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ACCUMULATION OF SOME HEAVY METALS IN SOME EUCALYPTUS SPECIES GROWN IN SANDY SOIL AMENDED WITH SEWAGE SLUDGE

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ABSTRACT

A factorial experiment (3 X 5) was conducted at the Experimental Farm of El-Kassasin Hort. Res. Station, Hort. Res. Inst., Agric Res. Center, Egypt during the two successive seasons of 2009/10 and 2010/11. The main purpose of this research was to evaluate the capability of three Eucalyptus species (E. citriodora, E. gomphocphala and E. camaldulensis) grown under sandy soil conditions for reduce or eliminate contamination of some heavy metals resulted from sewage sludge application. This capability was determined under five tested levels of sewage sludge (0, 10, 20, 30 or 40 %) as untraditional organic fertilizer mixed with the sandy soil prior to eucalyptus plantation.

Obtained results showed that, E. gomphocephala retained the highest values of Zn, Pb and Cd content. Also the same species recorded significant increases in uptake of different plant organs and total uptake per plant of the above mentioned elements comparing to the other tested species. While, the highest values of translocation factor of Zn, Pb and Cd from root to leaves or to stem were noticed in E. citriodora in most cases.

Generally, as the mixed sewage sludge level was increased from zero up to the highest level of 40 %, the content as well as uptake of plant organs and total plant uptake of Zn, Pb and Cd were gradually increased. Translocation factor of Zn, Pb and Cd showed unspecific results with sewage sludge treatments.

Interaction treatments between eucalyptus species and sewage sludge applications supported that, E. gomphocephala was more capable to absorb heavy metals; Zn, Pb and Cd from the growing medium comparing to the other two tested eucalyptus species (E. citriodora and E. camaldulensis). Since, under the same sewage sludge level E. gomphocephala had more contents and uptakes of heavy metals comparing the other species. So, planting E. gomphocephala in sandy

soil fertilized with sewage sludge was more effective in reducing the residues of such heavy metals pollute in growing medium.

Key words: Heavy metals, eucalyptus species grown, sandy soil amended, sewage sludge.

INTRODUCTION

Sewage sludge is a serious problem, in many countries, due to its high treatment costs and its risk on environment and human health. Although, the volume of produced sewage sludge represents only 1 to 2 % of the treated waste water volume, its management costs are usually ranging from 20 to 60 % of the total operating costs of the wastewater treatment (Marcos and Chernicharo. (2005). Sludge is produced as by product of wastewater treatment processes. Sludge generated from such water is a good source as organic fertilizer. It contains beneficial constituents such as macro and micronutrients essential elements for plant growth and about 50% organic matter (Badawy and El-Motaium, 1999). Use of sewage sludge (biosolid) as a fertilizer or soil conditioner is the best recycling option from agriculture and environmental view point. Sludge has many advantages in improving soil fertility and increasing crop production (Kumazawa, 1997). Sludge provides the soil with organic matter, nutrients and improves the soil water holding capacity and cations exchange capacity. In addition, the sewage sludge application improves the soil structure and fertility (Cuevas *et al*., 2000, Mata-Gonzalez *et al*., 2002). However, there is environmental and health concern when using sewage water and/or sludge in agriculture. This concern is related to the presence of heavy metals and toxic organic pollutants.

According to Singh and Agrawal (2008), characteristics of sewage sludge depend upon its source and type of the followed treatment processes. It is rich in organic and inorganic plant nutrients, it is a good substitute for the other organic fertilizer, but availability of potential toxic metals often restricts its uses. Its addition modifies soil physical, chemical and biological properties. Growth and yield of plants grown in adequately sludge amended soil are generally more than that of well fertilized controls. Heavy metals availability increases in sludge amended soil at excessive rates for many years. However, plants differ in their abilities to absorb sludge derived metals from the soil

Eucalyptus species (Family, Myrtaceae) occur naturally in all Australian mainland status (Hall *et al*., 1970). They have bean widely planted over seas in areas with Mediterranean climate. However, Eucalyptus species are believed to be introduced into Egypt in the 1800's (El-Lakany *et al.,* 1980). They are highly adopted to local environmental conditions and grown very fast.

These species are traditionally planted as windbreak, for shade and to supply wood for lumber, particle board and charcoal production.

