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Taxodium trees as a phytoremediation to soil contaminants

Ouf, A.A.[1], F.A. Hassan[1], A.I.A. Abido[2] and M.K. Gaber[2]

[1]*Timber Trees Dept., Sabahia, Hort., Res. Station, Alexandria, Hort., Res. Inst., Agric. Res. Center, Egypt.*
[2]*Plant Production Dept., The Faculty of Agric. (Saba Basha), Alexandria, Egypt.*

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ABSTRACT

Contaminated agricultural soil represents a crucial obstacle on the growth, wood properties and chemical constituents of bald cypress seedlings (*Taxtodium Distishum* Rich.) as well as soil chemical properties. Therefore, A pot experiment was conducted in the nursery of Timber trees Research Department of Sabahia Horticultural Research Station in Alexandria Egypt from May 2015 to October 2016 for three periods (6, 12, 18 months). Two types of agricultural soil were used, one of which was contaminated with heavy metals from the white pigment area from the Sabaghy El Baida in Kafr El-Dawar, an industrial city in El-Beheira governorate, and the other was taken from the nursery of the Horticulture Research Station in Sabahia, Alexandria.

The contaminated soil was superior than the unpolluted soil (control) in improving the growth parameters (plant height, stem diameter, leaf area, leaves number, fresh and dry weights of leaves, shoots and roots, root length and shoot/ root ratio and wood properties (Specific gravity and Fiber length). Also, showed the highest concentration, uptake and total uptake of N, P, K, Cd, Pb and Zn in different plant parts (leaves, shoots and roots). The data also showed that use contaminated soil for planting *T. distichum* seedlings increased N, P and K and DTPA-extractable heavy metals (Cd, Pb and Zn). The decrease in the concentration of some heavy metal Cd, Pb and Zn in the contaminated soil at the end of experiment suggested that bald cypress trees was an important kind for phytoremediation to improve soil properties, and increasing fuel and timber production economic.

***Keywords*:** contaminated soil, heavy metals, *Taxodium distichum*.

Introduction

Phytoremediation the word's derived from the Greek (phyto) = plant, and Latin (remedium) = restoring balance, or remediation. Phytoremediation covers a range of mechanisms such as phytoextraction, rhizofiltration, phytostabilization, phytodegradation, rhizodegradation, and phytovolatization (Khan *et al.,* 2000). Phytoremediation is a well-known avenue that uses plants and ambient related rhizospheric microorganisms to diminish, disrupt, or contain concoction contaminants located in the dregs, dirt, surface water, groundwater and even the environment (Anon, 1998). Scientists have found out plants can used to treat most categories of contaminants, including chlorinated solvents, oil hydrocarbons, metals, pesticides, explosives, radionuclides, and abundance supplements. Plant species are chosen for phytoremediation depend on their abilities to degrade proteins they deliver, evapotranspirate groundwater, their development rates and yield, the deeper of their root zone, and their capacity to bioaccumulate contaminants (Mertens *et al*., 2007). Phytoremediation is of low cost, in situ applicable method for the scavenge of sites contaminated with organic pollutants or toxic metals. Depending on the level of contamination and both size and volume of polluted area, a different technology uses plants to clean up in the environment. Plants can scavenge a numerous sort of contamination as reported earlier. Plants, also help prevent wind, rain, groundwater from movement of pollution away from sites to other areas. The potential utilization of trees as a reasonable vegetation cover for overwhelming metal-sullied arrive has received an expanding consideration. Trees have been recommended as a minimal effort, economical and naturally stable prerequisite for the remediation of preferred on metal-debased land (Dickinson, 2000). Particularly when it is not economically to use different remedies or there is no time to utilize the land (Riddell-Black, 1994). Advantages can occur essentially from adjustment of the waste or dirt, although the fact that now and again phytoextraction might be adequate to give tidy up of the dirt.

