EDTA-assisted Phytoextraction of Lead from Artificially Polluted Soil by Sunflower Plants

Ramadhan Omer H. Sulaivani, and Hassan A. M. Mezori

***Abstract*—**Phytoremediation of soil contaminated by heavy metals has got popularity worldwide, because of its advantages over other traditional remediation methods such as low costs, lesser effects on soil properties and microorganisms. This study was conducted under lath house conditions in Faculty of Agriculture and Forestry, University of Duhok, Iraq, using sunflower plants. Seeds of sunflower *(Helianthus annuus* vr. Sirena) were planted in plastic pots contained soil artificially polluted with concentrations of lead (0.0, 50, 100, 200, 400, 800, and 1200 mg. kg-1 soil) and treated with four levels of EDTA (0.0, 0.5, 1.0, and 2.0 g. kg-1 soil), two weeks before uprooting plants, lead concentration in plant tissues was determined by atomic absorption spectrophotometer.

The results indicated that the biomass of roots, stems, and leaves of sunflower was reduced by lead toxicity especially after application of EDTA; the inhibition of total biomass was 4.0, 20.0, 32.0 and 60.0 % when treated with (lead alone, 0.5, 1.0, and 2.0 g of EDTA. kg-1 soil) respectively compared with the control.

Accumulation of lead by plant increased by the increase of lead concentrations in the soil . Lead accumulation in the root of the plant was generally more than that in the stem and leaves. Lead accumulation was (37.54, 66.14, 75.40, and106.20 µg. g-1d. wt) in intact plant treated with (0.0, 0.5, 1.0, and 2.0 g. kg-1 soil) of EDTA respectively.

Generally the application of EDTA increased bioaccumulation and translocation factors and removed lead in tissues of sunflower; bioaccumulation and translocation factors were less than (1), removed lead by plants treated with (0.5 and 1.0 g of EDTA. kg-1 soil) was more than that removed by plants treated with (2.0 g of EDTA. kg-1 soil)

***Keywords*—** phytoextraction, phytoremediation, toxicity, bioaccumulation, translocation, sunflower, EDTA

I. Introduction

DURING the last decades a dramatic industrial development occurred in the world, this led to addition of huge quantities of different pollutants to the environment which significantly exceed those from natural sources [1] Heavy metals have a great concern and high risk to human health and the environment, due to the tendency to bioaccumulation and magnification in trophic levels [2]. Lead is considered as one of the most dangerous heavy metal in the environment [3]. Phytoremediation is a process of using plants to improve the degraded environments; by absorbing the metals and translocation them to above ground tissues, then to remove the harvested biomass from the site [4]. It is a cleanup technology for removing HM from the contaminated soils [5] Phytoremediation of heavy metals can be done by two strategies, either by hyperaccumulator plant [6] , [7] or by non-accumulator plants [4]. The success of phytoextraction of metals by plants depends on: (i) the bioavailability of heavy metals in the rooting zone (ii) the plant biomass, and (iii) heavy metals content in aerial parts [8]. Sunflower was one of the plants that have been proposed for phytoextraction of heavy metals [9], it showed high resistance to heavy metals toxicity [10]. And has the ability to extract high concentrations of toxic metals [11]. Lead has low solubility in the soil and high retention on soil particles, therefore the application of chalets such as Ethylene Diamine Tetra Acetic Acid (EDTA) has been proposed to increase the metal solubility and absorption by plant roots and translocation from roots to shoots. [12]. Using EDTA to enhance phytoextraction of heavy metals is an emerging technological approach for remediation of contaminated soils [8]. Bioaccumulation factor refers to the ability of plant to absorb heavy metals from the soil and accumulating them into its tissues [13]. Translocation factor (TF) is plants efficiency in translocation the accumulated heavy metals from roots to above-ground tissues. Several authors reported that EDTA enhanced the translocation of metals from roots to shoots. [14]. There are different sources of lead pollution in Duhok city [15], [16], and [17]. Large amounts of lead founded in soil and plants adjacent to roadway of Duhok city (Iraq) [18]. The present study aimed to evaluate the ability of sunflower plants to be used as phytoremedaitor of lead, and to study the role of EDTA for improving the phytoremediation of soil artificially polluted by lead.

