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INFLUENCE OF SOME CHELATORS ON THE PHYTOEXTRACTION ABILITY OF SUNFLOWER (*HELIANTHUS ANNUUS*) FOR Cd AND Pb METALS IN POLLUTED SOIL

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ABSTRACT : Chelation and complexation of heavy metals were evaluated as practical ways to solubilize, detoxify, and enhance heavy metals accumulation by plants. Sunflower (*Helianthus annuus*) was selected as a potential heavy metals accumulator for metals in two selected soils different in texture and contamination levels. To enhance metals phyto-extraction, ammonium nitrate and organic chelators (EDTA, and citric acid) were added to soils at rates of 0 to 20 mmol kg^{-1}. Pots experiment was run for 8 weeks.

Plant dry matter production (biomass) and metals accumulation were varied with soil contamination levels, chelator form and rate, and soil type. The highest metals concentration of Cd and Pb was obtained in plants grown on clayey soil however, the lowest content was observed in the sandy soil. Addition of citric acids significantly increased metals accumulation and translocation to the shoots. Adding high rate of citric acid (20 mmol kg^{-1}) to clayey soils increases metals accumulation in shoots several-fold of magnitude Citric acid was the most effective chelator of Cd and Pb metals that could enhance their accumulation in sunflower. Ammonium nitrate had low effect on metal translocation to shoots. In conclusion, the relationship between enhancing metal solubility in soils and plants, and feasible practices to minimize the risk of heavy metal leaching should be considered.

Key words: Heavy metals, phyto-accumulation, translocation, citric acid, chelators.

INTRODUCTION

The success of phyto-remediation depends upon the ability of a plant to uptake and translocate heavy metals, the function of the specific phenotype and genotype (Chen *et al.*, 2004). Several studies have documented that chelating agents such as Ethylene Diamine Triacetic Acid (EDTA), *N*-(2-hydroxyethyl)-ethylene diamine triacetic acid (HEDTA), and citric acid (CA) can be used to increase metal mobility, thereby enhancing their phyto-extraction (Chen and Cutright, 2001). For instance, 1.0 g/kg EDTA was reported to be the most effective chelator, increasing shoot Pb concentration in pea and corn cultivars (Huang *et al.*, 1997). A similar study on Pb accumulation with HEDTA increased the Pb concentration from 40 mg kg^{-1} to 10,600 mg kg^{-1} (Huang and Cunningham, 1996).

Some metals such as Pb are largely immobile in soil and their extraction rate is limited by solubility and diffusion to root surface. Chemically enhanced phyto-extraction has been developed to overcome these problems (Huang and Cunningham, 1996 and Blaylock *et al.*, 1997). This approach makes use of high-biomass crops that are induced to take up large amounts of metals when their mobility in soil is enhanced by chemical treatments. Several chelating agents, such as citric acid, EDTA, CDTA, DTPA, EGTA, EDDHA, and NTA, have been studied for their ability to mobilize metals and increase metal accumulation in different plant species (Cooper *et al.*, 1999). The most promising application of this technology is for the remediation of Pb-contaminated soils using Indian mustard (*Brassica juncea* L. Czern). in combination with EDTA (Wu *et al.*, 2004).

Despite the success of this technology, some concerns have been reported regarding the enhanced mobility of metals in soil and their potential risk of leaching to ground water (Michael *et al.*, 2007).

Chelating agents, such as EDTA, citric acid, etc., have been used as a viable environmental technology for mobilizing lead and zinc (Huang *et al.*, 1997 ; Wu et al., 1999 and Luo *et al.*, 1999) in soil to enhance their phyto-extraction. The role of citric acid on the availability, accumulation, and detoxification of Pb and Cd were discussed by (Chen *et al.*, 2004).

Michael *et al.*, 2007 and Evangelou, 2007a evaluated the effects of increasing doses of EDTA (0.1, 1, 10 mmol kg^{-1} dry soil) and citric acid (0.01, 0.05, 0.25, 0.442, 0.5 mmol kg^{-1} dry soil) on bioavailable fractions of Cu, Zn, Cd, and Pb. They concluded that both citric acid and EDTA produced a rapid initial increase in labile heavy metal fractions. Metal mobilization remained constant in time for soils treated with EDTA, but a strong exponential decrease of labile metal fractions was noted for soils treated with citric acid. The half life of heavy metal mobilization by citric acid varied between 1.5 and 5.7 days.