El-Settawy and El-Harriry (2009) on *Eucalyptus camaldulensis, Casuarina glauca and Acacia saligna* found that application of sewage sludge increased heavy metals (Zn, Pb and Cd) in shoot tissues, woods from bark to pith and in soil. However, eucalyptus seedlings displayed bioextractability towards heavy metals (Assareh *et al.*, 2008). Translocation factor of Ni (TF > 0.7) was the most efficiently up taken metals, whereas the TF for Pb varied from 0.4 to 0.7. Values of TF of certain metals were higher in trees grown on sludge than in naturally grown (Dutkus and Baltrenaite, 2007), this means that tree species may be successfully planted in soil fertilized with sewage sludge. Furthermore, Bose *et al*. (2008) found that metals (Cr, Fe, Cd, Cu, Ni, Zn, Mn and Pb) accumulation in different parts of *Cenna indica* L. grown on industrial sludge–amended soil was increased with time and increasing the used sludge dose. Also, metals concentration in *Cenna indica* L. after 90 days growth was in the order of Fe > Cr > Mn > Zn > Ni > Cu > Cd > Pb and the metals translocation was found lesser in shoots. However, Jingjun *et al.* (2008) concluded that the suitability for land application of sewage sludge can be limited by the presence of heavy metals. In addition, Wang *et al.* (2008) found that the soil nutrient content, organic matter and heavy metals concentrations were increased after sewage sludge application.

So, this research aimed to evaluate the efficiency of three eucalyptus species (*E. citriodora, E. gomphocphala and E. camaldulensis*) grown under sandy soil conditions to absorption some heavy metals resulted from sewage sludge application to reduce or eliminate their contamination.

MATERIALS AND METHODS

This study was carried out at the Experimental Farm of El-Kassasin Hort. Res. Station, Hort. Res. Inst., Agric Res. Center, Egypt during the two successive growing seasons of 2009/10 and 2010/11 aiming to evaluate the efficiency of some eucalyptus species grown under sandy soil conditions to absorb some heavy metals resulted from sewage sludge (biosolids) application to reduce or eliminate their contamination.

The experimental layout was factorial experiment between three *Eucalyptus species* and five sewage sludge levels, so the experiment was implicated fifteen treatments. These treatments were arranged as a split – plot in a randomized complete block design with three replicates, each replicate contained six plants (six polyethylene bags, each contain one plant). *E. species* were randomly assigned in the main plots, while the sewage sludge levels were randomly arranged in the sup- plots.

Eucalyptus species: Three *Eucalyptus species* were tested*; i.e., E. citriodora* L. (Limon scented spotted gum), *E. gomphocephala* Dehn (Turat) and *E. camaldulensis* Dehn (River-redgum or Murrary red gum). They were purchased from a commercial nursery as a uniform transplants aged one year old on April 1st for the two tested seasons.

Sewage sludge levels: Treatment bulks of sewage sludge were supplied by Ismailia Waste Water Station at Sarabium. Chemical and physical properties of the used sewage sludge are shown in Table 1. It was used only once by mixing it with the sandy soil before eucalyptus transplanting. The five tested levels of sewage sludge (biosolids) were 0, 10, 20, 30 or 40 %, (w/ w).

On April 1st for the two tested seasons, sewage sludge at the above mentioned levels were mixed with sandy soil (analyzed as: 83.0% sand, 7.9 pH, 0.62 % organic matter, 123 ppm N, 199 ppm P and 144 ppm K). Then, the uniform eucalyptus transplants were transplanted in 17 x 25 cm black polyethylene bags, one transplant/ bag. After that, bags were set under lathe house conditions for two weeks, and then transferred to open conditions. All normal agriculture practices were done when ever needed until the end of experiment on April 1st 2010 and 2011 for the 1st and 2nd seasons, respectively (one year after planting).