II. Materials And Methods

The present study was conducted at the Faculty of Agriculture and Forestry, University of Duhok, Iraq, under lath house conditions. The soil was collected from the top 20 cm of soil profile from fields in February, 2011, soil and loam were air dried and sieved through a 2-mm sieve, mixed at ratio of (3soil:1loam).The soil was distributed in pot (6 kg/ pot), and artificially polluted with eight concentration of lead; (0.0, 50, 100, 200, 400, 800, and 1200 mg. kg-1 soil). Lead was prepared by dissolving analytical grade Pb $(NO_3)_2$ in (1250 ml) deionized distilled water. NH_4NO_3 was added to the pots to compensate the N from Pb $(NO_3)_2$, at rates of 463.56, 309.05, 154.52, 77.26, 38.63, 19.31 and 0 mg. kg-1soil, to the concentration of lead in pots (0, 50, 100, 200, 400, 800, and

Ramadhan Omer H. Sulaivani Faculty of Agriculture and Forestry, Depart. of forestry

Hassan A. M. Mezori Scientific Research Center, faculty of Science, University of Duhok / Duhok/ Iraq. Email: hasanmezori@uod.a).

1,200 mg. kg-1soil) respectively. The treated pots were watered by deionized distilled water and incubated for four weeks at room temperature to enable the added salt to reach a steady state before planting Ten seeds of sunflower (Helianthus annuus vr. Sirena) were planted in each pot On May 01, 2012, after germination seedlings were thinned to three /pot. EDTA was added on June 14, 2011. After two weeks of application of EDTA, sunflower plants were uprooted washed carefully, separated to roots, stems, and leaves, dried in an oven at (70 0C ± 2) for 72 hours, dry weight was recorded, and then grounded into fine powder by stainless grinder. The plant powder was digested by adding 10 ml of acid mixture (4/2 (V/V) (HNO3 / HClO4) to (0.5 g) of plant power in a 100 ml conical flask, according to the procedure of digestion used by [19], the contents were evaporated until the volume was reduced to about 3 to 5 ml, Finally the digested samples were diluted with deionized distilled water , completed to (50 ml) in a volumetric flask. Lead concentration was determined by (GBC) atomic absorption spectrophotometer. Biological accumulation factor (BAF) calculated according to the formula,BAF=(Pb plant)/(Pb soil), Pb plant is lead concentration (mg. kg−1 d. wt) in plant tissues. Pb soil is lead content (mg. kg−1) in soil. Translocation factor (TF), is defined as the ratio between the total element concentrations in the shoots and roots. TF=(Pb shoots)/(Pb roots), Pb shoots is lead concentration (µg. g−1 d. wt) in above ground tissues (stems or leaves), Pb roots is lead concentration (µg. g−1 d. wt) in roots. Removed lead calculated according to [20]. The factorial experimental in completely randomized block design (RCBD) was used for statistical analyses by using the Micro soft (SAS 2002). Analysis of variance (ANOVA), the differences between various treatments means were tested with Duncan Multiple Range test at 5% level.

III. The Results

Biomass of root, stem, and leaves of sunflower was decreased as lead content in the soil increased (tables, 1, 2, 3). No significant differences of root biomass was noticed between all concentrations of lead used and the control (Table 1), while when EDTA was added, significant differences were obtained when 2.0 g.kg-1 of EDTA was added.

TABLE I
EFFECT OF LEAD AND EDTA ON ROOTS BIOMASS (MG. PLANT-1) OF SUNFLOWER PLANT

lead	EDTA (g. kg-1 soil								
(mg.kg-1 soil)	0	Inhibition %	0.5	Inhibition %	1.0	Inhibition %	2.0	Inhibition %	Total mean of lead
0	307 a	---	291 a	5	282 a	8	158 b	48	259 a
50	306 a	0.1	288 a	6	277 a	10	150 b	51	255 a
100	301 a	2	281 a	8	269 a	12	138 b	55	247 ab
200	287 a	6	279 a	9	269 a	12	133 b	57	242 ab
400	282 a	8	273 a	11	258 a	16	131 b	57	236 ab
800	280 a	9	270 a	12	257 a	16	127 b	59	234 ab
1200	271 a	11	270 a	12	250 a	18	114 b	63	226 b
Total mean of EDTA	291 a	6	279 ab	9	266 b	13	136 c	56	243

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple range Test

Results of tables (2 and 3) indicated that the dry weight of stem and leaves reduced, and more reduction obtained when EDTA was added. The addition of EDTA significantly inhibits stems biomass when all concentrations of lead +EDTA were used. The leaves biomass was decreased but no significant differences were observed when all concentrations of lead alone and lead+0.5EDTA were used, while when (2.0 g. kg-1) of EDTA was used all the concentration differ significantly from the control.

