Bull. Fac. Agric., Cairo Univ., 55
(2004): 661-672.

STUDIES ON SOME HYPERACCUMULATOR PLANTS IN EGYPT

(Received :22.2.2004)

By
M. M. Kamel and H. A. Khater

Department of Soil Sciences, Faculty of Agriculture, Cairo University, Giza, Egypt.

ABSTRACT

A great number of plant species was collected from different contaminated soils in Egypt. The soils had been contaminated with heavy metals by industrial activity or the disposal of sewage sludge to land. The heavy metals zinc, copper, nickel and lead contents of the plant species have been determined. Some of the tested plant species were reviewed as hyperaccumulator plants. The hyperaccumulator species growing in areas contaminated with metals contained maximum amounts of Zn (15102 µg/g dry weight), Cu (3039 µg/g dry weight), Ni (7336 µg/g dry weight) and Pb (2532 µg/g dry weight). The obtained results indicated that Torpedograss is considered as Zn and Cu-accumulator, while Johnsongrass, Giant Red as Pb-accumulators and Perennial grass as Ni- accumulator in the tested soils. These results showed that any of these hyperaccumulator plants can be used to remediate Zn, ,Cu, Ni and Pb polluted soils.

Key words: *heavy metal, hyperaccumulator, polluted soil, remediation.*

1. INTRODUCTION

The area of land contaminated with heavy metals has increased during the last century due to mining, use of agricultural chemicals and other industrial activities.

The term hyperaccumulator has become to mean a plant capable of taking up concentrations of trace metals approximately 100 times greater than normal species (Baker and Brooks, 1989). Hyperaccumulator species are defined as those whose leaves contain >100 mg Cd kg^{-1}, 1000 mg Ni and Cu kg^{-1}, or 10000 mg Zn and Mn kg^{-1} (dry weight) when grown in metal-rich soils (Baker and Brooks, 1989; Baker *et al.*, 1994a). Possibly, hyperaccumulator plants have a higher requirement for metals such as Zn, which is essential micronutrients, and show a positive response to increased soil or solution concentrations of these elements (Hajar, 1987).

The distribution of metallophytes such as *T.caerulesens* has been studied in relation to heavy metal polluted soils. *T.caerulesens* was found to colonise areas with high Cd, Cu, Pb and Zn present in soils due to historical mining activity and the subsequent contamination of top soil with mine spoil rich in heavy metals (Baker and Proctor, 1990). This ability to grow in soils polluted with heavy metals, coupled with hyperaccumulating heavy metals in the shoot material has been recognized as a potential technique to decontaminate polluted soils (Baker *et al.*, 1994a,b).

Little literature was found with respect to hyperaccumulator plants grown on soils of Egypt. However, (Kamel, 1999) used *Barnyard Grass* plant to study its ability to remove Pb and Cd from the polluted soils. The results showed that the amounts of Pb and Cd removed by the plants represent 50% of the total content of these elements in the studied soils.

The present study includes a survey of a great number of plant species in Egypt with respect to their ability to accumulate heavy metals in their tissues, and the possbile use of these plants as hyperaccumulators to remediate heavy metals polluted soils.

2. MATERIALS AND METHODS

Fifty shoot plant samples were collected from different polluted soils and open drain banks in Egypt. The plants rinsed once with dilute HCl and twice with distilled water, dried in an areated oven at 70°C to constant weights, ground in porcelain mortar, and proseved for analyses. One-half gram sample plant material was digested using concentrated H_2SO_4 & $HClO_4$. The digestate was filtered and raised to 50 ml in a volumetric flask.

Soil samples were collected from the same locations of the plant samples. The collected soil samples were air dried, crushed with a wooden, sieved to pass through a 2 mm sieve and preserved for analysis.

Heavy metals were extracted by DTPA method (Lindsay and Norvell, 1978).Both soil extracts and plant digestates were analyzed for Zn, Cu, Ni and Pb using atomic absorption (Tables 1 and 2).

Table (1): Heavy metal concentrations (µg/g soil) in the studied soils.