Schmidt, 2003 stated that suitable agents at proper dosage combined with suitable crops can be chosen for certain sites and contaminants. Enhanced phyto-extraction can be the key element to improve the implementation of phyto-remediation, because increasing accumulation rates of crops will maximize contaminant removal.

The aim of this study was to evaluate the ability of phyto-extraction for Cd and Pb metals using sunflower (*Helianthus annuu)* and chemically enhanced phyto-extraction chelators such as ammonium nitrate, EDTA, and citric acid in contaminated soil. On the other hand, the prospective risk associated with metals mobilization by EDTA and Citric acid will be also investigated.

MATERIALS AND METHODS

Soil Sampling and Analyses

Two surface contaminated soil samples (0-20 cm) were collected from different contaminated locations at north of greater Cairo, Egypt, to represent two different soil types (sandy and alluvial) as well as two different sources of contaminated wastewater. The sandy soil is located in El-Gabal El-Asfar farm and is subjected to sewage effluent irrigation for more than 50 years. The alluvial soil is located in Mostorud area and is irrigated with industrial contaminated water for more than 30 years due to direct discharge of industrial wastewater to irrigation water canals. Soil samples were air-dried, crushed to pass a 2.0 mm sieve then analyzed for conventional physical and chemical properties using methods outlined by Jackson (1973);

Available Cd and Pb were determined by DTPA method according to Lindsay and Norvell (1978); Total Cd and Pb were determined according to the standard methods Jackson (1973) using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Table (1) shows some physical and chemical properties of the tested soil samples. Table (2) shows the total and extractable DTPA content of Cd and Pb (mg kg^{-1}) in the investigated soil.

Table 1. Some physical and chemical properties of the investigated soils.

Soil prosperities	Mostorud	El-Gabal El-Asfar
Soil separates,%		
Sand	31.49	79.83
Silt	24.31	0.84
Clay	44.20	19.33
pH*	6.74	6.91
EC,** dS/m	8.43	1.23
CaCO3 (%)	1.60	0.70
O.M (%)	7.99	6.17
CEC, mmol/100g^{-1} soil	37.44	13.26
Soluble ions, $mmol_c/L^{-1}$		
Ca^{++}	34.7	3.5
Mg^{++}	24.1	2.4
Na^{+}	22.9	5.2
K^{+}	2.6	1.2
SO_4	62.4	2.0
HCO_3	4.4	6.3
Cl^-	17.5	4.0

* In the soil water suspension(1: 2.5).
** In the extract of saturated soil paste.

Table 2. Initial total content and extractable DTPA of Cd and Pb heavy metals mg kg^{-1} in investigated soils.

Samples location	Total content (mg kg^{-1})		extractable content (mg kg^{-1})	
	Cd	Pb	Cd	Pb
Mostorud	39	1612	1.2	11.6
El-Gabal EL-Asfar	27	1052	2.8	29.2

Pot experiment setup

The effect of EDTA, citric acid and ammonium nitrate on sunflower uptake of Cd and Pb metals was investigated in a greenhouse pot experiment. Five kg of air-dried surface soil sample (0-20 cm) were packed in plastic containers (30 cm internal diameter and 25 cm in height) in three replicates and complete randomized block experimental design. The chemical chelators of EDTA, citric acid and ammonium nitrate solutions were prepared and added to soil before planting at 0, 5, 10, and 20 mmol kg^{-1} soil and was thoroughly mixed. The recommended of dose nitrogen and phosphorus fertilizer were applied to each plot before the cultivation of the plants. Sunflower seeds were planted at rate 10 seeds per pot. After 7 days, the seedlings were thinned to 5 plants / pot. The soils were irrigated to maintain soil moisture at about 80 % of the soil field capacity during the growth period of the experiment (8 weeks).