Generally the reduction was in two directions, one with the lead increments in the soil, and the other with the increasing of EDTA concentrations added to the soil. All treatments of lead alone didn't differ significantly, while all the treatments of EDTA differ significantly when lead alone was used. EDTA reduced significantly the dry weight of sunflower when 2.0g of EDTA.kg-1was used.

TABLE II
EFFECT OF LEAD AND EDTA ON STEMS BIOMASS (MG. PLANT-1) OF SUNFLOWER PLANT

Lead (µg.kg-1 soil)	EDTA (g. kg-1 soil)								
	0	Inhibition %	0.5	Inhibition %	1.0	Inhibition %	2.0	Inhibition %	Total mean of lead
0	2515 [a]	--	1933 [b]	23	1613 [c-f]	36	958 [h]	62	1755 [a]
50	2502 [a]	1	1871 [bc]	26	1542 [d-g]	39	930 [h]	63	1711 [ab]
100	2444 [a]	3	1857 [bc]	26	1471 [efg]	42	861 [hi]	66	1658 [abc]
200	2406 [a]	4	1807 [bcd]	28	1422 [efg]	43	821 [hi]	67	1614 [bcd]
400	2391 [a]	5	1767 [bcd]	30	1368 [fg]	46	740 [hi]	71	1567 [cd]
800	2377 [a]	5	1766 [bcd]	30	1337 [g]	47	707 [hi]	72	1547 [cd]
1200	2369 [a]	6	1672 [b-e]	34	1328 [g]	47	601 [i]	76	1492 [d]
Total mean of lead	2429 [a]	4	1810 [b]	28	1440 [c]	43	803 [d]	68	1621

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple range Test

TABLE III
EFFECT OF LEAD AND EDTA ON LEAVES BIOMASS (MG.PLANT-1) OF SUNFLOWER PLANT

Lead (mg.kg-1 soil)	EDTA (g. kg-1 soil)								
	0	Inhibition %	0.5	Inhibition %	1.0	Inhibition %	2.0	Inhibition %	Total mean of lead
0	1267 [a]	---	1223 [ab]	2	1161 [b-d]	4	785 [e]	19	1109 [a]
50	1236 [a]	1	1203 [abc]	3	1101 [b-d]	7	784 [e]	19	1081 [ab]
100	1224 [ab]	2	1196 [abc]	3	1079 [b-d]	7	742 [e]	21	1060 [ab]
200	1206 [ab]	2	1184 [abc]	3	1071 [b-d]	8	680 [ef]	23	1035 [abc]
400	1197 [abc]	3	1184 [abc]	3	1031 [bcd]	9	655 [ef]	24	1017 [bc]
800	1184 [abc]	3	1179 [abc]	3	1004 [cd]	10	643 [ef]	25	1002 [bc]
1200	1167 [abc]	4	1107 [b-d]	6	970 [d]	12	540 [f]	29	946 [c]
Total mean of EDTA	1212 [a]	2.5	1182 [a]	3	1060 [b]	8	690 [c]	23	1036

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple range Test

Bioaccumulation of lead in the roots of sunflower plants was increased when lead concentration increased in the soil, and all the concentrations of lead differed significantly from the control except when 50 ppm of lead was used (table 4), addition of EDTA to lead concentrations, increased significantly bioaccumulation of lead in roots tissues; the EDTA levels enhanced lead extraction by roots.

Lead concentration in stems showed the same variation pattern as for lead concentration in roots (Table 5). The differences between control and all other treatments of lead alone and lead plus different concentrations of EDTA were significant, except when 50 ppm of lead was used. Addition of different concentrations of EDTA to with lead increased significantly bioaccumulation of lead.

Results of lead concentration in leaves of sunflower plant are presented in table (6). Lead accumulation in leaves of sunflower plants increased, the increasing was significant compared to the control when all concentrations of lead alone were used, except when 50 ppm of lead was used. Addition of different concentrations of EDTA enhanced significantly bioaccumulation of lead in the leaves, Total mean of all treatments differed significantly from the control and total means of EDTA differed significantly from each other.