No.	Location	Source of pollution	Zn	Cu	Ni	Pb
1	Bahr El Baqer	D	13.4	4.8	2.0	6.0
2	Bahr El Baqer	D	35.2	14.4	5.8	16.6
3	Ismaailia	D	20.2	8.8	1.6	5.4
4	El – Tebin	I	11.8	24..2	1.8	21.8
5	Helwan	I	19.8	7.8	3.2	31.4
6	El – Saf	I	2.6	3.6	2.8	9.3
7	Ain Helwan	I	3.4	6.4	7.6	6.8
8	Mostord	I	24.6	5.9	2.6	9.6
9	Shubra el Khimah	I	2.6	9.2	1.4	7.0

D=Domestic wastes I= Industrial wastes

3. RESULTS AND DISCUSSION

Table (2) shows the plant species, their english & arabic names and the concentrations of Zn, Cu, Ni and Pb in the plants and associated soil samples.

Table (2) also shows that the different plant species had different abilities to absorb and accumulate heavy metals. The concentrations of the studied heavy metals in the plants varied widely and ranged from 26-15102 µg/g for Zn, 6-3039 µg/g for Cu, 15-7376 µg/g for Ni and 4-2532 µg/g for Pb. The Zn contents of 17 plant samples lies within the agronomy normal concentration range (27-150 µg/g), whereas three plant samples lie within agronomy excessive range (150-400 µg/g). On the other hand, the concentration of Zn in the remaining plants (30 samples) varied widely and ranged between

Table (2): Concentrations of Zn, Cu, Ni and Pb in the plants (P) and associated soil samples (S).

No.	Species	English name	Arabic name	Heavy metal concentration (µg / g) Zn		Cu		Ni		Pb	
				P	S	P	S	P	S	P	S
Gramineae											
1	*Sorghum virgatum (Hack) stapf.*	Johnsongrass	جراوة	15102	35.2	1920	14.4	984	5.8	2532	16.6
2	*Sorghum virgatum (Hack) stapf.*	Johnsongrass	جراوة	11320	24.6	902	5.9	601	2.6	1991	9.6
3	*Sorghum virgatum (Hack) stapf.*	Johnsongrass	جراوة	11270	20.2	1190	8.8	414	1.6	1031	5.4
4	*Arundo donax L.*	Giant reed	غاب	9927	35.2	3039	14.4	912	5.8	1839	16.6
5	*Arundo donax L.*	Giant reed	غاب	7112	20.2	1991	8.8	502	1.6	1018	5.4
6	*Arundo donax L.*	Giant reed	غاب	6762	24.6	1106	5.9	722	2.6	1626	9.6
7	*Panicum repens L.*	Torpedograss	قصيبة	4531	4.8	2606	4.8	64	2.0	901	6.0
8	*Echinnochloa stagninum (Relz)Beauv.*	Barnyardgrass	نسيلة	3112	35.2	1406	14.4	2668	5.8	1003	16.6
9	*Echinnochloa stagninum (Relz)Beauv.*	Barnyardgrass	نسيلة	1191	19.8	786	7.8	1192	3.2	1016	31.4
10	*Eleusine indica (L.) Gaertn*	Goosegrass	نجيلة حمرا	729	2.6	16	3.6	42	2.8	32	9.3
11	*Eragrostis cilianensis All*	Stinkgrass(Lovegrass)	خافور	706	13.4	17	4.8	603	2.0	19	6.0
12	*Paspalum paspaloides (Michx) scribn*	Knotgrass	نجيل مداد	602	11.8	333	24.2	27	1.8	359	21.8
13	*Setaria verticillata (L.) Beauv.*	Bristly Foxtail	دفرة	117	11.8	918	6.4	33	7.6	76	6.8
14	*Lolium perenne L.*	Perennial Ryegrass	جاذون	112	2.6	302	9.2	400	1.4	20	7.0
15	*Dichanthium annulatum (Forssk) stapf*	Perennial grass	نجيل فارس	76	3.4	8	6.4	7376	7.6	1032	6.8
16	*Setaria glauca L. Beauv.*	Yellow Foxtail	ديل القط	73	11.8	212	24.2	91	1.8	1080	21.8
17	*Setaria glauca L. Beauv.*	Yellow Foxtail	ديل القط	42	19.8	17	7.8	116	3.2	1482	31.4
18	*Setaria viridis L. Beauv.*	Green Foxtail	ديل الفار	820	35.2	469	14.4	6102	5.8	1290	16.6
19	*Setaria viridis L. Beauv.*	Green Foxtail	ديل الفار	129	11.8	27	24.2	1462	1.8	1103	21.8

Table (2): Cont.

