
Organic carbon (%)	13.50
Total-N (%)	0.92
C/N ratio	15.0
C.E.C. (mq/100g)	44.00
pH (1:10, compost: water suspension)	6.40
EC, dSm^{-1} (1:10)	4.32
Total P (%)	0.34
Total K (%)	0.73
Available N ($\mu g\ g^{-1}$)	
NH_4^+	99.96
NO_3^-	1085.28
Total	1185.24
Available P ($\mu g\ g^{-1}$)	273.00
Available K ($\mu g\ g^{-1}$)	5382.00
Total trace elements ($\mu g\ g^{-1}$)	
Fe	1800.00
Mn	300.00
Zn	4000.00
Cu	80.00
Cd	0.50
Pb	3.20
DTPA-Extractable trace elements ($\mu g\ g^{-1}$)	
Fe	26.00
Mn	25.40
Zn	4.00
Cu	2.00
Cd	0.07
Pb	0.44

distilled water and separated into shoots and roots. The plant samples were oven dried at 70 C° for 24 hours to calculate the dry weight, then ground in a willy mill and kept in plastic bags for chemical analysis. The plant samples of red radish and kenaf were digested using $HClO_4$ and H_2SO_4 acids (Jackson, 1973). The Cd and Pb concentrations were determined using the Inductivity-Coupled Plasma emission spectrometry (ICP 400 Perkin Elmer). Also, soil samples for each treatment at the same period (harvest) were collected and air dried, crushed and sieved to pass through a 2 mm screen to be finally used for determination of Cd and Pb concentrations in the soil.

The data obtained from this study were statistically analyzed through analysis of variance (ANOVA) and least significant difference (LSD) at 0.05, which applied to make comparison among treatments according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Dry Matter Yield

The dry matter yields of shoots, roots and whole plants of red radish and kenaf grown on El-Gabal El-Asfar soil as affected by different sources and rates of soil amendments (gypsum, lime, organic compost , Fe-EDDHA and Zn-EDTA) are presented in Table 2. Data showed that the yields of dry matter of shoots, roots and whole plants for both the two species increased gradually with increasing applied rates of different soil amendments compared to the control treatment, except liming. Where, increasing the rate of applied lime beyond the rate 2 ton/fed slightly decreased the dry matter yields of shoots, roots and whole plants for both studied species.

Data also revealed that the compost treatments showed the greatest values of the yields of shoots, roots and whole plants for both two species, while Zn-EDTA showed the lowest one. The corresponding relative values at the high rate of compost were 56, 27 and 38% for shoot, root and whole plants of red radish and 73, 22 and 62% for kenaf plants, respectively. The corresponding relative values for Zn-EDTA were 15, 17 and 16% for red radish and 18, 6 and 16% for kenaf plants in the same order. This increase may be due to the role of compost treatment for stabilizing the Cd

Table 2. Effect of applied soil amendments on the dry matter yield ($g\ pot^{-1}$) of plant species

Treatments	Red radish			Kenaf		
	Shoot	Root	Whole plant	Shoot	Root	Whole plant
			Control			
	4.06	6.68	10.74	17.03	4.66	21.69
			Gypsum			
5 ton / fed.	5.30	8.15	13.45	23.06	4.88	27.94
10 ton / fed.	5.79	8.20	13.99	25.07	5.14	30.21
20 ton / fed.	5.88	8.37	14.25	25.82	5.23	31.05
			Liming			
1 ton / fed.	5.02	7.85	12.87	21.50	4.73	26.23
2 ton / fed.	5.28	8.10	13.38	23.84	5.10	28.94
4 ton / fed.	5.15	8.03	13.18	22.41	5.02	27.43
			Compost			
7 ton/ fed.	5.76	8.30	14.06	25.54	5.13	30.67
14 ton/ fed.	6.20	8.41	14.61	28.98	5.36	34.34
21 ton/ fed.	6.33	8.47	14.80	29.39	5.68	35.07
			Fe-EDDHA			
1 kg / fed.	4.72	7.56	12.28	19.89	4.85	24.74
2 kg / fed.	5.04	7.90	12.94	20.98	4.92	25.90
4 kg / fed.	5.10	8.01	13.11	21.19	4.97	26.10
			Zn-EDTA			
1 kg / fed.	4.25	7.40	11.65	18.48	4.81	23.29
2 kg / fed.	4.58	7.70	12.28	19.90	4.89	24.79
4 kg / fed.	4.68	7.79	12.47	20.17	4.93	25.10
			L.S.D at 5%			
Amendment	0.27	0.25	0.49	1.30	0.34	1.59
Rate	0.21	0.19	0.38	1.01	0.26	1.23
Amendment × Rate	n.s	n.s	n.s	n.s	n.s	n.s