TABLE IV
EFFECT OF LEAD AND EDTA ON LEAD BIOACCUMULATION (MG. G-1D.WT) IN ROOTS OF SUNFLOWER

Lead (mg.kg-1 soil)	EDTA (g. kg-1 soil) 0	0.5	1.0	2.0	Total mean of lead
0	16.86 ^{p}	24.94 ^{o}	30.60 ^{n}	31.38 ^{n}	25.95 g
50	19.96 ^{op}	33.08 ^{n}	35.94 ^{n}	74.10 ^{k}	40.77 ^{f}
100	32.14 ^{n}	47.48 ^{m}	56.50 ^{i}	111.74 ^{h}	61.97 ^{e}
200	57.32 ^{i}	89.02 ^{g}	71.10 ^{k}	163.08 ^{de}	95.13 d
400	81.58 ^{j}	116.38 ^{h}	116.56 ^{h}	167.44 ^{cd}	120.49 c
800	127.80 ^{g}	158.52 ^{e}	167.24 ^{cd}	172.82 ^{bc}	156.60 ^{b}
1200	137.66 ^{f}	165.74 ^{d}	174.62 ^{b}	195.02 ^{a}	168.26 ^{a}
Total mean of EDTA	67.62 ^{d}	90.74 ^{c}	93.22 $_{b}$	130.80 ^{a}	95.59

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple ranges Test

TABLE V
EFFECT OF LEAD AND EDTA ON LEAD BIOACCUMULATION (MG. G-1 D. WT) IN STEM OF SUNFLOWER

Lead (mg.kg-1 soil)	EDTA (g. kg-1 soil) 0	0.5	1.0	2.0	Total mean of lead
0	8.34 ^{p}	15.66 ^{no}	18.44 ^{n}	20.26 ^{n}	15.68 ^{g}
50	12.82 ^{op}	20.88 ^{n}	33.24 ^{kl}	40.32 ^{ij}	26.82 ^{f}
100	18.10 ^{n}	30.10 ^{lm}	39.78 ^{ij}	68.82 ^{ef}	39.20 ^{e}
200	17.42 ^{no}	41.60 ^{i}	51.24 ^{h}	74.46 ^{d}	46.18 ^{d}
400	28.08 ^{m}	52.02 ^{h}	64.62 ^{fg}	85.66 ^{c}	57.60 ^{c}
800	35.54 ^{jk}	63.36 ^{g}	72.92 ^{de}	92.30 ^{b}	66.03 ^{b}
1200	37.60 ^{ijk}	63.36 ^{g}	76.20 ^{d}	97.49 ^{a}	68.66 ^{a}
Total mean of EDTA	22.56 ^{d}	41.00 ^{c}	50.92 ^{b}	68.47 ^{a}	45.74

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple range Test.

Lead accumulation by intact plant biomass of sunflower plants in table (7) indicated that bioaccumulation of lead in sunflower tissues increased when both lead and EDTA concentrations increased, all treatments differed significantly from the control except when 50 ppm of lead were used.

Significantly increasing of lead accumulation in intact plants obtained when all concentration of EDTA added.

TABLE VI
EFFECT OF LEAD AND EDTA ON LEAD BIOACCUMULATION (MG.G-1D WT) IN LEAVES OF SUNFLOWER PLANT

Lead (mg.kg^{-1} soil)	EDTA (g. kg-1 soil) 0	0.5	1.0	2.0	Total mean of lead
0	8.70 ^{n}	13.16 ^{mn}	12.66 ^{mn}	17.32 ^{lm}	12.96 ^{g}
50	14.00 ^{mn}	32.88 ^{k}	35.20 ^{k}	110.64 ^{f}	48.18 ^{f}
100	20.28 ^{l}	47.42 ^{j}	48.74 ^{j}	128.42 ^{cd}	60.77 ^{e}
200	20.42 ^{l}	57.18 ^{i}	92.68 ^{g}	130.90 ^{cd}	75.29 ^{d}
400	30.36 ^{k}	70.12 ^{h}	117.92 ^{e}	148.34 ^{a}	92.19 ^{c}
800	30.92 ^{k}	111.92 ^{f}	136.82 ^{b}	150.42 ^{a}	107.52 ^{b}
1200	32.60 ^{k}	134.48 ^{bc}	130.44 ^{cd}	149.04 ^{a}	111.64 ^{a}
Total Mean of EDTA	22.47 ^{d}	66.73 ^{c}	82.10 ^{b}	119.01 ^{a}	72.65