No.	Species	English name	Arabic name	Heavy metal concentration (µg / g) Zn		Cu		Ni		Pb	
				P	S	P	S	P	S	P	S
Compositae											
20	*Centaurea calcitrapa L.*	Purple Starthistle	شوك	8974	19.8	102	7.8	301	3.2	1151	31.4
21	*Xanthium brasilicum Vellozo*	Cocklebur	شبيط	1232	3.4	718	6.4	37	7.6	64	6.8
22	*Conyza dioscoridis (L.) Desf.*	Fleabane	برنوف	1181	35.2	1191	14.4	1870	5.8	1100	16.6
23	*Conyza dioscoridis (L.) Desf.*	Fleabane	برنوف	816	11.8	1206	24.2	932	1.8	1145	21.8
24	*Silybum marianum (L.) Greath.*	Milk Thistle	شوك الجمل	1127.	35.2	316	14.4	1694	5.8	32	16.6
25	*Conyza aegyptiace (L.) Ait.*	Fleabane	نشاش الدبان	865	2.6	1114	9.2	1041	1.4	994	7.0
26	*Conyza linifolia (Wld) Tach.*	Fleabane	حشيشة الجبل	770	2.6	1023	9.2	733	1.4	976	7.0
27	*Senecio vulgaris L.*	Common Groundsel	مرير	63	3.4	132	6.4	617	7.6	62	6.8
28	*Bidens bipinnata L.*	Spnish Needles	خربوش القنفد	27	3.4	10	6.4	1124	7.6	4	6.8
29	*Ageratum conyzoides L.*	Tropic Ageratum	برجمان	26	3.4	612	6.4	703	7.6	42	6.8
Cyperaceae											
30	*Cyperus longus L.*	Nutsedge	السعد	1976	20.2	814	8.8	12	1.6	326	5.4
31	*Cyperus alopecuroides Rottb*	Samar Halow	سمار حلو	156	2.6	1063	3.6	706	2.8	1001	9.3
32	*Cyperus alopecuroides Rottb*	Samar Halow	سمار حلو	122	2.6	1679	9.2	509	1.4	926	7.0
33	*Cyperus difformis L.*	Smallflower	عجيرة	92	3.4	101	6.4	881	7.6	11	6.8
Chenopodiaceae											
34	*Chenopodium album L.*	Common Lambsquarters	منتنة	1946	13.4	12	4.8	1021	2.0	1132	6.0
35	*Rumex dentatus L.*	Dock (Sorrel)	الحميض	123	35.2	13	14.4	611	5.8	96	16.6
36	*Rumex dentatus L.*	Dock (Sorrel)	الحميض	36	2.6	12	3.6	332	2.8	23	9.3
37	*Beta vuligaris L.*	Wild Beet	سلق برى	46	3.4	6	6.4	16	5.8	1042	6.8

Table (2): Cont.

No.	Species	English name	Arabic name	Heavy metal concentration (µg / g)							
				Zn		Cu		Ni		Pb	
				P	S	P	S	P	S	P	S
Malvaceae											
38	*Malva pavi flora L.*	Chesseweed	خبيزة شيطانى	5023	35.2	119	14.4	66	5.8	956	16.6
39	*Malva pavi flora L.*	Chesseweed	خبيزة شيطانى	4220	20.2	109	8.8	23	1.6	223	5.4
Typhaceae											
40	*Typha elephantina Roxb.*	Common Cattail	ديس	1762	11.8	1610	24.2	332	1.8	1962	21.8
41	*Typha elephantina Roxb.*	Common Cattail	ديس	1426	13.4	501	4.8	406	2.0	795	6.0
Juncaceae											
42	*Juncus rigidus C.A.Mey.*	Juncus	-	767	11.8	3012	24.2	513	1.8	1291	21.8
43	*Juncus rigidus C.A.Mey*	Juncus	-	417	35.2	1733	14.4	920	5.8	1070	16.6
Portulacaceae											
44	*Portulaca oleracea L.*	Common Purslane	رجلة	7160	13.4	232	4.8	36	2.0	1019	6.0
Oxalidaceae											
45	*Oxalis Corniculata L.*	Creeping Woodsorrel	حميض	986	2.6	190	3.6	56	2.8	29	9.3
Amaranthaceae											
46	*Amaranthus ascendens Lois.*	Livid Amaranth	عرف الديك	337	24.6	1206	5.9	762	2.6	760	9.6
Euphorbiaceae											
47	*Euphorbia peplus L.*	Petty Spurge	اللبينة	212	35.2	10	14.4	1699	5.8	32	16.6
Solanaceae											
48	*Solanum nigrum L.*	Black Nightshade	عنب الديب	106	19.8	8	7.8	1012	3.2	1101	31.4
Leguminosae											
49	*Alhagi maurorum Medic.*	Thorn	العاقول	56	3.4	37	24.2	1186	1.8	25	21.8
Convolvulaceae											
50	*Convulvulus arvensis L.*	Field Bindweed	عليق	52	11.8	1912	24.2	15	1.8	32	16.6