Table 1: Chemical and physical analysis of the used dry sewage sludge

Parameters	**Value**	**Total heavy metals (ppm)**	
Organic matter	24.55	**Fe**	92.5
Organic carbon	13.25	**Mn**	166
Total nitrogen	2.20 %	**Zn**	258
C/N ratio	7.20 %	**Cu**	735
Available phosphorus	1.30 %	**Cd**	3
Total potassium	0.48 %	**Ni**	42
pH (1:2.5 sludge : water)	7.9	**Pb**	201
E.C (1:1 sludge : water, ds/ m)	3.6		

Recorded Data:

On April 1st 2010 and 2011 for the 1st and 2nd seasons, respectively at the end of experiment (one year after planting), the following data were recorded:

1. ***Absorbed Heavy metals by eucalyptus plant tissues*:** Leaf, stem and root samples for chemical analysis were randomly taken; and they were dried at 70°C for 72 hours, finely ground and wet digested. Then, concentration of Zn, Pb and Cd were determined according to the method of Page *et al.* (1982) using Atomic Absorption spectrophotometer set (Perkiin Elmer

3300). Element concentrations in plant tissues were calculated and expressed as mg/ kg dry weight. Also, uptake of different plant organs and the total plant uptake of each element were calculated. Additionally, elements translocation from root to stem (stem/ root) and from root to leaves (leaves/ roots) was also calculated according to Ghorab (2005).

2. ***Residues heavy metals in growth medium:*** Samples of the used soil mixtures were taken at the end of experiment, then they were digested using a ternary acid mixture of concentrated nitric acid + concentrated sulphuric acid + perchloric acid (60%) as recommended by (Hess 1971). After that, heavy metals concentrations of Zn, Pb and Cd were determined in the digested solution using Atomic Absorption spectrophotometer (Perkiin Elmer 3300).

Statistical analysis:

Collected data were subjected to statistical analysis according to Steel and Torrie (1980). Mean separation was done using least significant difference (L.S.D) at 5% level.

RESULTS AND DISCUSSION

1. *Absorbed Heavy metals by eucalypts plant tissues;*

1.1 heavy metals contents:

Data presented in Table 2 indicated that, eucalyptus species recorded significant differences among them for heavy metals (Zn, Pb and Cd) content in leaves, stem and root. *Eucalyptus gomphocephala* recorded the highest value of Zn, Pb and Cd in different plant organs, while *E. citriodora* recorded the lowest values in this respect. On the other hand, *E. camaldulensis* gave the intermediate values between the two other species. *Eucalyptus gomphocephala* retained the highest values of Zn (42.5, 17.3 and 47.9 mg/kg DW for leaves, stem and root, respectively), Pb (7.71, 8.33 and 7.67 mg/kg DW) from leaves, stem and roots, respectively) and Cd (2.06, 2.06 and 7.78 mg/kg DW for leaves, stem and roots, respectively.)

Data in the same Table 2 showed that all treatments of sewage sludge gave significant increments of Zn, Pb and Cd contents in leaves, stem and root as compared to control treatment. Plantation in mixture medium containing 40 % wedge sludge + 60 % sandy soil recorded the highest values of Zn content in leaves, stem and root (53.20, 21.50 and 57.45 mg /kg DW), respectively), Pb (10.10, 11.9 and 11.1 mg/kg DW, respectively) and Cd (2.47, 2.55 and 9.03 mg/kg DW, respectively).

Also, interaction treatments between eucalyptus species and sewage sludge rates had significant effects on Zn, Pb and Cd contents in different plant organs (Table 2). Planted *E. gomphocephala* in sandy soil contained 40

Table 2. Effect of plant species, sewage sludge levels and their interactions on Zn, Pb and Cd contents in different organs of eucalyptus plant (average two seasons 2009/ 10 and 2010/ 11).