Means, with same letters, are not significantly different at 5% level based onDuncan's multiple range Test

TABLE VII
EFFECT OF LEAD AND EDTA ON LEAD BIOACCUMULATION (MG. G-1D. WT) ININTACT SUNFLOWER PLANTS

Lead (mg.kg-1 soil)	EDTA (g. kg-1 soil) 0	0.5	1.0	2.0	Total mean of lead
0	11.30 ^{q}	17.92 ^{opq}	20.57 ^{op}	23.05 ^{nop}	18.21 ^{g}
50	15.53 ^{pq}	28.95 ^{mn}	34.79 ^{lm}	75.02 ^{gh}	38.57 ^{f}
100	23.51 ^{no}	41.67 ^{kl}	48.34 ^{k}	102.99 ^{f}	54.13 e
200	31.72 ^{m}	62.53 ^{j}	71.67 ^{hi}	122.81 ^{d}	72.19 ^{d}
400	46.67 ^{k}	79.44 ^{g}	99.70 ^{f}	133.81 ^{bc}	89.91 ^{c}
800	64.75 ^{ij}	111.27 ^{e}	125.66	138.51 ^{b}	110.05 ^{b}
1200	69.29 ^{hij}	121.19 ^{d}	127.09 ^{cd}	147.18 ^{a}	116.19 ^{a}
Total mean of EDTA	37.54 ^{d}	66.14 ^{c}	75.40 ^{b}	106.20 ^{a}	71.32

Means, with same letters, are not significantly different at 5% level based on Duncan's multiple range Test.

Bioaccumulation factor (Table 8).of lead in roots, stems and leaves of sunflower plants increased with the increments in EDTA levels added to the soil. All concentrations of EDTA increased BAF of leaves over stems, compared with plants received only lead. Higher BAF was in the plants treated with lead+2.0EDTA. Bioaccumulation factor of roots was higher than both stems and leaves.

Translocation factor of lead from roots to stems increased with addition of 0.5 and 1.0 g of EDTA. Kg-1 soil, then decreased with 2g of EDTA (table 8). TF of lead in the leaves was greater than the stems.

TABLE VIII
EFFECT OF LEAD AND EDTA ON BIOACCUMULATION FACTOR, TRANSLOCATION FACTOR, AND REMOVED LEAD BY SUNFLOWER PLANTS

Tested parameters	Treatments	Plant parts			Means
		Roots	Stems	Leaves	
Bioaccumulation factor	Lead	0.20	0.09	0.09	0.13
	Lead+0.5 EDTA	0.37	0.21	0.27	0.28
	Lead+1.0 EDTA	0.40	0.27	0.31	0.33
	Lead+2.0 EDTA	0.61	0.35	0.60	0.52
	Mean of plant parts	0.40	0.23	0.32	
	Intact plant		0.31		
Translocation factor		Roots	Stems	Leaves	Means
	Lead	–	0.42	0.44	0.43
	Lead+0.5 EDTA	–	0.52	0.76	0.64
	Lead+1.0 EDTA	---	0.64	0.89	0.77
	Lead+2.0 EDTA	---	0.55	0.94	0.74
	Mean of plant parts	–	0.53	0.76	
	Intact plant		0.65		
Removed lead (µg. plant-1)		Roots	Stems	Leaves	Summation
	Lead	19	54	27	100
	Lead+0.5 EDTA	25	73	78	175
	Lead+1.0 EDTA	24	71	84	180
	Lead+2.0 EDTA	17	52	80	149
	Summation	85	251	269	
	Intact plant		605		

The amount of lead removed by sunflower parts ranged from (17 µg. plant-1) in roots of plants treated with lead+2.0EDTA to (84 µg. plant-1) in leaves of plants treated with (lead+1.0EDTA). Addition of (0.5 and 1.0 g of EDTA) increased removed lead by roots, stems, and whole plant, while the removed lead decreased when 2.0 g of EDTA was added. Removed lead by roots in treatment (0.5+EDTA) was more than (1.0+EDTA and 2.0 +EDTA), while in leaves the removed lead decreased with treatments (2.0+EDTA). Leaves removed more lead than stems and roots.

IV. DISCUSSION

Lead is one of the widely distributed heavy metals that polluted soils and plants. It remains very long period in the soil, because it is not biodegradable [21]. Heavy metals such as lead have get much environmental concern because they tend to bioaccumulate in the food chain and are toxic to humans, animals, and plants [22].