Corresponding Author: Ouf, A.A., Timber Trees Dept., Sabahia, Hort., Res. Station, Alexandria, Hort., Res. Inst. Agric. Res. Center, Egypt.

Before these merits can be understood, the trees must end up built up on a site. The convenient variety of phytoremediation techniques, its employment is constrained by various factors. Phytoremediation can work at sites that are well suited for plant growth. This means that the concentration of pollutants cannot be toxic to the plants, and the pollution cannot be so deep in the soils or groundwater that plant roots cannot reach it. As a result, phytoremediation may be a good strategy for sites conducive to plant growth with shallow contamination, it may be a good secondary or phase in treatment train for highly polluted sites, or it may not be a viable option for site (Rosselli, 2003). The reasons behind selecting *Taxodium sp*. in process Phytoremediation for controlling of soil contaminants: its evaporation capacity, production is biodegradable decomposition, Increase the rate of its growth and depth in which the roots are located where they can reach the surface of the groundwater. It has a high ability to collect and accumulate pollutants. These trees are called hyperaccumulator (Ghorab, 2005).

The aim of the present work is to study the absorption of soil contaminants by using plants, especially wood trees, where they are not eaten and in specific *Taxtodium distishum* growth performance.

Materials and Methods

This study was carried out in the nursery of Timber Trees Department of Sabahia, Horticultural, Research Station in Alexandria, Egypt. The study lasted 18 months from May 2015 to October 2016, to investigate the uptake of soil pollutants using perennial plants, especially trees on vegetative growth, wood properties (specific gravity and fiber length), chemical composition of wood and soil properties of *Taxtodium distishum* trees seedlings for three periods (6, 12 and 18 months) and using tap water for irrigation. Two types of soils were used contaminated and Uncontaminated (control) soil. Trace elements in samples were analyzed using atomic absorption spectrophotometer. Soluble N was determined using kjeldahl method (Page *et al.,* 1982). Soluble P was determined using ascorbic acid molybdenum blue method (Watanabe and Olsen, 1965).

All the homogenous seedlings were brought from the nursery of the Research Department of the Horticultural Research Station. Two types of agricultural soil were used, one of which was contaminated with heavy metals from the white pigment area from the Sabaghy El Baida in Kafr El-Dawar, an industrial city in El-Beheira governorate, and the other was taken from the nursery plant of the Horticulture Research Station at Sabahia, Alexandria (Table 1). A plant species of the given plant were used as one years old of *T. distishum*. Seedlings were moved and cultivated in plastic pots (40 cm in length and 40 cm in diameter), filled with 18 kg of normal and natural soil (one seedlings/pot). All seedlings are sprinkled with tap water to standardize the irrigation rate (2 liter / pot). The irrigation was twice times during summer and weakly in winter. Before the start of the experiment, the soil was washed with tap water for 5 consecutive days and then left to dry before placing it in the pots.

At the beginning of the experiment, plastic tarpaulins were put in place. The experiment was covered with a high-end plastic sheeting mounted on side panels. At the end of each period (6, 12 and 18 months), three seedlings were selected for each transaction randomly to determine the following dada:

A. Vegetative growth, was expressed *via* Plant height (cm), Stem diameter (mm), Leaves number/plant, Leaf area (cm^2/leaf), root length (cm), Fresh and dry weights (g/plant) for leaves, shoots and roots and shoot/root ratio.

B. wood properties, was expressed *via* specific gravity and fiber length.

C. Chemical composition of the different plant parts:

Both N and P were measured colormetrically according to Evenhuis (1976), Murphy and Riley (1962), respectively. Also, K and Na were measured against standard using at lame photometer (Page *et al*., 1982). Cd, Pb and Zn (ppm) were determined by Perkin Elmer, 3300 atomic absorption spectrophotometer. Also, the total uptake of these elements plant was calculated.