The characters / Treatments		Heavy metals contents (mg/kg D.W.)								
		Zn			Pb			Cd		
		Leaves	Stem	Roots	Leaves	Stem	Roots	Leaves	Stem	Roots
Effect of eucalyptus species:										
E. citriodora		37.3	13.9	35.9	5.20	2.84	4.57	1.77	1.90	6.00
E. gomphocephala		42.5	17.3	47.9	7.71	8.33	7.67	2.06	2.06	7.78
E. camaldulensis		40.4	15.8	40.1	7.04	6.07	6.78	1.90	1.96	7.42
LSD at 0.05 level		**1.65**	**0.25**	**3.5**	**1.10**	**0.55**	**0.80**	**0.05**	**0.05**	**0.65**
Effect of sewage sludge level *:										
0 % (Control)		27.4	8.67	30.5	3.08	1.67	2.23	1.35	1.43	5.52
10 %		33.5	13.3	34.0	4.98	3.07	3.25	1.62	1.75	5.88
20 %		40.6	16.4	39.1	6.33	4.93	6.08	1.95	1.93	6.68
30 %		45.7	18.4	45.4	8.73	7.22	9.05	2.17	2.20	8.22
40%		53.2	21.5	57.4	10.1	11.9	11.1	2.47	2.55	9.03
LSD at 0.5 5 level		**1.45**	**0.80**	**2.5**	**1.15**	**0.3**	**0.70**	**0.05**	**0.05**	**0.11**
Effect of interaction between eucalyptus species and sewage sludge levels:										
E. citriodora	**0 %**	25.8	6.85	29.1	2.75	1.20	2.10	1.30	1.40	5.15
	10%	31.9	12.6	31.8	4.30	1.85	2.15	1.55	1.65	5.30
	20%	38.6	15.0	35.3	5.15	2.45	4.20	1.80	1.90	5.45
	30%	43.5	16.6	39.3	6.30	3.95	6.00	2.00	2.10	6.75
	40%	46.9	18.3	44.0	7.50	4.75	8.40	2.20	2.45	7.35
E. gomphocephala	**0 %**	29.2	10.3	31.8	3.45	1.95	2.20	1.40	1.45	5.75
	10%	35.5	14.1	35.5	5.55	4.05	4.70	1.70	1.85	6.30
	20%	42.6	18.0	43.0	7.25	6.80	7.35	2.05	2.00	7.40
	30%	48.0	20.1	51.3	10.3	9.75	11.05	2.35	2.30	9.25
	40%	57.3	24.0	77.8	12.0	19.1	13.05	2.80	2.70	10.2
E. camaldulensis	**0 %**	27.1	8.85	30.6	3.05	1.85	2.40	1.35	1.45	5.65
	10%	33.2	13.3	34.6	5.10	3.30	2.90	1.60	1.75	6.05
	20%	40.7	16.1	39.0	6.60	5.55	6.70	2.00	1.90	7.20
	30%	45.7	18.6	45.5	9.60	7.95	10.1	2.15	2.20	8.65
	40%	55.3	22.1	50.5	10.85	11.7	11.8	2.40	2.50	9.55
LSD at 0.5 5 level		**2.70**	**1.30**	**4.01**	**2.02**	**0.55**	**1.25**	**0.10**	**0.11**	**0.65**

* Sewage sludge was applied by mixing it at different tested rates with the sandy planting medium before eucalyptus seedling transplanting.

% sewage sludge gave highest values of Zn, Pb and Cd contents in leaves, stem and roots as compare to the other interaction treatments.

1.2 Heavy metals uptake by different plant organs:

Results in Table 3 show that, there were significant differences among three *Eucalyptus species* under study respecting heavy metals uptake by leaves, stem and roots. *Eucalyptus gomphocephala* was the superior in uptake the three determined metals. Since, it had the highest values of Zn uptake in leaves, stem and roots (8224, 11446 and 12533 mg/kg DW, respectively); Pb uptake in leaves, stem and root (1581, 6179 and 1912 mg/kg DW, respectively) and Cd uptake in leaves, stem and root (399, 1324 and 2000 mg/kg DW, respectively). While, *E. citriodora* exhibited the lowest values in different plant organs in this respect.

Mixing sewage sludge at the different rates with the used sandy soil had significant effects on Zn, Pb and Cd uptake by different plant organs compared to control treatment (Table 3). Planted eucalyptus in mixture media of 30 % sewage sludge + 70 % sandy soil recorded maximum values of Zn uptake by different plant organs*; i.e.,* 11012 mg/kg DW by leaves, 13014 mg/kg DW by stem and 13168 mg/kg DW by roots. Also, the same treatment gave maximum values of Pb by leaves and roots (2195 and 2544 mg/kg DW, respectively). While application of sewage sludge at the rate of 40 % recorded maximum values of Pb uptake by stem (8082 mg/kg DW). However, the highest values of Cd uptake by different plant organs were obtained by 30 % sewage sludge + 70 % sandy soil (524, 1531 and 2416 mg/kg DW for leaves, stem and root, respectively).