The dry biomass of sunflower decreased as lead, or EDTA in the soil increased, (tables 1- 3). It was clear that the higher reduction in biomass was obtained when (2 g EDTA. Kg-1soil) was used. This reduction can be attributed to the toxic effects of EDTA [23] and lead in the soil. The biomass reduction was in accordance with results obtained by other researchers [24] and [25]. The reduction of biomass can be explained either by the interference with physiological and biochemical processes [26], or by reducing the absorption and translocation of nutrients in plants [25]."

Phytoremediation is an attractive remediation technology for removing heavy metals from the soil. Some plants species have the ability to uptake, tolerate and even hyperaccumulate HM from soil. The accumulation of lead in roots, stems, leaves, and intact plant of sunflower plants was dose dependent and accumulated more lead in their root compared to stems and leaves (tables 4 - 7), these findings were supported by results of different authors [14] , [27].

The effect of EDTA on enhancing lead accumulation by roots, stems, leaves, and intact plant of sunflower was very clear, 0.5 g of EDTA increased lead accumulation in sunflower plants about (2.3 folds) compared with the same treatments of lead without EDTA. This can be explained by damaging the plasma membranes of plant cells, which disrupted the mechanism of heavy metals transportation to the roots and consequently increased the amounts of chelated-metal complex absorbed by the plant [28]. EDTA increases the availability of lead in soil. The concentration of lead in roots, stems, leaves, and intact plant of sunflower were confirmed with the results of [29].

Extraction of lead by sunflower plant increased as lead added to the soil increased. This state was enhanced with addition of EDTA. The concentration of lead in all plant parts increased with the concentration of chelator applied to the soil.

Dramatic differences in lead concentrations noticed between treatments having no EDTA and those with 2.0 g. kg-1 EDTA, especially in the leaves. These results are supported by findings of [30].

Bioaccumulation factor (BAF) in roots, stem, and leave of sunflower (Table 8) were increased when lead concentration alone or lead plus EDTA was applied. Generally BAF of roots was more than both stems and leaves. Bioaccumulation factor of sunflower plants increased by about 2.2, 2.5, and 4 folds in plants treated by 0.5, 1.0, and 2.0 g EDTA kg-1 soil respectively . BAF in stems of sunflower was more or equal to leaves plant treated with lead alone, but EDTA increased BAF in leaves of the same plant compared with stems. This is due to the EDTA increased the dissolved lead in the soil solution [31].

Translocation factor provides an indication of metal transportation in the plants. The ability of plants to absorbed

and transport heavy metals to the shoots are very important in phytoremediation. The TF of lead in stems and leaves of sunflower (Table 8), was less than one, which indicated that the amount of retained lead by roots was more than that transported to the shoots. Translocation factor of sunflower plants increased by about 1.5, 1.8, and 1.7 folds in plants treated with 0.5, 1.0, and 2.0 g EDTA. Kg-1 soil respectively, this may be due to the enhancement of the translocation of lead from roots to shoots [32].

Lead remove by sunflower plants increased by about 1.8, 1.8 and 1.5 folds in plants treated by 0.5, 1.0, and 2.0 g EDTA. Kg-1 soil respectively (Table 8) . However 2.0 g of EDTA enhanced lead accumulation by sunflower plants, but on the other hand it reduced dry weight of sunflower plants therefore the plants treated with 0.5 and 1.0 g of EDTA removed more lead as their biomass did not reduce so much compared with those treated with 2.0 g EDTA .kg-1 soil. From these results it could be concluded that sunflower plant (i) can be considered as a moderate accumulator plant for lead. (ii) cannot be used for animal feeding as lead exceeded European standards [33]. (iii) EDTA had positive effect on phytoextraction and translocation of leads.