D. Soil analysis, at the end of each period, soil samples were taken from each treatment to determine their chemical properties according to Page *et al*. (1982). Heavy metals (Cd, Pb, and Zn) were extracted by DTPA and measured in the solution by atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Table 1: Physical and chemical analysis of the tested soil.

Parameter	Control soil	Contaminated soil
Practical size distribution		
Sand%	70.00	**72.00**
Silt%	20.00	**21.00**
Clay%	10.00	**13.00**
Soil texture	Sandy loam	**Sandy loam**
pH	8.31	**8.33**
E.C. ds/m	1.89	**2.80**
SAR	6.59	**8.54**
$CaCO_3$%	6.70	**6.80**
Organic matter%	0.24	**0.38**
Soluble cations (meq/l)		
Ca^{2+}	5.54	**6.50**
Mg^2	2.20	**4.16**
Na^+	33.70	**40.20**
K^+	0.59	**0.67**
Soluble anions (meq/l)		
CO_3^-	0.00	**0.00**
HCO_3^-	4.20	**5.00**
Cl^-	37.00	**43.00**
SO_4^-	4.71	**8.04**
Available K (ppm)	6.50	**9.40**
Available N (ppm)	1.68	**2.24**
Available P (ppm)	12.50	**17.50**
Total heavy metals (ppm)		
Cd	0. 034	**0.304**
Pb	5.67	**11.00**
Zn	37.15	**243.05**

The experiments design, the complete randomized design (CRD) was used for the experiment as described by Snedecor and Cochran, (1989). The two treatments were replicated three times, each repetition contained six Seedlings. The means among all used treatments were compared by Duncan's Multiple Range Test, using SAS procedures (SAS, 1990).

Results and Discussion

A. Vegetative growth:

Average values of the vegetative growth parameters (plant height, stem diameter, leaf area, leaves number, fresh and dry weights of leaves, shoots fresh and dry weights) as affected by grow in polluted soil are presented in Table (2).

All tested growth parameters were affected significantly ($p \leq 0.05$) by both tested soils. The usage of contaminated soil increased significantly ($p \leq 0.05$) all the studied vegetative growth parameters compared to the unpolluted soil (control treatment). Generally, the vegetative growth parameters after 18 months were significantly higher more than those 6 months, while control treatments gave the lowest values ($p \leq 0.05$) level. These results are in agreement with many investigators, who found that soil physical properties, that reflect on the growth and enhanced the cell elongation and division Rosselli *et al*. (2003) on five woody species; Gawronsk *et al*. (2004) on *Salix sp.;* Ali (2005) on *Khaya senegaleusis*. Further, results of Table (2) cleared that root fresh and root dry weights of *Taxodium distichum* that growing in polluted soil, the data were significantly ($p \leq 0.05$) differences for all the periods of the present study. This trend was found with the three periods. Also, the same trend was found with results for root length and Shoot/root ratio. These results are in

Table 2: Average values of some vegetative parameter of Taxodium *distichum* as affected by types of tested soil under the study during 18 months (2015–2016).

Treatments	**Measurements**					
Uncontaminated (control) soil	**Plant height (cm)**	**Stem diameter (mm)**	**Leaves number / plant**	**Leaf area(cm^2) /leaf**	**Leaves fresh weight (g/plant)**	**Leaves dry Weight (g/plant)**
6 months	70.40 f	8.07 e	199.00 f	7.98 f	68.40 f	**29.20 e**
12 months	92.20 d	13.09 d	298.40 e	13.90 d	84.20	**42.20 d**
18 months	138.40 b	16.08 c	394.60 c	18.40 c	119.60 c	**59.00 c**
Contaminated soil						
6 months	87.60 e	13. 07d	324.60 d	10.91 e	101.40 d	**43.80 d**
12 months	114.80 c	20.05 b	443.60 b	21.40 b	143.80 b	**66.20 b**
18 months	199.20 a	30.00 a	531.20 a	28.32 a	183.20 a	**88.00 a**
Uncontaminated (control) soil	**Shoots fresh weight (g/plant)**	**Shoots dry weight (g/plant)**	**Roots fresh weight (g/plant)**	**Roots dry weight (g/plant)**	**Root length (cm)**	**Shoot/root ratio**
6 months	69.40 f	32.00 f	57.00 f	26.00 e	83.60 e	**1.42 d**
12 months	94.80 e	44.80 e	75.20 d	30.80 d	98.20 d	**1.49 d**
18 months	138.80 c	67.00 c	105.60 c	39.20 b	122.20 b	**2.06 a**
Contaminated soil						
6 months	103.00 d	48.40 d	65.20 e	34.60 c	106.00 c	**1.70 c**
12 months	152.80 b	72.80 b	119.40 b	39.80 b	119.00 b	**1.86 b**
18 months	231.60 a	105.80 a	169.60 a	56.40 a	172.00 a	**2.08 a**