400-15102 µg/g, the concentrations of Zn in these plants are being much higher than the agronomy tolerable range (300 µg/g). Zinc levels above 1000 µg/g is seen to be common in these plants. High concentrations were found in some of these plants (4000-15102 µg/g) such plants are hyperaccumulators of Zn (Ebbs and Kochian, 1997). *Sorghum virgatum* (Hack) stapf. absorb Zn to the highest shoot tissue concentration of 15102, 11320 and 11270 µg/g from soil containing 35.2, 24.6 and 20.2 µg/g soil, respectively. This plant species was followed by *Arundo donax* L. These two plants are found in a wide varity of habitats and on many different soil types. High Zn levels were found also in a *Centaurea calcitvapa* L., *Malva paviflora* L. and *Portulaca oleracea* L.

Concentration of Cu varied widely among the studied plants, being from 6 to 3039 µg/g. Thirteen set of the 50 plant samples contained from 5-30 µgCu/g, being within the normal agronomy range of Cu in plants and 21 plant samples possessed Cu that is within the tolerable agronomy range (50 µg/g). The remaining 16 samples could be considered as Cu hyperaccumulators, *i.e.*, having from 1000-3039 µg/g plant. These plants can be arranged in the following decreasing order with respect to there Cu content: *Arundo donax* L. > *Juncus rigidus C. A. Mey.* > *Panicum repens* L. > *Sorghum virgatum* (Hack) stapf > *Convulvulus arvensis* L.

Concentration of Ni in the studied plants varied between 12 to 7336 µg/g. Plant species capable of accumulating Ni to an inordinately degree (>1000 µg/g) have been termed hyperaccumulators (Baker and Brooks, 1989). In this study, there are 13 plants containing Ni over 1000 µg/g. These plants are found predominately in families of Gramineae and Compositae. The maximum Ni concentration (7336 µg/g) was found in *Dicathium annulatum* (Forssk) Stapf.

High concentrations of Pb were found in 24 plants (1000-2532 µg/g). The maximum Pb concentration was found in *Sorghum virgatum* (Hack) Stapf. This plant was collected from soil contaminated with different wastes. High Pb levels were found in *Arundo donax* L., *Setaria glauca* L. *Beauv.* and *Setaria viridis* L. *Beauv.*

The ratio between plant metal concentration and available metal content in soil indicates the concentration factor (CF). CF reflects the