Plant shoots were harvested after 60 days (8 weeks) by cutting the stems approximately 2 cm above the soil surface. The roots were collected and another soil samples were taken for Cd and Pb analyses. Plant samples (shoots and roots) were washed thoroughly and dried at 80 C for 60 h and their dry weight was recorded. Dried samples were ground and dry ashed according to Chapman and Pratt (1961). Total heavy metals in soils and plant samples were analyzed for Cd and Pb concentration using inductively coupled plasma (ICP-AES). Data were statistically analyzed for ANOVA and least significant difference (LSD) using MSTAT software according to the standard statistical methods (Power, 1985).

RESULTS AND DISCUSSION

Dry Matter Accumulation

The mean dry matter (DM) yield for sunflower shoots and roots grown on investigated contaminated soils (Mostorud and El-Gabal El-Asfar) was shown in (Fig. 1).The dry matter yield was significantly affected by soil type, chelators rate and their interactions. However, the cumulative biomass for whole plant showed that plant grown on the clayey soil exhibited the highest cumulative biomass. The dry matter yield of sunflower shoots and roots was insignificantly increased by increasing the application rate of chelators.

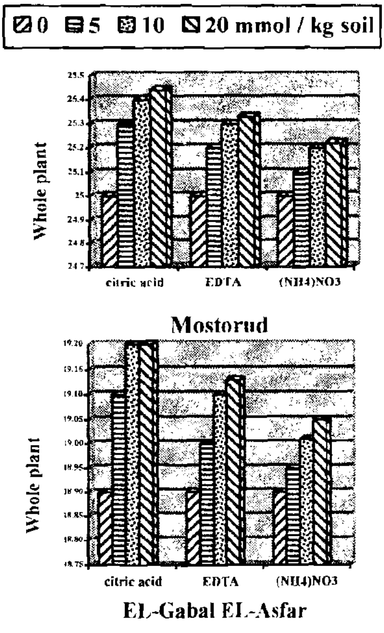

Fig. 1. Dry matter yield of sunflower whole plant (g pot^{-1}) as affected by investigated chelators in the tow ontaminated soils.

Dry matter yield of sunflower whole plant, g pot^{-1}, has insignificantly increased from 25.5 g pot^{-1} at zero citric acid to 26.9 g pot^{-1} at 20 mmol citric acid kg^{-1} soil in Mostorud soil. Dry matter yield of sunflower for whole plant, g pot^{-1}, has significantly increased from 18.9, g pot^{-1}, at zero citric acid to 20.9. g pot^{-1}, at 20 mmol citric acid kg^{-1} soil in El-Gabal El-Asfar soil.

Chelating agents and phyto-extraction

Phyto-extraction, the use of plants to extract heavy metals from contaminated soils, could be an interesting alternative to conventional remediation technologies. However, alkaline soils with relatively high total metal contents are difficult to phyto-remediate due to low soluble metal concentrations. Soil chelators such as ethylene diamine triacetic acid (EDTA) have been suggested to increase heavy metal bioavailability and uptake in aboveground plant parts. Strong persistence of EDTA and risks of leaching of potentially toxic metals and essential nutrients have led to research on easily biodegradable soil amendments such as citric acid which could be used for enhancing heavy metals plant uptake. Chelation and acidification are the chemical processes commonly used to bring adsorbed metals into solution. Chelating agents are reported to be the most practical way to solubilize and detoxify metals (Chen and Cutright, 2001) and (Chen *et al.*, 2004). Several organic as well as inorganic agents can effectively and specifically increase solubility and, therefore, accumulation of heavy metals by several plant species (Wu *et al.*, 2004; Meers *et al.*, 2005a and Evangelou *et al.*, 2006). Crops like willow (*Salix viminalis L.*), Indian mustard [*Brassica juncea (L.) Czern.*], corn (*Zea mays L.*), and sunflower (*Helianthus annuus L.*) show high tolerance to heavy metals and are, therefore, to a certain extent able to use the surpluses that originate from soil manipulation. cadmium and zinc concentrations could be enhanced by inorganic agents like elemental sulfur or ammonium sulfate (Evangelou, 2007b).