REFERENCES

[1] S. Clemens. "Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants". Biochimie, 88: P. 1707–1719. 2006 http://dx.doi.org/10.1016/j.biochi.2006.07.003

[2] S. A. Odoemelam, and R. A. Ukpe. "Heavy meal decontamination of polluted soils using Bryophyllum pinnatum". African Journal of Biotechnology, 7 (23): P. 4301-4303. 2008

[3] M. Borišev, S. Pajević, N. Nikolić, A. Pilipović, B. Krstić, S. Orlović. "Phytoextraction of Cd, Ni, and Pb Using Four Willow Clones (Salix spp.)". Polish J. of Environ. Stud. Vol. 18, (4): P. 553-561. 2009

[4] E. Saifullah, M. Meers, P. Qadir, de Caritat, F. M. G. Tack, G. D. Laing, and M. H. Zia. "EDTA-assisted Pb phytoextraction". Chemosphere, 74: P. 1279–1291. 2009 http://dx.doi.org/10.1016/j.chemosphere.2008.11.007

[5] W. Hong-qi, L. Si-jin, L. Hua, and Y. Zhi-hua. "EDTA-enhanced phytoremediation of lead contaminated soil by Bidens". maximowicziana. Journal of Environmental Sciences 19: P. 1496–1499. 2007 http://dx.doi.org/10.1016/S1001-0742(07)60243-5

[6] R. R. Brooks. "Plants that Hyperaccumulate Heavy Metals. CAB International, Wallingford In: R. H. Groves. 1998. Book Reviews. Annals of Botany, 82: P. 267-271. 1998

[7] J. K. Adesodun, M. O. Atayese, T. A. Agbaje; B. A. Osadiaye, O. F. Mafe, and A. A. Soretire. "Phytoremediation Potentials of Sunflowers (Tithonia diversifolia and Helianthus annuus) for Metals in Soils Contaminated with Zinc and Lead Nitrates". Water Air Soil Pollut., 207: P. 195–201. 2001 http://dx.doi.org/10.1007/s11270-009-0128-3

[8] M. Komárek, P. Tlustoš, J. Száková, V. Chrastný, V. Ettler. "The use of maize and poplar in chelant-enhanced phytoextraction of lead from contaminated agricultural soils". Chemosphere, 67: P. 640–651. 2007 http://dx.doi.org/10.1016/j.chemosphere.2006.11.010

[9] H. Chen, and T. Cutright. "EDTA and HEDTA effects on Cd, Cr, and Ni uptake by Helianthus annuus". Chemosphere, 45: p. 21–28. 2001 http://dx.doi.org/10.1016/S0045-6535(01)00031-5

[10] U. Schmidt. "Enhancing Phytoextraction: The Effect of Chemical Soil Manipulation on Mobility, Plant Accumulation, and Leaching of Heavy Metals". J. Environ. Qual., 32: P.1939–1954. 2003 http://dx.doi.org/10.2134/jeq2003.1939

[11] M. Solhi, H. Shareatmadari and M. A. Hajabbasi "Lead and zinc extraction potential of two common crop plants, Helianthus annuus and Brassica napus". Water, Air, and Soil Pollution, 167: P. 59–71. 2005 http://dx.doi.org/10.1007/s11270-005-8089-7

[12] M. B. Gabos, C. A. Abreu, and A. R. Coscione. "Edta assisted phytorremediation of a Pb contaminated soil: metal leaching and uptake by jack beans". Sci. Agric. 66(4): P. 506-514. 2009 http://dx.doi.org/10.1590/S0103-90162009000400012

[13] H. Ali, M. Naseer, and M. A. Sajad. "Phytoremediation of heavy metals by Trifolium alexandrine". International Journal of Environmental Sciences, 2 (3): P. 1459 – 1469. 201.

[14] M. L. Lone, Z. He, P. J. Stoffella, and X. Yang. "Phytoremediation of heavy metal polluted soils and water: Progresses and perspectives". J Zhejiang Univ Sci B, 9(3): P. 210-220. 2008 http://dx.doi.org/10.1631/jzus.B0710633

[15] R. O. H. Sulaivany, and H. A. M. Mezori. "Heavy metals concentration in selected vegetables grown in Dohuk city, Kurdistan region, Iraq". Safety and Security Engineering II, WIT Transaction on the Built Environment, Vol 94: 255 – 265. 2007

[16] R. O. Hussain. "Lead concentration in wheat and soil adjacent to Zakho-Semel roadway in Duhok city-Kurdistan region, Iraq". J. Duhok Univ., Vol. 12, (1): P. 102 – 108. 2009

[17] R. O. Hussain, and H. A. Mezori. "Heavy metals concentration in some stone fruit plants grown in Duhok city, Kurdistan Region, IRAQ". J. Duhok Univ., Vol. 12, (2). 2009

[18] M. B. Hashim, and M. A. Sultan. "Using remote sensing data and GIS to evaluate air pollution and their relationship with land cover and land use in Baghdad city". Iranian J. of Earth Sci., 2: P. 20-24. 2010.