and Pb as reported by Abd-El-Malak, (2007) who cleared that addition of organic matter to the soil generally decreased the adverse effect of Cd and Pb on plant growth probably due to its role of active organic substances in chelating Cd and Pb as legands. In addition, the role of compost for increasing the productivity of soil as a result of soil improvement (Kandil, 2005). The beneficial effect of using different soil amendments on the growth may be attributed to reducing phytotoxicity of the studied heavy metals, enhanced the yield of shoots, roots and whole plants and decreased the harmful effect of metal concentrations.

Moreover, the effectiveness of the applied soil amendments on the studied plant parameters was in the following descending order, compost > gypsum > liming > Fe-EDDHA > Zn-EDTA.

Content and Uptake of Cd and Pb in Plants

Data in Tables 3 and 4 show the effect of soil amendments applied at different rates on Cd and Pb concentrations in shoots and roots of red radish and kenaf plants cultivated on El-Gabal El-Asfar polluted soil. Generally, application of the used soil amendments at different rates decreased both Cd and Pb concentrations in shoots and roots of red radish and kenaf plants as compared with the control. The decrease was progressive and significant with increasing the rate of application. The concentrations of Cd and Pb in the shoots and roots of red radish plants were higher than those of kenaf plants probably due to plant species and the used soil amendments. Also, results showed that red radish plants accumulated more Cd and Pb in roots than in shoots. These results are in good agreement with those obtained by Eissa and El-Kassas (1999) and Badawy and El-Motaium (2003), who found that concentrations of Cd in roots are always higher than those of shoots, or fruits and grains.

On the other hand, kenaf plants accumulated more Cd and Pb in shoots than in roots, indicating the ability of kenaf plants to translocate more Cd and Pb to the shoots to decrease the adverse effect of Cd or Pb on root growth. In this connection, Lasat, (2002), reported that phytoextraction is the use of higher plants to remove inorganic contaminants from polluted soil and translocate to

Table 3. Effect of applied soil amendments on Cd content (µg g^{-1}) in plant species

Treatments	Cd concentration (µg g^{-1})			
	Red radish		Kenaf	
	Shoot	Root	Shoot	Root
Control				
	22.00	27.00	4.39	1.77
Gypsum				
5 ton/fed.	15.00	18.00	2.40	1.45
10 ton/fed	13.00	16.00	2.11	1.13
20 ton/fed	12.00	15.00	1.90	0.96
Liming				
1 ton/fed.	17.00	20.00	2.76	1.72
2 ton/fed.	15.00	18.00	2.41	1.30
4 ton/fed.	14.00	17.00	2.30	1.16
Compost				
7 ton/fed.	12.00	16.00	1.70	1.15
14 ton/fed.	10.00	14.00	1.30	0.88
21 ton/fed.	9.00	13.00	1.19	0.73
Fe-EDDHA				
1 kg/fed.	11.00	22.00	3.50	0.98
2 kg/fed.	9.00	20.00	3.10	0.70
4 kg/fed.	8.00	19.00	2.90	0.62
Zn-EDTA				
1 kg/fed.	9.00	24.00	3.90	0.75
2 kg/fed.	7.00	22.00	3.50	0.51
4 kg/fed.	6.00	21.00	3.30	0.43
L.S.D at 5%				
Amendment	1.00	1.00	0.18	0.10
Rate	1.00	1.00	0.14	0.17
Amendment × Rate	3.00	3.00	n.s	n.s