Average values followed by a similar letter within a column are not significantly different, using least significantly differences test procedure (L.S.D) at $p \leq 0.05$ level of probability.

harmony with those were obtained by Ali (2005) on *Khaya senegalensis, Swietenia mahagoni* and *Taxodium distichum*; kayad (2005) on *Melia azedarach***;** Hassan *et al*. (2008) and Soliman (2010) on *Taxodium distichum.*

B. Wood properties:

The results tabulated in Table (3) showed that there are significant differences in specific gravity for *Taxodium distichum* seedlings between contaminated and control soil, after 6, 12 and18 months of planting. Therefore, contaminated soil reached the significantly level among the three periods of study resulted in 0.533, 0.540 and 0.556 respectively. Also, period of 18 months resulted in the highest significant specific gravity for contaminated soil of 0.556 then 6 months recorded lowest specific gravity of 0.533. It is obvious that the polluted soil improved wood specific gravity may be due to more accumulation of metabolic products in fibers wood as result to growth stimulating.

On the other extreme, the contaminated soil had markedly effects on the fiber length of bald cypress plants, significant differences reached the three periods of study, the longest fiber length reached after 18 months followed by 12 months and 6 months that were 2.061, 1.886 and 1.842 mm respectively. The contaminated soil affected fiber length as of specific gravity through the three study periods. The obtained results are in agreement with those found by Ali (2010) on *Albizza lebbek* and *Citharexylum spinosum*; El-Kayal (1996) on *Acacia stenophylla*, *Casuarina glauca*, *Eucalyptus camaldulnsis*, *Melia azedarach* and *Taxodium distichum*; Foulger *et al*. (1994) on *Populus deltoid*

Table 3: Average values of contaminated soil on specific gravity and fiber length of *Taxodium distichum* as affected by type tested soil during 18 months (2015–2016).

Uncontaminated (control) soil	Specific gravity	Fiber length (mm)
6 months	0.33502 f	**1.498 f**
12 months	0.34246 e	**1.590 e**
18 months	0.39248 d	**1.863 c**
Contaminated soil		
6 months	0.53280 c	**1.842 d**
12 months	0.53968 b	**1.886 b**
18 months	0.55598 a	**2.061 a**

Average values followed by a similar letter within a column are not significantly different, using least significantly differences test procedure (L.S.D) at $p \leq 0.05$ level of probability.

C. Chemical composition:

Average values of Tables (4 and 5) exhibited that usage of contaminated soil gave the highest concentrations of N, P, K, Cd, Pb and Zn in leaves, shoots and root of *Taxodium distichum* compared to control treatment. The concentration of N, P and K contents of leaves were much higher than that of shoots and roots. The results are agreement with the findings of Soliman (2010) on *Taxodium distichum*; Ghorab (2005) on *Albizia lebbek, melia azedarach, Pongamia glabra, Taxodium distichum* and *Tipuana speciosa*. In contrary, heavy metals contents (Cd, Pb and Zn) tended to accumulate in root than that of leaves and shoots with few exceptions. The effect of contaminated, soil, when time increased from 6 to 18 months the uptake of N, P, K, Cd, Pb and Zn in the all parts of plant and increased with little exception.