Regarding interaction treatments, data in Table 3 indicate that , plantation *E. gomphocephala in the mixture* medium contain 30 % sewage sludge + 70 % sandy soil gave the highest values of Zn uptake by leaves (13860 mg/kg DW), Pb uptake by leaves and roots(2974 and 3824 mg/kg DW, respectively) and Cd uptake in leaves, stem and root (678, 2212 and 3739 mg/kg DW, respectively). In addition, planted *E. gomphocephala* in the mixture media contain 40 % sewage sludge + 60 % sandy soil gave the highest values of Zn uptake by stem and root (19577 and 24096 mg/kg DW, respectively) and Pb uptake by stem (15539 mg/kg DW).

1.3 Total heavy metals uptake per plant:

Results of Table 4 indicate that there were significant differences between Eucalyptus species for total plant uptake of Zn, Pb and Cd. The highest values of Zn, Pb and Cd total uptake by plant (32203, 9672 and 3724 mg/kg DW, respectively) were noticed in *E. gomphocephala*, while the lowest values in this respect were recorded in *E. citriodora*.

Table 3. Effect of plant species, sewage sludge levels and their interactions on Zn, Pb and Cd uptake by different organs of eucalyptus plant (average two seasons 2009/ 10 and 2010/ 11).

Characters / Treatments		Heavy metals uptake (mg/kg D.W.)								
		Zn			Pb			Cd		
		Leaves	Stem	Roots	Leaves	Stem	Roots	Leaves	Stem	Roots
Effect of eucalyptus species:										
E. citriodora		3707	2532	2087	525	535	373	174	336	348
E. gomphocephala		8224	11446	12533	1581	6179	1912	399	1324	2000
E. camaldulensis		7645	8970	7993	1419	3757	1495	355	1070	1496
LSD at 0.05 level		**494**	**505**	**990**	**643**	**504**	**235**	**152**	**235**	**510**
Effect of sewage sludge level *:										
0%(Control)		2004	1539	2316	226	297	163	98	243	420
10 %		3505	3946	3720	525	994	360	168	516	651
20 %		6318	7128	5646	1013	2397	962	304	824	984
30 %		11012	13014	13168	2195	5682	2544	524	1521	2416
40%		9788	12620	12838	1917	8082	2270	452	1447	1935
LSD at 0.5 5 level		**354**	**444**	**390**	**442**	**286**	**176**	**129**	**228**	**461**
Effect of interaction between eucalyptus species and sewage sludge levels:										
E. citriodora	**0 %**	1490	648	1157	158	112	98.0	75.1	132	204
	10%	2645	1634	1546	356	239	140	128	213	257
	20%	3454	2823	2054	460	458	308	160	357	316
	30%	6351	3905	2929	919	922	650	292	492	502
	40%	4597	3651	2751	734	945	667	215	487	459
E. gomphocephala	**0 %**	2425	2222	3086	286	415	194	116	311	557
	10%	4429	5647	5894	691	1616	639	211	738	1046
	20%	8104	10398	8829	1379	3928	1457	390	1155	1519
	30%	13860	19387	20758	2974	9397	3824	678	2212	3739
	40%	12301	19577	24096	2573	15539	3444	600	2202	3141
E. camaldulensis	**0 %**	2096	1747	2706	235	365	196	104	286	499
	10%	3441	4557	3721	527	1126	302	165	597	649
	20%	7397	8164	6055	1199	2805	1120	363	960	1117
	30%	12826	15751	15818	2691	6728	3159	602	1858	3007
	40%	12467	14633	11667	2443	7762	2698	540	1651	2206
LSD at 0.5 5 level		**614**	**770**	**676**	**766**	**496**	**305**	**225**	**395**	**800**

* Sewage sludge was applied by mixing it at different tested rates with the sandy planting medium before eucalyptus seedling transplanting.

Table 4. Effect of plant species, sewage sludge levels and their interactions on Zn , Pb and Cd total uptake per eucalyptus plant (average two seasons 2009/ 10 and 2010/ 11)