Table 4. Effect of applied soil amendments on Pb content ($\mu g\ g^{-1}$) in plant species

Treatments	Pb concentration ($\mu g\ g^{-1}$)			
	Red radish		Kenaf	
	Shoot	Root	Shoot	Root
Control				
	193.00	242.00	19.10	11.18
Gypsum				
5 ton/fed.	145.00	165.00	11.70	9.21
10 ton/fed.	125.00	158.00	10.59	7.52
20 ton/fed.	120.00	152.00	9.40	6.81
Liming				
1 ton/fed.	155.00	177.00	13.10	10.38
2 ton/fed.	146.00	168.00	11.45	8.62
4 ton/fed.	142.00	164.00	10.10	7.91
Compost				
7 ton/fed.	130.00	143.00	10.11	7.65
14 ton/fed.	114.00	136.00	8.25	6.36
21 ton/fed.	106.00	130.00	7.95	5.32
Fe-EDDHA				
1 kg/fed.	119.00	196.00	15.32	6.53
2 kg/fed.	110.00	184.00	14.15	5.41
4 kg/fed.	104.00	179.00	13.71	4.71
Zn-EDTA				
1 kg/fed.	95.00	218.00	17.21	5.29
2 kg/fed.	82.00	205.00	15.35	4.33
4 kg/fed.	77.00	198.00	14.91	3.70
L.S.D at 5%				
Amendment	2.00	2.00	0.84	0.28
Rate	2.00	2.00	0.65	0.22
Amendment × Rate	4.00	n.s	n.s	n.s

above ground parts. Baker and Whiting (2002) found that high tissue concentrations of metal (loid)s were in above-ground tissues.

Data also, indicated that the efficiency of applied soil amendments on decreasing concentrations of Cd and Pb in the different parts of red radish and kenaf plants (shoots and roots) grown on El-Gabal El-Asfar polluted soil was observed, where the compost treatment, under different rates, was the most efficient amendment in decreasing Cd and Pb concentrations in shoots and roots of red radish and kenaf plants as compared with the control plants, especially at the rate of 21 ton/fed. In this concern, Scherer *et al.* (1997) found that Cd and Pb concentrations of the plant material were mainly reduced after compost application. Abd El-Malak (2007) reported that organic manure played an effective role for immobilizing Pb, and in turn reflected on reducing its content in second phases of its uptake by lettuce plants and accumulate in root and shoot tissues.

However, liming amendment was the lowest efficiency for decreasing Cd and Pb concentrations, especially in the shoots. These results are in agreement with that obtained in case of the dry matter yield. Hegazy *et al.* (1996) found that Cd concentration seemed to be inversely to be related to the soil content of $CaCO_3$. Hardiman *et al.* (1984) observed a reduction of Pb in plant tissues grown on soil amended with limestone or calcium carbonates.

Data concerning the influence of various soil amendments applied at different rates on the uptake of Cd and Pb by shoots, roots and whole plants of red radish and kenaf plants grown on El-Gabal El-Asfar soil are given in Tables 5 and 6. Addition of soil amendments with different rates gradually decreased Cd and Pb taken up by shoots, roots and whole plants of red radish and kenaf in comparison with the control treatment. Most of Cd and Pb taken up by red radish plants were retained in the roots and consequently less amount of Cd and Pb were translocated to shoots, indicating the ability of roots to accumulate high amounts of Cd and Pb. Kabata-Pendias and Pendias (1993) and Inouhe *et al.* (1994) stated that the increase in the uptake of cadmium mostly accumulates in the roots. The cadmium blockage in the roots

Table 5. Effect of applied soil amendments on Cd uptake (µg pot^{-1}) by plant species