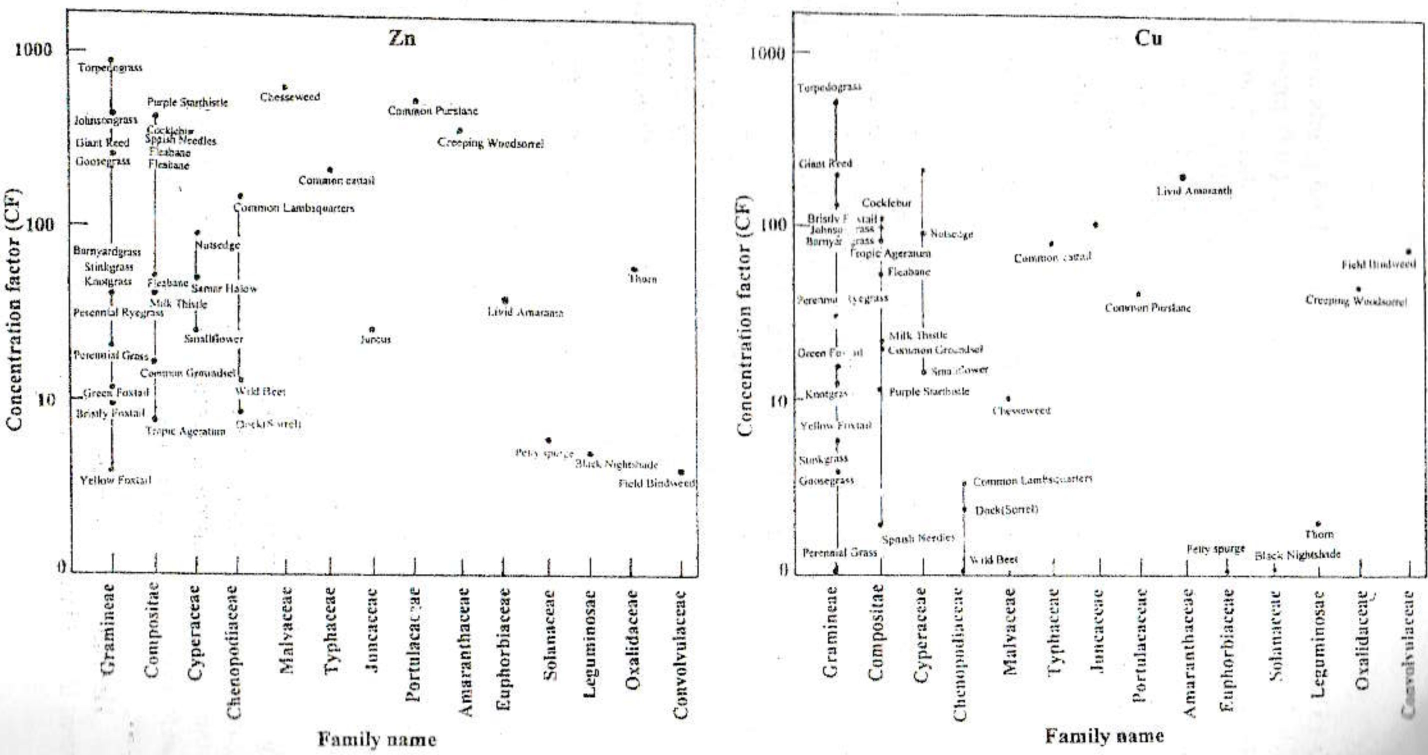

Fig.(1): Concentration factor (plant metal concentration /soil available metal) for Zn and Cu in plant samples.