Characters / Treatments		Total uptake (mg/kg D.W.)		
		Zn	**Pb**	**Cd**
Effect of eucalyptus species:				
E. citriodora		8327	1434	859
E. gomphocephala		32203	9672	3724
E. camaldulensis		24610	6673	2922
LSD at 0.05 level		**1989**	**1382**	**897**
Effect of sewage sludge level *:				
0 % (control)		5859	687	762
10 %		11172	1880	1335
20 %		19093	4372	2113
30 %		37196	10422	4462
40%		35248	12270	3835
LSD at 0.5 5 level		**1189**	**904.6**	**819**
Effect of interaction between eucalyptus species and sewage sludge levels:				
E. citriodora	**0 %**	3295	368	412
	10 %	5825	736	598
	20 %	8332	1227	835
	30 %	13185	2492	1287
	40%	11000	2347	1162
E. gomphocephala	**0 %**	7734	896	984
	10 %	15971	2947	1996
	20 %	27331	6764	3064
	30 %	54005	16195	6630
	40%	55975	21558	5944
E. camaldulensis	**0 %**	6549	797	889
	10 %	11720	1956	1412
	20 %	21617	5126	2441
	30 %	44397	12580	5468
	40%	38768	12905	4398
LSD at 0.5 5 level		**2060.0**	**1567.0**	**1420.0**

* Sewage sludge was applied by mixing it at different tested rates with the sandy planting medium before eucalyptus seedling transplanting.

sewage sludge effects on the total plant uptake of different estimated metals, data of Table 4, indicate that fertilized eucalyptus plants with sewage sludge at different levels had significant increments regarding Zn, Pb and Cd total

uptake by plant as compared to control treatment (without sewage sludge). Plantation eucalyptus plants in mixture medium contain of 30 % sewage sludge + 70 % sandy soil gave the highest values of Zn and Cd total uptake (35248, 4462 mg/kg DW, respectively). While plantation in the mixture contain 40 % sewage sludge + 60 % sandy soil gave the highest value of Pb total uptake by seedling (12270 mg/kg DW).

The interaction of eucalyptus species X sewage sludge levels recorded significant increases in Zn, Pb and Cd total uptake by plant (Table 4). The combination treatment of *E. gomphocephala* X sewage sludge at 40 % recorded the highest values of Zn and Pb total uptake by plant (55975 and 21558 mg/kg DW, respectively), while, the highest value of Cd total uptake (6630 mg /kg DW) was recorded under effect of interaction between *E. gomphocephala* and sewage sludge at 30 %.

1.4 Translocation factors (TF) ratio of Zn, Pb and Cd in leaves and stem

Data in Table 5 reveal that there were significant differences between different eucalyptus species for Zn and Pb TF in leaves and for Pb TF in stem, while Cd TF to leaves and stem did not significantly affected among different eucalyptus species. *Eucalyptus citriodora* came in the first rank (1.04 and 1.14) for Zn and Pb TF in leaves and Cd TF in stem (0.32).

Addition of sewage sludge at different levels recorded significant increments in TF of Zn and Pb in leaves and stem as compared to control. But, it had no significant effect on TF of Cd in leaves and stem compared to control (Table 5). Sewage sludge at 20 % gave highest value of Zn TF in leaves and stem (1.04 and 0.42, respectively). While, the lowest level (10 %) of sewage sludge recorded the highest value of Pb TF in leaves (1.54) and Cd TF in stem (0.30). The highest value of Pb TF in stem (1.07) was obtained mixing sewage sludge at 40 % with the sandy soil.

The interaction between eucalyptus species and sewage sludge had significant effect on Zn and Pb TF in leaves and stem, while did not significantly affect on Cd TF in leaves and stem (Table 5). The interaction of *E. citriodora* X sewage sludge at 30 % gave the highest value of Zn TF in leaves (1.11), while, the highest value of Zn TF in stem (0.44 %) was obtained by the interaction between *E. camaldulensis* and sewage sludge at 40 %. However, *E. gomphocephala* planted in sandy soil contained 40 % sewage sludge recorded the highest value of Pb TF in stem (1.46). Meanwhile, the highest value of Cd TF in leaves and stem (0.33 and 0.35,

Table 5. Effect of plant species, sewage sludge levels and their interactions on Zn, Pb and Cd translocation to leaves and stem of eucalyptus plant (average two seasons 2009/ 10 and 2010/ 11).