Treatments	Cd uptake(µg pot^{-1})					
	Red radish			Kenaf		
	Shoot	Root	Whole plant	Shoot	Root	Whole plant
Control						
	89.32	180.36	269.68	74.76	8.25	83.01
Gypsum						
5 ton/fed.	79.50	146.70	226.20	55.34	7.08	62.42
10 ton/fed.	75.27	131.20	206.47	52.90	5.81	58.71
20 ton/fed.	70.56	125.55	196.11	49.06	5.02	54.08
Liming						
1 ton/fed.	85.34	157.00	242.34	59.34	8.14	67.48
2 ton/fed.	79.20	145.80	225.00	57.45	6.63	64.08
4 ton/fed.	72.10	136.51	208.61	51.54	5.82	57.36
Compost						
7 ton/fed.	69.12	132.80	201.92	43.42	5.90	49.32
14 ton/fed.	62.00	117.74	179.74	37.67	4.72	42.39
21 ton/fed.	56.97	110.11	167.80	34.97	4.15	39.12
Fe-EDDHA						
1 kg/fed.	51.92	166.32	218.24	69.62	4.75	74.37
2 kg/fed.	45.36	158.00	203.36	65.04	3.44	68.48
4 kg/fed.	40.80	152.19	192.99	61.45	3.08	64.53
Zn-EDTA						
1 kg/fed.	38.25	177.60	215.85	72.07	3.61	75.68
2 kg/fed.	32.06	169.40	201.46	69.65	2.49	72.14
4 kg/fed.	28.08	163.59	191.67	66.56	2.12	68.68
L.S.D at 5%						
Amendment	1.65	3.31	3.29	6.82	0.33	1.82
Rate	1.28	2.56	2.55	5.28	0.26	1.41
Amendment × Rate	2.85	n.s	n.s	n.s	n.s	n.s

Table 6. Effect of applied soil amendments on Pb uptake (μg pot^{-1}) by plant species

Treatments	Pb uptake (μg pot^{-1})					
	Red radish			Kenaf		
	Shoot	Root	Whole plant	Shoot	Root	Whole plant
Control						
	783.58	1617.00	2400.58	325.27	52.10	377.37
Gypsum						
5 ton/fed.	768.50	1345.00	2113.50	269.80	44.94	314.74
10 ton/fed	723.75	1296.00	2019.75	265.49	38.65	304.14
20 ton/fed	705.60	1272.00	1977.60	242.71	35.62	278.33
Liming						
1 ton/fed.	778.10	1389.00	2167.10	281.65	49.10	330.75
2 ton/fed.	770.88	1361.00	2131.88	272.97	43.96	316.93
4 ton/fed.	731.30	1317.00	2048.30	248.75	39.71	288.46
Compost						
7 ton/fed.	748.80	1187.00	1935.80	258.21	39.24	297.45
14 ton/fed.	706.80	1144.00	1850.80	239.09	34.09	273.18
21 ton/fed.	670.98	1101.00	1771.98	233.65	30.22	263.87
Fe-EDDHA						
1 kg/fed.	561.68	1482.00	2043.68	304.71	31.67	336.38
2 kg/fed.	554.40	1454.00	2008.40	296.86	26.62	323.48
4 kg/fed.	530.40	1434.00	1964.40	290.51	23.41	313.92
Zn-EDTA						
1 kg/fed.	403.75	1613.00	2016.75	318.04	25.44	343.48
2 kg/fed.	375.56	1579.00	1954.56	305.47	21.17	326.64
4 kg/fed.	360.36	1542.00	1902.36	300.73	18.24	318.97
L.S.D at 5%						
Amendment	1.65	2.00	3.30	11.07	1.02	1.62
Rate	1.28	1.00	2.55	8.57	0.79	1.26
Amendment × Rate	2.85	3.00	5.71	n.s	n.s	2.81

probably involves formation of this metal bonding with sulfhydrol and with proteins forming so called phytochelatins. Also, Gondek and Filipek-Mazur (2003) observed that heavy metals accumulation was primarily in the root systems. Abd El-Malak (2007) showed that most of Cd and Pb uptake by plant organs of lettuce were retained in the roots, and consequently less Cd and Pb contents were transported to the shoots.