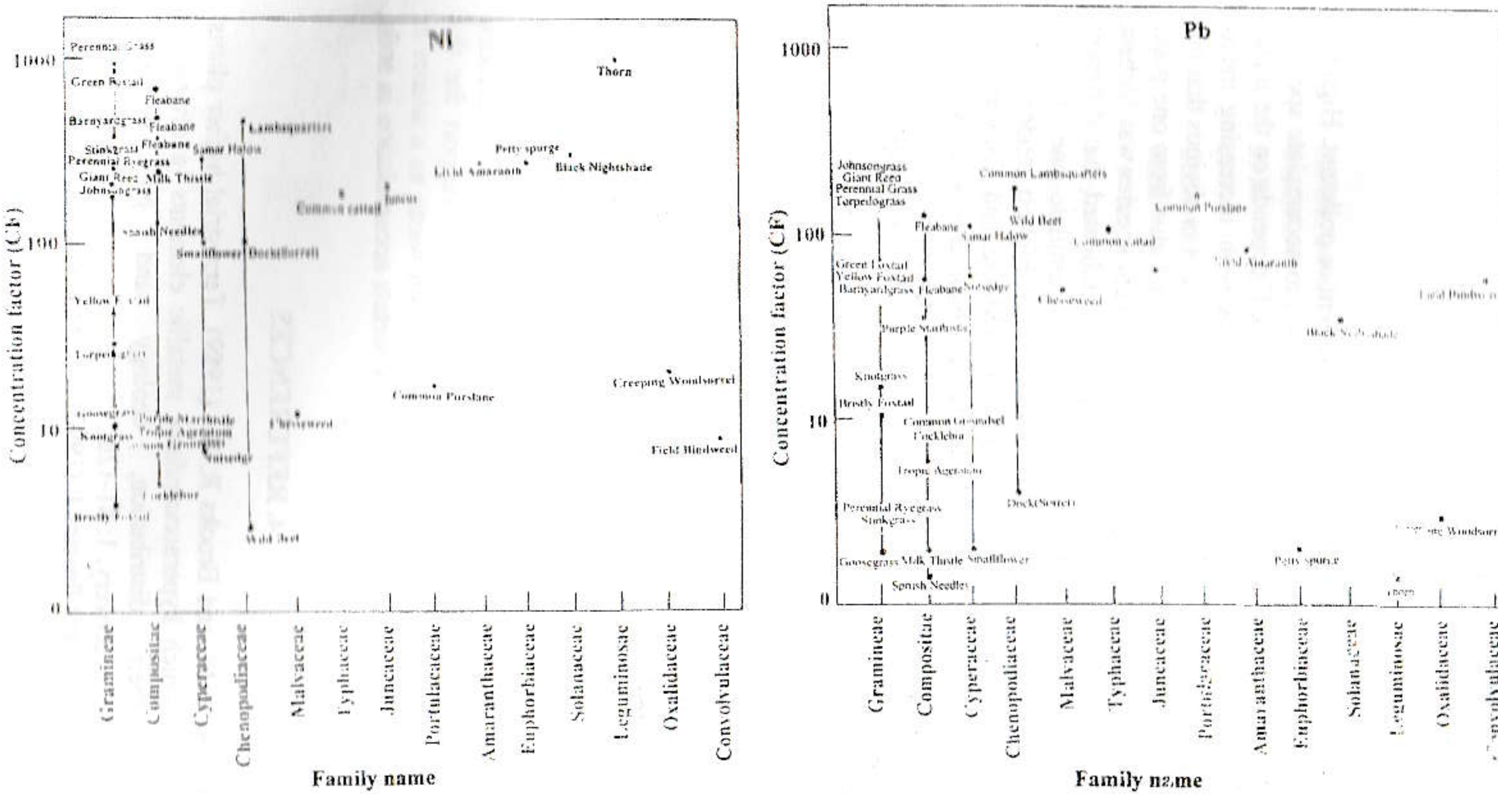

Fig.(2): Concentration factor (plant metal concentration /soil available metal) for Ni and Pb in plant samples.

affinity of the studied plants to specific element or pollutant. High CF values express the high affinity of such plants to accumulate specific elements. Apart from the plant species, the CF depends on the metal concentration in soil itself, *i.e.*, it increases with increasing metal concentration in the soil. From Figures (1and 2), it is obvious that the CF varied widely from one metal to another, and also from one plant species to another. Generally, the CF for all plant species was highest for Zn, Cu and Ni, least for Pb. The results indicated that different plant species showed different ability to accumulate one or more heavy metal ions. *Panicum repens* L. showed highest tendency for accumulating Zn and Cu, *Alhagi maurorum* Medic. and *Dichanthium annulatum* (Forsk) Stapf for Ni; *Chenopodium album* L., *Sorghum virgatum* (Hack) Stapf. and *Arundo donax* L. for Pb.

In conclusion, the most efficient plants in accumulating heavy metals from the studied plants are *Panicum repens* L., *Sorghum virgatum*, *Arundo donax* L., *Dichanthium annulatum (Forssk) Stapf, Chenopodium album* L. and *Alhagi maurorum* Medic.

It is interesting to note that the amounts of heavy metals removed by these hyperaccumulators are very high. These plants can be used for the bioremediation of soils polluted with heavy metals. This technique could be recommended as an environmently safe and a cheap method for the remediation of the heavy metal polluted soils in Egypt.

Acknowledgements

The authors would like to thank the Department of Scientific Research-Cairo University for providing financial support for this work. (project title: Evaluation of using urban waste as a source of irrigation and fertilization on the heavy metals accumulation in soils, plants and groundwater) 2002-2004.