[19] H. Tandon. "Methods of analysis of soils, plants, water and fertilizers. Fertilizers Development and Consultation, New Delhi India, p.144. 1999

[20] B. E. Pivetz. Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites. Office of Solid Waste and Emergency Response, US EPA, Washington, D.C. United States Environmental Protection Agency. EPA /540/S-01/500. 2001

[21] B. V. Tangahu, S. R. Sheikh, H. Abdullah, M. Basri, N. A. Idris, and M. Mukhlisin. (2011). "A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants through Phytoremediation". International Journal of Chemical Engineering: P. 1-31. 2011 http://dx.doi.org/10.1155/2011/939161

[22] I.Velcheva, S. Petrova,V. Dabeva, and D. Georgiev. "Eco-physiological Study on the Influence of Contaminated Waters from the Topolnitza River Catchment Area on Some Crops". Ecologia Balkanica, 4(2): P. 33-41. 2012

[23] A. L. Epstein , C. D. Gussman, M. J. Blaylock, U. Yermiyahu, J. W. Huang, Y. Kapulnik, and C. S. Orser "EDTA and Pb-EDTA accumulation in Brassica juncea grown in Pb-amended soil". Plant Soil, 208: P. 87–94. 1999 http://dx.doi.org/10.1023/A:1004539027990

[24] S. Mukhtar, H. Nawaz Bhatti, M. Khalid, M. Anwar Ulhaq and S. M. Shahzad. "Potential of sunflower (Helianthus annuus L.) for phytoremediation of nickel (Ni) and lead (Pb) contaminated water". Pak. J. Bot., 42(6):P. 4017-4026. 2010

[25] S. Pinho, and B. Ladeiro. "Phytotoxicity by Lead as Heavy Metal Focus on Oxidative Stress". Review Article. Journal of Botany, Article ID 369572: P. 1-10. 2012.

[26] S. Mukhopadhyay, and S. K. Maiti. "Phytoremediation of metal Mine waste". Applied Ecology and Environmental Research, 8(3): P. 207-222 2010

[27] C. H. Anderson, A. Deram, D. Petit, R. R. Brooks, R. Stewart, and R. Simcock. "Induced hyperaccumulation: metal movement and problems". Boca Raton: Lewis: P. 63–79. 2010

[28] A. Wallace, E. M. Romney, J. W. Cha, S. M. Soufi, and F. M. Chaudhry. "Nickel phytotoxicity in relationship to soil pH manipulation and chelating agents". Commum Soil Sci Plant Anal, 8: P. 757–764. 1977 http://dx.doi.org/10.1080/00103627709366770

[29] P. Madejón, J. M. Murillo, T. Maranñón, F. Cabrera, and M. A. Soriano. "Trace element and nutrient accumulation in sunflower plants two years after the Aznalco´llar mine spill". The Science of the Total Environment, 307: P. 239–257. 2003 http://dx.doi.org/10.1016/S0048-9697(02)00609-5

[30] F. Hadi, A. Bano, and M. P. Fuller. "The improved phytoextraction of lead (Pb) and the growth of maize (Zea mays L.): the role of plant growth regulators (GA3 and IAA) and EDTA alone and in combinations". Chemosphere, 80: p. 457–462. 2010

http://dx.doi.org/10.1016/j.chemosphere.2010.04.020

[31] Z. Shen, X. Li, C. Wang, H. Chen, and H. Chua. "Lead Phytoextraction from Contaminated Soil with High-Biomass Plant Species". J. Environ. Qual., 31: P. 1893–1900. 2002
http://dx.doi.org/10.2134/jeq2002.1893

[32] S. Kim, and I. Lee. 'Comparison of the ability of organic acids and EDTA to enhance the phytoextraction of metals from a multi-metal contaminated soil". Bull Environ Contam Toxicol, 84: P. 255–259. 2010
http://dx.doi.org/10.1007/s00128-009-9888-0

[33] E. Meers, S. Van Slycken, K. Adriaensen, A. Ruttens, J. Vangronsveld, G. Du Laing, N. Witters, T. Thewys, and F.M.G. Tack. "The use of bio-energy crops (Zea mays) for 'phytoattenuation' of heavy metals on moderately contaminated soils". A field experiment. Chemosphere, 78: P. 35–41. 2010.
http://dx.doi.org/10.1016/j.chemosphere.2009.08.015