Cadmium uptake and recovery by sunflower

Cadmium soil contamination is very high in industrial areas exceeding the Cd soil concentration of agricultural soils with an average of 7-fold (Alloway and Ayrea, 1997). Tables 3 and 4 showed that the ability of sunflower to uptake Cd in shoots and roots were significantly enhanced with soil chelators and the rate of application up to 20 mmol kg^{-1}. It could be noticed that Cd was accumulated in roots more than in shoots regardless of soil type or chelators. It is worth to mention that Cd accumulation (in shoots and roots) was highly enhanced by using citric acid compared to any other chelators which could follow the order: citric acid > EDTA > ammonium nitrate. Chen and Cutright (2001) noticed an effective root to shoot translocation for Cd and Ni after the addition of EDTA, whereas for Cr no translocation could be observed. Additionally, the stability constant is not a reliable measurement scale for the effectiveness of a chelating agent.

Table 3 showed the cadmium content in sunflower shoots as affected by chelators application rate. Data indicated that Cd content in sunflower of shoot has significantly increased from 3.6 mg kg^{-1} at zero citric acid to 4.8 mg kg^{-1} in shoot (LSD 2.19, $p<0.05$) at 20 mmol citric acid kg^{-1} soil and from 6.3 to 8.4 in root (LSD 2.13, $p<0.05$) at the mostorud soil. Cadmium content in sunflower of shoot has significantly increased from 2.6 mg kg^{-1} at zero citric acid to 4.3 mg kg^{-1} in shoot (LSD 2.19, $p<0.05$) at 20, mmol citric acid kg^{-1} soil and from 4.8 to 6.4 in root (LSD 2.13, $p<0.05$) at the El-Gabal El-Asfar soil. However, these values were still within the range found in contaminated plants (5-30 mg kg^{-1}) (Kabata-Pendias and Pendias, 1992).

Table 4 showed that cadmium uptake and recovery from contaminated investigated soil by the whole sunflower plant was increasingly enhanced by increasing the rate of applied chelators. These results are in agreement with the findings of (Evangelou *et al.*, 2007b) where citric acid was more enhancing agent for Cd uptake.

Cadmium uptake in the shoots, however, was not enhanced by the application of citric acid and EDTA. This result is at variance with that of Li *et al.*, (2005), in which a significantly enhanced uptake was observed in the case of Cd. It is, though, in agreement with Meers *et al.*, (2005a); Tandy *et al.*, (2006) and Michael *et al.*, (2007), who did not notice an enhanced uptake. In the case of Cd, EDTA enhanced the uptake in

Table 3. Cadmium content in sunflower shoots and roots ($mg\ kg^{-1}$) as affected by tested soil chelators ($mmol\ kg^{-1}$) in the investigated contaminated soils.

Treatment	Rate of application ($mmol\ kg^{-1}$)	Shoot		Root	
		Mostorud	EL-Gabal	Mostorud	EL-Gabal
Citric acid					
	0	3.6	2.6	6.1	4.8
	5	4.3	3.6	7.7	5.8
	10	4.6	3.9	8.1	6.2
	20	4.8	4.3	8.4	6.4
EDTA					
	0	3.6	2.6	6.1	4.8
	5	4.0	3.1	7.0	5.3
	10	4.3	3.3	7.4	5.7
	20	4.5	3.6	7.6	6.1
Amn- nitrate					
	0	3.6	2.6	6.1	4.8
	5	3.8	2.8	6.5	5.1
	10	4.2	3.1	6.9	5.4
	20	4.4	3.4	7.2	5.7
$LSD_{0.05}$					
S=Soil		12.11		11.31	
A= Amendment		2.19		2.13	
R=Rate		10.13		9.17	
SxA		3.61		2.31	
SXR		3.34		4.17	
AXR		2.91		2.64	
SxAxR		11.33		10.73	

Table 4. Recovery percentage of cadmium removed from tested soils by sunflower (mg kg^{-1})as affected by different rates of citric acid -EDTA and ammoniom nitrat (mmol kg $^{-1}$) application at the studied contaminated soils.