4. REFERENCES

Baker A. J. M. and Brooks R. R. (1989). Terrestrial higher plants which hyperaccumulator metallic elements -a review of their distribution, ecology and phytochemistry. Biorecovery, 1: 81-126.

Baker A. J .M. and Proctor J. (1990) The influence of Cd, Cu, Pb and

Zn on the distrubution and evolution of metallophytes in the British Isles. Plant Syst. Evol., 173:91-108.

Baker A. J. M., McGrath S. P., Sidoli C. M. D. and Reeves R. D. (1994 a) The possibility of *in-situ* heavy metal decontamination of polluted soils using crops of metal-accumulating plants. Resour.Conserv. Recycl.,11: 41-49.

Baker A. J. M., Reeves R. D. and Hajar A. S. M. (1994 b) Heavy metal accumulation and tolerance in British populations of the metallophyte *T. caerulescens* J. & C. *presl* (Brassicaceae). New Phytol, 127: 61-68.

Ebbs S. D. and Kochian L.V. (1997). Toxicity of Zn and Cu to Brassica species :Implications for phytoremediation. J. Environ. Qual., 26: 776-781.

Hajar A. S. M. (1987). Comparative ecology of *Minuartia verna* (L.) Hiern and *T. Alpestre* L. in the Southern Pennines, with special reference to heavy metal tolerance. Ph.D. Thesis, Univ. of Sheffield, Sheffield, UK.

Kamel M. M. (1999). Studies on the remediation of heavy metal polluted soils. Ph.D. Thesis, Soil Dept., Fac. of Agric., Cairo Univ., Giza, Egypt.

Lindsay W. L. and Norvell W. A. (1978). Development of a DTPA soil test for Zn,Fe,Mn,and Cu. Soil Sci. Soc. Amer. J., 42: 421-428.

دراسات على بعض النباتات التى لها القدرة على الامتصاص التراكمى فى مصر

محمد محمد كامل -حسن أحمد خاطر

قسم الأراضى-كلية الزراعة-جامعة القاهرة-الجيزة-مصر.

ملخص

تـزايدت بشـكل كبير مساحات الأراضى الملوثة بالفلزات الثقيلة فى كل أنحـاء العالم وأصبح الاتجاه السائد الآن هو إيجاد طريقة لمعالجة هذه الأراضى الملوثة. تعتبر النباتات التى لها القدرة على الامتصاص التراكمى لتركيزات عالية مـن الفلـزات الثقيلة هى إحدى الطرق المستخدمة فى علاج مثل هذه الأراضى الملوثة.

تهـدف هذه الدراسة إلى عمل حصر لهذه النباتات والتعرف على تركيز الفلزات الثقيلة بها، و تطلب ذلك جمع ٥٠ عينة نباتية من مختلف الأماكن الملوثة فـى مصـر و بعـد إعدادهـا للتحليل قدر بها تركيز الفلزات الثقيلة (الزنك- - الـنحاس- النـيكل -الرصاص) فكانت النتائج كالآتى:- أظهرت بعض النباتات كفـاءة عالية فى امتصاص تركيزات عالية من أى من العناصر الثقيلة كل نبات علـى حسب تخصصه فى امتصاص فلز معين أو أكثر من فلز، حيث احتوى كل جـرام مـادة جافة من النباتات التى حققت أفضل امتصاص للفلزات الثقيلة على التركـيزات الآتـية: ١٥١٠٢ ، ٣٠٣٩، ٢٥٣٢، ٧٣٣٦ مـيكروجرام لكل من عناصر الزنك و النحاس و الرصاص و النيكل على التوالي. ولقد أظهرت النتائج قدرة عالية لنبات القصيبة على تجميع الزنك والنحاس،الجراوة والغاب في تجميع الرصاص،نجيل فارس في تجميع النيكل وذلك في المواقع المدروسة.

يتضـح من تلك الدراسة إمكانية استخدام بعض النباتات المدروسة والتى لها القدرة على الامتصاص التراكمى فى معالجة الأراضى الملوثة بالفلزات الثقيلة فى مصر.

المجلة العلمية لكلـية الزراعة- جامعة القاهـرة- المجلـد (٥٥) العـدد الرابع (أكتوبر ٢٠٠٤) : ٦٦١-٦٧٢.