On the contrary, most of Cd and Pb taken up by kenaf plants were translocated to shoots and accumulated in the above ground parts, presumably due to decrease the adverse effect of Cd or Pb on plant growth. Chaney *et al.* (1997) reported that phytoextraction refers to the uptake and translocation of metal contaminants in the soil by plant roots into the above-ground portions of the plants. Robinson *et al.* (2000) mentioned that the technology of phytoextraction relies on plants that translocate heavy metals into their aboveground parts. Deng *et al.* (2004) reported that species able to accumulate relatively high metal concentrations in the aboveground tissues could be good candidates for phytoextraction.

The variation in Cd and Pb uptake between red radish and kenaf is mainly attributed to crop species as reported by (Tiller, 1989, and Tlustos *et al.*, 1997) who stated that the accumulation of cadmium in plant biomass was not only affected by the soil properties, but by the crop species planted on the soil as well. The uptake of Cd and Pb by red radish plants was higher when compared with the kenaf plants, indicating that red radish plants were more sensitive to Cd and Pb than kenaf plants. The compost treatment was the most efficient amendment to reduce Cd and Pb uptake, while liming treatment was the lowest efficient. The efficiency of decreasing Cd and Pb uptake by whole plant of red radish and kenaf could be arranged in the descending order: compost > Zn-EDTA > Fe-EDDHA > gypsum > liming. This exhibit the function of compost to reduce the hazardous effect of Cd or Pb to accumulate in edible parts of plants. In this concern, Gorlach and Gambus (1992) found that addition of peat and manure reduced the uptake of Pb. Chaney *et al.* (2000) declared that addition of organic fertilizers, can inhibit the uptake of some major metal contaminants, such as Pb, due to metal precipitation as pyromorphite and chlropyromorphite.

Generally, the results showed that red radish plants absorb and accumulate higher amounts of Cd and Pb than kenaf plants. Since, Cd contents in red radish plants exceeded the normal range in comparison with the concentration of Cd reported by Bergman and Cumakov, (1977) and Davis *et al.*, (1978) who found that the recommended levels of Cd were 0.05-0.2 mg kg^{-1}, while toxic limit for this element ranging from 5 to 30 mg Cd kg^{-1} plant (Kabata-Pendias and Pendias, 2001). Also, the concentration of Pb in all the plant organs of red radish were higher than the normal range (5-9 mg kg^{-1}) and (2-14 mg kg^{-1}) as reported by Chapman (1966) and Cottenie *et al.* (1982), respectively. On the other hand, Kabata-Pendias and Pendias (2001) stated that the normal Pb concentration in plants grown in uncontaminated and unmineralized areas appears to be quite constant, ranging from 0.1-10 mg kg^{-1} and averaging 10 mg kg^{-1}, while toxic range of Pb according to Smith, (1996) was 30 to 300 mg kg^{-1}. Whereas, kenaf plants absorb and accumulate lower amounts of Cd and Pb than red radish plants. So, it could be concluded that using red radish plants growing on polluted soil may increase the concentrations of Cd and Pb in plants grown thereon, potentially affecting plant growth, soil fertility, animal and human health, when used as a food source.

The comparison between the two tested plants showed that kenaf plants were more effective as tolerant for stabilization of available Cd and Pb, whereas red radish plants were absorbed available amounts of these heavy metals. The superiority of kenaf plants over red radish plants might be attributed to the lower absorbing area of roots of the former plants. In this concern, Robinson et al. (2000) stated that metal-tolerant plants have lower heavy metal concentrations in their tissues, yet contribute to metal extraction by high biomass yields (Baker and Brooks, 1989).