Treatment (mmol kg –1)	Cd -soil initial (mg kg-1)	Cd-soil final (mg kg-1)	Total- Cd uptake by whole plant (mg kg-1)	Cd-removal* by whole plant (%)	Cd -soil initial (mg kg-1)	Cd-soil final (mg kg-1)	Total- Cd uptake by whole plant (mg kg-1)	Cd-rmoval* by whole plant (%)
		Mostorud				EL- Gabal EL-Asfar		
Citric acid								
0	39	29.4	9.6	24.6	27	19.6	7.4	27.4
5		27.0	12.0	30.8		17.7	9.3	34.4
10		26.4	12.6	32.3		16.9	10.1	37.4
20		25.8	13.2	33.8		16.3	10.7	39.6
EDTA								
0	39	29.4	9.6	24.6	27	19.6	7.4	27.4
5		28.0	11.0	28.2		18.6	8.4	31.1
10		27.3	11.7	30.0		18.0	9.0	33.3
20		26.9	12.1	31.1		17.3	9.7	35.9
Amn - nitrate								
0	39	29.4	9.6	24.6	27	19.6	7.4	27.4
5		27.7	11.3	29.1		19.1	7.9	29.3
10		27.9	11.1	28.5		18.5	8.5	31.5
20		27.4	11.6	29.7		17.9	9.1	33.7

the roots, but the Cd concentration in the shoots was only slightly higher than in the roots.

Lead uptake and recovery by sunflower

Tables 5 and 6 showed that the application of soil chelators significantly increased sunflower Pb uptake in shoots and roots. Also, increasing the rate of application up to 20 mmol kg^{-1} significantly enhanced Pb uptake in sunflower shoots and roots. It could be noticed that pb accumulated in roots more than in shoots under any tested soil or soil amendments type. It is worth to mention that citric acid enhanced pb accumulation (in shoots and roots) more than EDTA then Amn-nitrate treatment in any tested soil and amendment rate. Saifullah *et al.*, (2009) studied the effect of type and concentration of chelators (EDTA, DTPA, citric acid at 0–10 mmol kg^{-1} soil) on Pb accumulation in Sesbania Drummondii Cory in soils contaminated with a high concentration of Pb (7.5 g kg^{-1}). The effect of chelators on accumulation of Pb in shoots was found to be strongly concentration dependent. The highest uptake of Pb was found with EDTA application at 10 mmol kg^{-1} soil. EDTA was the most efficient chelator. Low EDTA rates have been reported to facilitate the breakdown of barriers to the uptake of metals by plants (Meers *et al.*, 2005b). High levels of EDTA application are detrimental or even lethal to plants because of high concentrations of free EDTA that could decrease the availability of essential nutrients (Wu *et al.*, 2004).

Chelate-assisted phyto-extraction has the potential to become an effective remediation approach for Pb-contaminated soils. Careful management of soils and the appropriate selection of plants and irrigation strategies are of paramount importance (Chen *et al.*, 2004), while the focus might need to shift towards the use of more degradable alternatives, thus effectively reducing the risks implied with this technology (Meers *et al.*, 2004). An overview of alternative soil amendments proposed for enhanced phytoextraction is provided by Meers *et al.*, (2008).

Table 5 showed the lead content in sunflower shoots as affected by chelators application rate. Data indicated that Pb content in sunflower of shoot was significantly increased from 98.1