This finding could be taken place due to progressive increase of vegetative growth. These results, in agreement with previous findings of Swealem *et al.* (2014) on sunflower; Guo Ying *et al.* (1996) on *Populus canadensis*; Hassan *et al.* (2002) on *Acacia saligna, Albizzia lebbek*, *Melia azedarach, Taxodium diatichum* and *Tipuana specios*.

Results of Table (6) indicate that no significant differences in Cd concentration in all study priods (6, 12 and 18) months. The same trend was found with Pb concentration. The highest Zn concentration after 6 months, although there are decreasing after 12 and 18 months. This result is similar to the findings of Guo Ying *et al.* (1996) on *Populus canadensis* and Sebastiani *et al.* (2004) on *Populus species*

Table 4: Average values of Nitrogen, Phosphorus and Potassium content, uptake and total uptake of Taxodium *distichum* as affected by type tested soil during 18 months (2015–2016).

Nitrogen -Concentration (%)									
	6 months			**12 months**			**18 months**		
Treatments	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated (control) soil	1.96 d	0.60 f	0.76 e	2.13 b	0.61e	0.92 b	1.93 e	0.79 c	**0.74 f**
Contaminated soil	2.47 a	0.74 d	0.77 d	2.13 b	1.14 a	1.10 a	2.10 c	0.88 b	**0.81 c**
Uptake (g)									
Uncontaminated (control) soil	0.57 e	0.19 d	0.17 f	0.90 d	0.27cd	0.28 c	1.13 c	0.53 b	**0.24 d**
Contaminated soil	1.17 c	0.36 c	0.22 e	1.41 b	0.83 a	0.43 a	1.85 a	0.93 a	**0.41 b**
Total uptake (g / plant)									
Uncontaminated (control) soil		0.93 f			1.45 e			**1.90 c**	
Contaminated soil		1.75 d			2.67 b			**3.19 a**	
Phosphorus -Concentration (%)									
	6 months			**12 months**			**18 months**		
	Leaves	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated (control) soil	0.35 c	0.12 b	0.12 b	0.20 e	0.12 b	0.15 c	0.15 f	0.12 b	**0.14 d**
Contaminated soil	0.40 b	0.12 b	0.14 d	0.34 d	0.13 a	0.30 a	0.46 a	0.13 a	**0.20 b**
Uptake (g)									
Uncontaminated (control) soil	0.10 d	0.04 d	0.03 d	0.08de	0.05 c	0.04 c	0.09 e	0.08 b	**0.05 c**
Contaminated soil	0.18 c	0.06 c	0.04 c	0.23 b	0.09 b	0.12 a	0.40 a	0.14 a	**0.10 b**
Total uptake (g / plant)									
Uncontaminated (control) soil		0.17 e			0.17 e			**0.22 d**	
Contaminated soil		0.28 c			0.44b			**0.64a**	
Potassium -Concentration (%)									
	6 months			**12 months**			**18 months**		
Treatments	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated(control) soil	1.00 c	0.40 c	0.27 f	0.75 e	0.35 d	0.40 c	0.75 e	0.30 e	**0.33 e**
Contaminated soil	1.75 a	0.44 b	0.36 d	0.85 d	0.40 c	0.41 b	1.15 b	0.85 a	**0.44 a**
Uptake (g)									
Uncontaminated (control) soil	0.29 e	0.13 e	0.06 b	0.32 e	0.16 d	0.12ab	0.44 d	0.20 c	**0.11ab**
Contaminated soil	0.77 b	0.21 c	0.29 a	0.56 c	0.29 b	0.16 ab	1.01 a	0.90 b	**0.22ab**
Total uptake (g / plant)									
Uncontaminated (control) soil		0.48 f			0.60 e			**0.75 d**	
Contaminated soil		1.27 b			1.01c			**2.13 a**	

Table 5: Average values of Cadmium, Lead and Zinc content, uptake and total uptake of Taxodium *distichum* as affected by type tested soil during 18 months (2015–2016).