Chemical Behaviour of Cd and Pb in Polluted Soil as Affected by Soil Amendments

Results in Tables 7 and 8 show the effect of soil amendments applied at different rates on total, available and availability index of Cd and Pb in El-Gabal El-Asfar soil after cultivation with red radish and kenaf plants. Application of the used soil amendments at different rates increased progressively total Cd and Pb. The highest increase in total Cd and Pb was obtained with compost application at a rate of 21 tons/fed. The corresponding relative values of increase were 250 and 64 % after red radish and 187 and 58 % after kenaf plants for Cd and Pb, respectively. The superiority of the organic compost over the other used amendments has also been documented by Kandil (2005) who found that compost materials significantly increased the total Cd and Pb in the polluted soil of El-Gabal El-Asfar after spinach plantion. However, this increase was not significant.

On the contrary, available and availability index of Cd and Pb in the soil after cultivation with both plants were reduced under different sources of soil amendments. The highest reduction of available and availability index of Cd and Pb was obtained also, under application of compost at a rate of 21 ton/fed. The corresponding relative values for Cd were 65 and 90 % for red radish plants, and 66 and 88% for kenaf plants in the same order, respectively. While, the corresponding relative decreases for Pb were 64 and 78.5% for red radish plants and 68 and 80 % for kenaf plants in the same order. These results are in agreement with those reported by kandil (2005) who found that addition of banana and cotton composts to El-Gabal El-Asfar soil significantly decreased the extactable Cd and Pb. The positive effect of compost on decreasing available Cd and Pb in soil may be due to the fixation, precipitation or formation of complex compounds between the compost as an organic material and these metals (He and Singh, 1993). Abdel Sabour *et al.* (1996) reported that the lower availability ratio could be explained by the possible precipitation reactions or the high affinity to form organic complexes. Hundal *et al.* (2003) found that, availability of heavy metals could be decreased by organic matter additions to soil by formation of insoluble metal organic complexes with humic acids, thereby lessening risk of metal toxicity of plants. Therefore, some beneficial effects to heavy metal concentrations in soils could be achieve by applying compost to agricultural land. Asgier *et al.* (2000) showed that added organic matter contributed to immobilization of Cd. This may be also due to active organic acids (humic and fulvic acids) that form relatively stable complexes with Cd. Badawy (1987) reported that the low mobility of Pb may be due to the formation of strongly bound insoluble chelates by reaction with organic matter or the precipitation of Pb ions as insoluble compounds. Also, results showed that there were significant differences between the different rates of application and among the different used amendments. The concentrations of heavy metals in plants were significantly related to total and DTPA extractable of heavy metals. In this concern, Lund *et al.* (1981) reported that Cd concentrations in radish, Swiss chard, and pepper were significantly related to both total soil Cd and DTPA extractable Cd. However, the increase in soil pH due to application of $CaCO_3$ as compared with initial pH value might be considered an additional reason for reducing extractable content of the studied heavy metals. This may indicate that fixation and/or precipitation of the tested metals due to reaction with $CaCO_3$ might account for such reduction (Street, *et al.*, 1977). Xu and Schwartz (1994) mentioned that precipitation as metal carbonates is considered to be one of the mechanisms for lime-induced immobilization of heavy metals. Alloway *et al.* (1988) showed that soils containing free $CaCO_3$ could sorb Cd and reduce its bioavailability. Oste *et al.* (2001) said that the addition of lime (pH increase) could decrease the free Cd concentration in soil pore water. Tadross (2004) reported that fixation or precipitation of Pb due to reaction with $CaCO_3$ or adsorption on its surface may account for such decrease in availability of Pb.