mg kg^{-1} at zero citric acid to 104.2 mg kg^{-1} in shoot (LSD 2.09, $p<0.05$) at 20 mmol citric acid kg^{-1} soil and from 168.8 to 177.4 in root (LSD 2.41, $p<0.05$) in Mostorud soil. Lead content in sunflower of shoot was significantly increased from 61.3 mg kg^{-1} at zero citric acid to 68.1 mg kg^{-1} in shoot (LSD 2.09, $p<0.05$) at 20 mmol citric acid kg^{-1} soil and from 134.4 to 141.2 in root (LSD 2.41, $p<0.05$) in the El-Gabal El-Asfar soil. However, these values were still within the range found in contaminated plants (Kabata-Pendias and Pendias, 1992). Lead concentration in uncontaminated freshwater grown plants ranges between 6.3 and 9.9 mg kg^{-1} (Outridge and Noller, 1991) and the concentration toxic to plants is 27 mg kg^{-1} (Beckett and Davis, 1977). Results indicated that plants grown in Pb-contaminated areas usually contained higher concentrations than this threshold table 5. These results are in agreement with the findings of Evangelou *et al.*, (2006). Citric acid addition enhanced Pb uptake. With increasing additions of EDTA, plant biomass of rape (*Brassica napus L. var. napus*) and Indian mustard were decreased when the soluble Pb concentrations exceeded values of 70 and 150 mg Pb kg^{-1}, respectively (Greman *et al.*, 2001 and Blaylock *et al.*, 1997). After adding 1 g EDTA kg^{-1} to a soil containing 110 mg Pb kg^{-1}, perennial ryegrass plants stopped growing and died (Albasel and Cottenie, 1985).

Table 5 show that increasing the application rate of chelators resulted in an enhancement of Pb uptake and recovery from contaminated investigated soil by whole sunflower plant. Salt *et al.*, (1998) described that as much as 28% of all Pb of a contaminated soil (up to1600 mg Pb kg^{-1}) was removed by Indian mustard over one cropping season after an unspecified amount of EDTA was applied. The fraction of Pb desorbed by chelating agents was considerably varied between soils, when comparing different studies it is assumed that the soil concentration of soluble Pb should correlate with the Pb concentration in plants grown on these soils. Where sufficient data was provided, a positive relationship apparently existed between the Pb concentrations in the soil solution and in plant tissues (Changcun *et al.*, 2009).

Table 5. Lead content in sunflower shoots and roots (mg kg $^{-1}$) as affected by tested soil chelators (mmol kg $^{-1}$) in the investigated contaminated soils.

Treatment	Rate of application (mmol kg $^{-1}$)	Shoot		Root	
		Mostorud	EL-Gabal	Mostorud	EL-Gabal
Citric acid					
	0	98.1	61.3	168.8	134.4
	5	99.7	64.4	172.3	136.5
	10	101.7	66.8	174.2	139.8
	20	104.2	68.1	177.4	141.2
EDTA					
	0	98.1	61.3	168.8	134.4
	5	98.8	63.7	171.2	135.2
	10	100.4	65.2	173.2	137.2
	20	103.2	65.9	174.8	138.7
Amn- nitrate					
	0	98.1	61.3	168.8	134.4
	5	98.4	61.9	169.8	134.8
	10	99.5	62.8	171.0	135.2
	20	101.3	63.3	173.1	137.2
LSD $_{0.05}$					
S=Soil		12.11		1136	
A= Amendment		2.08		2.41	
R=Rate		11.21		10.22	
SxA		2.41		4.93	
SXR		4.11		3.25	
AXR		3.23		3.23	
SxAxR		10.01		11.21	

Table 6. Recovery percentage of lead removed from tested soils by sunflower (mg kg^{-1}) as affected by different rates of citric acid - EDTA and ammoniom nitrat (mmol kg^{-1}) application at the studied contaminated soils.

Treatment (mmol kg –1)	Pb -soil initial (mg kg-1)	Pb -soil final (mg kg-1)	Total- Pb uptake by whole plant (mg kg-1)	Pb - removal* by whole plant (%)	Pb -soil initial (mg kg-1)	Pb -soil final (mg kg-1)	Total- Pb uptake by whole plant (mg kg-1)	Pb - rmoval* by whole plant (%)
	Mostorud				EL- Gabal EL-Asfar			
Citric acid								
0	1612	1345.3	266.7	16.5	1052	856.3	195.7	18.6
5		1340.0	272.0	16.9		851.1	200.9	19.1
10		1336.1	275.9	17.1		845.4	206.6	19.6
20		1330.4	281.6	17.5		842.7	209.3	19.9
EDTA								
0	1612	1345.3	266.7	16.5	1052	856.3	195.7	18.6
5		1342.0	270.0	16.7		853.1	198.9	18.9
10		1338.4	273.6	17.1		849.6	202.4	19.2
20		1334.0	278.0	17.2		847.4	204.6	19.4
Amn - nitrate								
0	1612	1345.3	266.7	16.5	1052	856.3	195.7	18.6
5		1343.8	268.2	16.6		855.3	196.7	18.7
10		1342.7	269.3	16.7		854.0	198.0	18.8
20		1337.6	274.4	17.0		851.5	200.5	19.1