Characters / Treatments		Heavy metal translocation factor[@]					
		Zn		Pb		Cd	
		Leaves	Stem	Leaves	Stem	Leaves	Stem
Effect of eucalyptus species:							
E. citriodora		1.04	0.39	1.14	0.63	0.29	0.32
E. gomphocephala		0.89	0.36	0.96	1.03	0.26	0.26
E. camaldulensis		1.01	0.40	1.04	0.90	0.26	0.26
LSD at 0.05 level		**0.07**	**NS**	**0.13**	**0.16**	**NS**	**NS**
Effect of sewage sludge level *:							
0 % (control)		0.90	0.28	1.41	0.75	0.25	0.26
10 %		0.99	0.39	1.54	0.94	0.27	0.30
20 %		1.04	0.42	1.04	0.81	0.29	0.28
30 %		1.01	0.41	0.96	0.80	0.26	0.27
40%		0.93	0.37	0.91	1.07	0.27	0.28
LSD at 0.5 5 level		**0.04**	**0.02**	**0.10**	**0.09**	**NS**	**NS**
Effect of interaction between eucalyptus species and sewage sludge levels:							
E. citriodora	**0 %**	0.89	0.23	1.31	0.57	0.25	0.27
	10 %	1.00	0.40	2.00	0.86	0.29	0.31
	20 %	1.09	0.42	1.23	0.58	0.33	0.35
	30 %	1.11	0.42	1.05	0.66	0.30	0.31
	40%	1.07	0.42	0.89	0.57	0.30	0.33
E. gomphocephala	**0 %**	0.92	0.32	1.57	0.89	0.24	0.25
	10 %	1.00	0.40	1.18	0.86	0.27	0.29
	20 %	0.99	0.42	0.99	0.93	0.28	0.27
	30 %	0.93	0.39	0.93	0.88	0.25	0.25
	40%	0.74	0.31	0.92	1.46	0.28	0.27
E. camaldulensis	**0 %**	0.89	0.29	1.27	0.77	0.24	0.26
	10 %	0.96	0.39	1.76	1.14	0.26	0.29
	20 %	1.04	0.41	0.99	0.83	0.28	0.26
	30 %	1.01	0.41	0.95	0.79	0.25	0.25
	40%	1.10	0.44	0.92	1.00	0.25	0.26
LSD at 0.5 5 level		**0.07**	**0.04**	**0.18**	**0.16**	**NS**	**NS**

[@] Element translocation was calculated by divide its percent in the plant organ (stem or leaf tissues) by its percent in root tissues according to Ghorab (2005).

* Sewage sludge was applied by mixing it at different tested rates with the sandy planting medium before eucalyptus seedling transplanting.

respectively) were obtained by the combination between *E. citriodora* and sewage sludge at 20 % per seedling

Generally, these results indicate that, the highest content of heavy metals was found in stem, leaf and root tissues in most cases with high sewage sludge levels (30 or 40 %). Such results are in harmony with those obtained by Dutkus and Baltrnaite (2007); Lazdi *et al.* (2007) on willow Assareh *et al.* (2008) on eucalyptus spp., Bose *et al.* (2008) on canna, Jingjun *et al.* (2008) on *pinus radiata*, Wang *et al*. (2008) on some grass and El-Settawy and El-Hariry (2009) on *eucalyptus camaldulensis, Casuarina glauca and Acacia saligna***.** All found that, the sewage sludge treatment gave high concentration of heavy metals in different plant organs

Little is known about the mechanism of metal ion translocation to the shoot, though it was suggested that coordination of the metal ion with free histidine may play a role (Kramer *et al.*, 1996). Once in the shoot, the hyper-accumulated metals such as Cd, Ni and Zn accumulate preferentially in either the epidermal or mesophyll cells, depending on the plant species.

2. Residues heavy metals in growth medium:

Some residues heavy metals (Zn, Pb and Cd) in the used soil as affected by planting eucalyptus species under different tested levels of sewage sludge are shown in Table 6.

It is clear that Zn, Pb and Cd metals residues in the used soil was mostly increased as sewage sludge level was increased up to the highest level of 40 % sewage sludge. The maximum values of Zn, Pb and Cd were recorded under 40 % sewage sludge level regardless planted eucalyptus species. In addition, soil analysis of *E. citriodora* recorded the highest contents of the three heavy metals (Zn, Pb and Cd) as compared to soil analysis of *E. camaldulensis* and *E. gomphocephala*, respectively. Also, it could be noticed that *E. gomphocephala* was more effective in reducing the evaluated three heavy metals in soil. Since, under the same level of sewage sludge application plantation *E. gomphocephala* apparently reduced the residues metals of Zn, Pb and Cd in the soil comparing to of *E. citriodora* or *E. camaldulensis*.