Generally, the soil amendments could be arranged descendingly according to their decreasing available Cd and Pb as follows: compost > gypsum > liming > Fe-EDDHA > Zn-EDTA. Accordinglly, these soil amendments (gypsum, liming, compost, Fe-EDDHA and Zn-EDTA) have the ability to minimize the immediate risk of the presented heavy metals through decreasing its mobility, hence reducing phytoavailability. Also, data indicated that the extractable heavy metals in soil of El-Gabal El-Asfar after cultivated with red radish were higher than those cultivated with kenaf plants under all the used amendments treatments. Moreover, the highest values of extractable Cd and Pb in the soil after cultivation with red

Table 7. Effect of applied soil amendments on total, available and availability index of Cd in soil after cultivation

Treatments	Red radish			Kenaf		
	Cd (µg g^{-1})		A.I. %	Cd (µg g^{-1})		A.I. %
	Total	Available		Total	Available	
Control						
	0.80	0.37	46.25	1.15	0.32	27.83
Gypsum						
5 ton/fed.	1.70	0.25	14.71	2.10	0.22	10.48
10 ton/fed.	1.90	0.19	10.00	2.40	0.16	6.25
20 ton/fed.	2.00	0.17	8.50	2.60	0.13	5.00
Liming						
1 ton/fed.	1.40	0.28	20.00	1.80	0.25	13.89
2 ton/fed.	1.60	0.23	14.38	2.20	0.19	8.46
4 ton/fed.	1.70	0.21	12.35	2.35	0.16	6.81
Compost						
7 ton/fed.	2.20	0.21	9.55	2.70	0.17	6.30
14 ton/fed.	2.60	0.16	6.15	3.10	0.13	4.19
21 ton/fed.	2.80	0.13	4.64	3.30	0.11	3.33
Fe-EDDHA						
1 kg/fed.	1.20	0.32	26.67	1.40	0.27	19.29
2 kg/fed.	1.40	0.28	20.00	1.70	0.23	13.53
4 kg/fed.	1.50	0.25	16.67	1.90	0.19	10.00
Zn-EDTA						
1 kg/fed.	1.05	0.35	33.33	1.24	0.29	23.20
2 kg/fed.	1.20	0.30	25.00	1.55	0.25	16.13
4 kg/fed.	1.30	0.28	21.54	1.63	0.22	13.94
LSD at 5%						
Amendment	0.09	0.02		0.09	0.02	
Rate	0.07	0.02		0.07	0.02	
Amendment × Rate	n.s	n.s		n.s	n.s	

A.I. % = DTPA extractable content/Total content x 100 (Abbas, 2007)

Table 8. Effect of applied soil amendments on total, available and availability index of Pb in soil after cultivation

Treatments	Red radish Pb ($\mu g\ g^{-1}$) Total	Red radish Pb ($\mu g\ g^{-1}$) Available	Red radish A.I. %	Kenaf Pb ($\mu g\ g^{-1}$) Total	Kenaf Pb ($\mu g\ g^{-1}$) Available	Kenaf A.I. %
Control						
	75.60	19.84	26.24	86.73	17.56	20.25
Gypsum						
5 ton/fed.	103.40	14.02	13.56	115.83	11.23	9.70
10 ton/fed.	110.50	12.94	11.71	121.50	9.38	7.72
20 ton/fed.	112.65	11.31	10.04	132.37	8.55	6.93
Liming						
1 ton/fed.	98.15	16.75	17.07	110.55	12.86	11.63
2 ton/fed.	104.29	14.36	13.77	114.82	10.61	9.24
4 ton/fed.	107.44	13.23	12.31	116.67	9.74	8.35
Compost						
7 ton/fed.	112.66	11.62	10.31	125.46	8.86	7.06
14 ton/fed.	120.50	8.17	6.76	134.80	6.61	4.90
21 ton/fed.	123.80	7.09	5.73	137.40	5.70	4.15
Fe-EDDHA						
1 kg/fed.	92.69	17.91	19.32	101.75	14.89	14.63
2 kg/fed.	97.18	15.56	16.01	105.40	12.68	12.03
4 kg/fed.	100.15	14.25	14.23	107.20	11.26	10.50
Zn-EDTA						
1 kg/fed.	85.57	18.45	21.56	95.38	15.96	16.73
2 kg/fed.	89.73	17.22	19..19	100.77	13.81	13.70
4 kg/fed.	91.60	16.45	17.96	102.58	12.77	12.45
LSD at 5%						
Amendment	1.39	0.56		0.83	0.38	
Rate	1.07	0.43		0.64	0.29	
Amendment × Rate	n.s	0.97		1.43	n.s	

A.I. % = DTPA extractable content/Total content x 100 (Abbas, 2007)

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radish and kenaf plants were obtained by using metal chelates at the application rate of 4 kg/fed, while the lowest values were attained by application of organic compost at the rate of 21 ton/fed. The efficiency of studied materials on heavy metal concentrations was varied in accordance to sources and rates of application and/or the part of the grown plant.