					Cadmium -Concentration (ppm)				
		6 months			**12 months**			**18 months**	
Treatments	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated(control) soil	0.00c	0.00c	0.00c	0.00c	0.00c	0.00c	0.00c	0.02c	**0.02c**
Contaminated soil	0.03b	0.04b	0.10a	0.05b	0.04b	0.07b	0.03b	0.07b	**0.16a**
					Uptake (mg)				
Uncontaminated(control) soil	0.000c	0.001c	0.001c	0.000c	0.000c	0.000c	0.000c	0.000c	**0.000c**
Contaminated soil	0.001b	0.003b	0.006b	0.002 b	0.004b	0.038a	0.009b	0.004b	**0.086 a**
					Total uptake (mg / plant)				
Uncontaminated(control) soil		0.002 c			0.000 c			**0.000c**	
Contaminated soil		0.010 b			0.044b			**0.099 a**	
					Lead -Concentration (ppm)				
		6 months			**12 months**			**18 months**	
Treatments	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated (control) soil	2.21 d	4.53 c	8.73 bd	4.70 b	6.00 b	8.86 d	4.74b	6.00 b	**17.20b**
Contaminated soil	3.82 c	5.80b	10.79c	5.04 b	9.42a	17.30 b	7.82 a	8.70a	**18.60a**
					Uptake (mg)				
Uncontaminated(control) soil	0.06e	0.14e	0.20e	0.20d	0.27d	0.27d	0.28c	0.40c	**0.56c**
Contaminated soil	0.17d	0.28d	0.31d	0.52a	0.69b	0.67b	0.45b	0.92a	**0.95a**
					Total uptake (mg / plant)				
Uncontaminated(control) soil		0.40e			0.74d			**1.24c**	
Contaminated soil		0.76d			1.88b			**2.32a**	
					Zinc -Concentration (ppm)				
		6 months			**12 months**			**18 months**	
Treatments	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**	**Leaves**	**Shoots**	**Roots**
Uncontaminated(control) soil	30.64 d	68.3 c	21.86e	37.50c	75.80 c	39.80 d	41.68 c	76.4 c	**48.40 c**
Contaminated soil	66.7 b	86.7 b	69.20b	67.98b	145 a	107.4 a	115.16a	138.8 a	**111.08a**
					Uptake (mg)				
Uncontaminated(control) soil	0.73 e	2.19 e	0.49 f	1.57 d	3.40 d	1.20 e	2.46 c	5.12 c	**1.59 d**
Contaminated soil	2.92 d	4.31 c	2.00	4.51 b	10.56 b	4.21 b	10.13 a	14.67 a	**5.72 a**
					Total uptake (mg / plant)				
Uncontaminated(control) soil		3.41 e			6.17 d			**9.17 c**	
Contaminated soil		9.23 c			19.28 b			**30.52 a**	

Table 6: Average values of Cadmium, Lead and Zinc content of *Taxodium distichum* as affected by type tested soil during 18 months (2015–2016).

Uncontaminated (control) soil	Cadmium Concentration (ppm)	Lead Concentration (ppm)	Zinc Concentration (ppm)
6 months	0.014b	2.640b	**15.096d**
12 months	0.016b	2.198b	**11.652d**
18 months	0.004c	2.002b	**8.000e**
Contaminated soil			
6 months	0.036a	5.326a	**182.304a**
12 months	0.033a	5.150a	**81.900b**
18 months	0.028a	4.514a	**20.440c**

Average values followed by a similar letter within a column are not significantly different, using least significantly differences test procedure (L.S.D) at $p \leq 0.05$ level of probability

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