Conclusively, for overcoming heavy metals pollution problem resulted from sewage sludge fertilizer application under sandy soil conditions, it could be recommend that planting *E. gomphocephala*. Since, this species proved its capability for absorb and reduce the residues of these elements in soil.

Table 6. Some residues heavy metals content (ppm) in the used soil as affected by planted eucalyptus species, sewage sludge level and their interaction treatments (values represented average two seasons of 2009/ 10 and 2010/ 11)

Treatments \ Characters		Heavy metals content (ppm)		
		Zn	**Pb**	**Cd**
Control (without sewage sludge)		10.32	1.63	ND*
E. citriodora	**10 %**	17.30	4.52	ND
	20 %	20.66	6.22	ND
	30 %	22.73	7.33	0.06
	40%	25.65	7.78	0.08
E. gomphocephala	**10 %**	12.77	3.00	ND
	20 %	17.63	3.80	ND
	30 %	19.85	4.72	0.03
	40%	21.75	5.22	0.04
E. camaldulensis	**10 %**	15.64	3.34	ND
	20 %	18.88	4.30	ND
	30 %	20.00	5.22	0.05
	40%	23.22	6.00	0.06

- ND: Not detected

Conclusively, for overcoming heavy metals pollution problem resulted from sewage sludge fertilizer application under sandy soil conditions, it could be recommend that planting *E. gomphocephala*. Since, this species proved its capability for absorb and reduce the residues of these elements in soil.

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تراكم بعض المعادن الثقيلة في بعض أنواع الكافور النامية في تربة رملية مزودة بالحمأة

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أُجريت تجربة عامليه (٣ x ٥) في المزرعة التجريبية لمحطة بحوث البساتين بالقصاصين- معهد بحوث البساتين- مركز البحوث الزراعية خلا موسمين متعاقبين ٢٠٠٩/ ١٠ ، ٢٠١٠/ ١١ ، كان الهدف الأساسي لهذا البحث هو تقييم مقدرة ثلاث أنواع من الكافور (*E. camaldulensis*، *E. gomphocphala* ، *E. citriodora*) نامية تحت ظروف التربة الرملية على تقليل أو إزالة التلوث ببعض العناصر الثقيلة نتيجة للمعاملة بالحمأة "الرواسب الصلبة للصرف الصحي" ، أُختبر ذلك تحت تأثير خمس مستويات من الحمأة (صفر ، ١٠ ، ٢٠ ، ٣٠ ، ٤٠ %) كسماد غير تقليدي خلطاً مع تربة رملية قبل زراعة نباتات الكافور.

أوضحت النتائج المتحصل عليها احتواء النوع *E. gomphocephala* على أعلى التركيزات من عناصر الزنك والرصاص والكادميوم (Zn ، Pb ، Cd) ، أيضاً سجل نفس النوع زيادات معنوية في امتصاص مختلف أعضاء النبات وفى الامتصاص الكلى للنبات من العناصر الذكورة سابقا مقارنة بباقي الأنواع المختبرة ، بينما لوحظت أعلى قيم معامل انتقال العناصر الثلاث Zn ، Pb ، Cd من جزر النبات للأوراق أو للساق في معظم الحالات في النوع *E. citriodora* .

كلما ذاد معدل الحمأة المخلوطة مع التربة من المستوى صفر حتى أعلى مستوى ٤٠ % ذاد تدريجيا المحتوى والامتصاص بمختلف أعضاء النبات وإجمالي الممتص من عناصر Zn ، Pb ، Cd ، لم تُظهر نتائج معامل الانتقال للعناصر الثلاث اتجاه واضح.

أيدت معاملات التفاعل بين أنواع الكافور ومستويات الحمأة أن النوع *E. gomphocephala* كان أكثر مقدرة على امتصاص المعادن الثقيلة (Zn ، Pb ، Cd) من وسط النمو مقارنة بالنوعين المختبرين الآخرين *E. citriodora* ، *E. camaldulensis* ، حيث سجل النوع *E. gomphocephala* تحت نفس مستوى الحمأة تركيز أعلى وامتصاص أعلى من المعادن الثقيلة مقارنة بالنوعين الآخرين ،

التوصيـــــة: لذلك فإن زراعة النوع *E. gomphocephala* في الأرض الرملية المسمدة بالحمأة فعال جداً في تقليل المتبقي في التربة من هذه المعادن الثقيلة.