From the above mentioned discussion, it was concluded that application of some chemical and organic amendments such as gypsum, lime organic compost and chelating agents to soil polluted with Cd and Pb reduced and immobilized such metals, being organic compost was most efficient. Also, phytoremediation technology by growing some crops, i.e., kenaf plants as a fiber crop was most efficient to reduce such metals from polluted soil, especially Cd and Pb.

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عـــلاج الأراضـــــي الملــوثــة بالعنــاصر الثقيلــة

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أجريت تجربة أصص في صوبة زجاجية لمعالجة الأراضى الملوثة بعنصرى الكادميوم والرصاص وذلك باستخدام بعض محسنات التربة الكيمياوية والعضوية مثل الجبس، الجير، الكمبوست العضوي والمواد المخلبية كالحديد والزنك وكذلك استخدام بعض النباتات كعلاج بالنباتات مثل نبات التيل (كمحصول ألياف) ومقارنتها بنباتات الفجل الأحمر (كمحصول خضر غذائى). تم تجميع عينات التربة من مزرعة الجبل الأصفر بمحافظة القليوبية والتي تم ريها بمياه المجاري لفترة زمنية طويلة. وتم خلط محسنات التربة جيداً مع أرض التجربة وكانت المعاملات الجبس بمعدلات صفر، ٥، ١٠،٢٠ طن/فدان، الجير بمعدلات صفر، ١، ٢، ٤ طن/فدان، سماد الكمبوست بمعدلات صفر، ٧، ١٤، ٢١ طن /فدان وبالنسبة لمخلبيات الحديد والزنك تم إضافة المعاملات بمعدلات صفر،٤،٢،١ كجم/فدان. وتم زراعة بذور الفجل الأحمر والتيل لمدة ٥٦، ٦٠ يوماً علي التوالي.

وقد أظهرت النتائج أن قيم المادة الجافة لكل من السوق والجذور والنبات الكامل لكل من الفجل والتيل زادت بزيادة معدلات الإضافة من محسنات التربة المختلفة وأن معاملة الكمبوست كانت الأكثر تأثيراً، كما أن إضافة محسنات التربة بالمعدلات المختلفة خفضت من امتصاص الكادميوم والرصاص بواسطة السوق والجذور لنباتات الفجل الأحمر والتيل بالمقارنة مع معاملة الكنترول، وان هذا الإنخفاض كان معنوياً وكانت الأفضلية لمعاملة الكمبوست تحت المعدلات المختلفة.

كما تلاحظ أيضا أن معظم الكادميوم والرصاص الممتص بواسطة نباتات الفجل الأحمر تركزت في الجذور وبالتالي انتقلت كميات قليلة منهما الى المجموع الخضرى وعلي العكس من ذلك فإن معظم الكادميوم والرصاص الممتص بواسطة نباتات التيل تراكمت في الأجزاء العليا.

انخفض تيسر عنصرى الكادميوم والرصاص في التربة بعد الزراعة نتيجة إضافة المحسنات الأرضية بمعدلاتها المختلفة وكان أعلي انخفاض عند إضافة سماد الكمبوست بمعدل ٢١ طن/فدان وبناء علي ذلك فإن هذه المحسنات (الجبس، الجير، الكمبوست، الحديد المخلبي، الزنك المخلبي) لها القدرة علي تقليل التأثير السام للمعادن الثقيلة الموجودة من خلال تقليل حركتها ومن ثم خفض التيسر الحيوي.