CONCLUSION

Plant dry matter production and metals accumulation were varied with contaminants concentration and species, chelator form and rate, and soil type. The highest metals accumulation was found in plants growing on clayey soil and the lowest was in plant growing on sandy soils. Metals accumulation and translocation to the shoots were significantly increased as application of citric acids. Addition of citric acid at 20 mmol kg^{-1} soil to clayey soil led to increasing Cd and Pb metals concentration in shoots several-fold of magnitude on the other hand, adding ammonium nitrate had a little effect on metals translocation to shoots. Citric acid was the most effective chelating agent in plant accumulation for Cd and Pb metals.

The concentrations of soluble heavy metals in the soil could be enhanced to attain high heavy metal removal rates by increasing the metal accumulation of plants. This could be achieved by adding certain chelating agents to the soil. However, enhanced chelating agents may cause unavoidable leaching of chelated metals down the soil profile which could lead to rapid leaching of these toxic metals to groundwater. The relationship between enhancing metal solubility in soils and plants, and feasible practices to minimize the risk of heavy metal leaching should be considered.

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تأثير بعض المواد المخلبية على القدرة الاستخلاصية لنبات عباد الشمس لكل من عنصرى الكادميوم والرصاص من الأراضي الملوثة

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تهدف هذه الدراسة الى تقييم تأثير بعض المواد المخلبية على زيادة صلاحية و انتقال العناصر الثقيلة من الأراضي الملوثة إلى نبات عباد الشمس. حيث أجريت الدراسة على نوعين من الأراضي (طينية ورملية) تروى بمصادر مختلفة من المياه الملوثة. و تم استخدام ثلاثة مواد مخلبية هي حامض الستريك و EDTA ونترات الأمونيوم وتم اضافتها بمعدلات متزايدة (صفر-٥-١٠-٢٠ ملليمول/كجم تربة). وقد أوضحت النتائج أنة يوجد تأثير واضح لنوع التربة على كمية المادة الجافة الناتجة لنبات عباد الشمس حيث كانت في الأراضي الطينية أكبر من الرملية. كما تأثرت كمية المادة الجافة أيضا بنسبة الأحماض العضوية المضافة. كما أن استخدام المواد المخلبية ادى إلى زيادة انتقال الكادميوم والرصاص في الجذر والساق إذا قورن بالكنترول . حيث كان معدل ٢٠ ملليمول للمحسنات الثلاثة ذات تأثير ملحوظ على زيادة انتقال الكادميوم والرصاص إلى الجذر والساق لنبات عباد الشمس. وكان حامض الستربك عند ٢٠ ملليمول أكثر المحسنات تأثيرا على زيادة استخلاص نبات عباد الشمس للكادميوم والرصاص وتركيزها في (الجذر والساق) مقارنة ب EDTA- ثم نترات الأمونيوم . وبالتالي يمكن استخدام نبات عباد الشمس كنبات فائق القدرة على تجميع العناصر الثقيلة من الأراضي الملوثة في أجزائه المختلفة (الجذر والساق) .

وعلى الرغم من أن استخدام بعض المواد المخلبية قد يشجع زيادة تركيز العناصر الثقيلة الذائبة فى التربة وبالتالي زيادة معدلات الإزاحة لهذه العناصر بواسطة النباتات الفائقة القدرة على تجميع هذه العناصر في أجزائها المختلفة ، إلا أن هذه المواد قد تؤدى إلى زيادة حركة وغسيل تلك المعادن السامة إلى اسفل القطاع الأرضي ثم إلى المياه الجوفية. لذا ينصح بضرورة دراسة العلاقة بين ذوباتية هذه المعادن فى الأرض و النبات وكذلك الطرق العملية التي يجب اتخاذها لتقليل مخاطر غسيل هذه العناصر.