MONITORING OF ENVIRONMENTAL POLLUTION IN A WOODY FOREST IRRIGATED WITH CONTAMINATED WASTEWATER SUBJECTED TO A PRIMARY TREATED

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ABSTRACT:

This study was aimed at monitoring the environmental pollution of a loamy sand soil cultivated with different tree woody species, *i.e., Morus alba*, *Khaya senegalensis*, *Acacia saligna* and *Populus nigra* and irrigated with treated contaminated wastewater through drip irrigation system. Some heavy metals, *i.e*, Cd, Co, Ni and Pb were determined in each of irrigation water, irrigated soil and grown woody trees, whether the expected phytoremediators were able to accumulate and translocate these heavy metals, from lower plant part tissues to the upper ones, taking into consideration their concentrations in irrigation water and irrigated soil. In order to achieve this target, two areas were selected in Egypt, *i.e.,* a) Egyptian Chinese friendship woody forest of the previous four tree species at Sadat City, Minufiyah Governorate, Egypt which irrigated with a primary treated wastewater and b) Egyptian-Japanese woody forest at Wadi Al-Natron, Behaira Governorate, which irrigated with natural underground water, as a control for *Acacia saligna* only.

The obtained results showed an always seasonal difference as regards different studied heavy metal concentrations in irrigation water during 2010 that was noticeably higher than 2009. However, Ni and Pb concentrations in irrigation water of Sadat City area exceeded the permissible values of Egypt contaminated water. Also, Ni concentration in the natural underground water of Wadi Al-Natron area exceeded the permissible limit values of fresh water. As for heavy metal concentrations in the soil, data revealed that Cd concentrations were found in a low concentration at soil supporting *Populus nigra* vs a high concentration in subsurface layer (20-40 cm) in the soil supporting *Acacia saligna*. The highest concentration of Ni was occurred at subsurface layer (20-40 cm) of soil supporting *Acacia saligna* and *Khaya senegalensis*. On the other hand, soil Pb and Co concentrations were almost similar for the four tree species.

Concerning the metal concentrations in tree species, there were insignificant differences for Cd concentrations in different tree stems, however, the different distribution pattern of Co concentrations in stem could be categorized in an ascending order of *Populus* > *Morus* > *Khaya* > *Acacia*. Co and Ni concentrations in leaves were also taken an ascending order of *Morus* > *Khaya* > *Acacia* > *Populus*. Pb concentrations in leaves were taken ascending order of *Morus* > *Acacia* > *Khaya* > *Populus*. All metals were successfully transported from roots to stems for all the investigated tree species. In *Morus alba* metals showed translocation preferences of Pb > Ni > Co > Cd vs Cd > Pb > Ni > Co in *Khaya*, Cd > Ni > Co > Pb in *Acacia* and Pb > Co > Ni > Cd in *Populus*. In addition, *Morus alba* exhibited Ni and Co highest translocation factor values that were found only at the highest temperature degrees.

Moreover, Ni and Co concentrations in plant were found to be affected by soil pH, organic matter and irrigation water salinity these may be assisting naturally to accelerate soil phytoremediation processes at warm climate under desert regions. So, it could be recommended that using *Morus alba* and *Populus nigra* for metal removal from soil is only technically feasible in short time period if more metal can be made available by adding chemicals to soil that increased their concentrations. It is essential in case of using *Morus alba* as a phytoremediator to discard any fruit or leaves, however, it is also recommended to study the effect of accumulated metals in *Morus* leaves on silk warm as a biological indicator. The metal amounts extracted by plants can be put into perspective by calculating a theoretically decrease in soil metal concentrations from the known plant maximum metal concentrations in order to calculate the concentration factor, *i.e.,* CF = metal concentration in plant tissue/its concentration in the soil. This could be achieved according to the number of planted trees/fed. Also, it should be following up Ni concentration in the natural underground water at the Egyptian-Japanese forest to avoid Ni pollution.

Keywords: Woody forest, environmental pollution, phytoremediation of heavy metals.

INTRODUCTION:

Heavy metals contamination of soil and groundwater is widespread and hazardous to human and animal life. There are many sites need remediation all over the world**.** Phytoremediation is a viable, relatively low-cost approach to removing heavy metals from soil and groundwater (**Salido *et al*., 2003).** Heavy metals contamination occurs from a variety of sources. Sewage sludge treatments used as a fertilizer are major contributors to soil contamination **(Do Nacimiento *et al*., 2006)**. Phytoremediation is the use of green plants to remove contaminants from soil and groundwater or to lower contaminant mobility by using phytoextraction, rhizofilteration, phytovolitization or phytotransformation **(Madrid *et al*., 2003).** Hyperaccumulators are plants that are able to take up large quantities of metals (**Roosens *et al*., 2003)**. The classification of a hyperaccumulator is based on the ability to uptake and retain, within the stem and leaves **(Turgut *et al*., 2005**).

The cost of phytoremediation can be as low as $0.05 per cubic meter **(Li, 2004)**. The total and available heavy metal concentrations of Cd, Ni, and Pb in the soil of the Egyptian Chinese forest at Sadat city, Menoufia Governorate, were found to be relatively high, their concentrations in the growing plant tissues, were over the allowable limits specially Ni **(Salem, 2004**). These metals were tested together for the best understanding of the plant response*; Morus alba, Acacia salegna, Khaya senegalensis and Populus nigra* are among the well growing woody species in the Egyptian Chinese forest. Most trace elements in water especially heavy metals do not exist in soluble forms for long time, they are present mainly as suspended in colloids or are fixed by organic and mineral substances. On average, 25,000 to 30,000 tons of cadmium is released into the environment each year (**ATSDR, 1999)**. In Egypt the content of heavy metals in irrigation water was studied by many investigators, **Abo El-Roos *et al.* (1996)** reported that the use of wastewater in irrigation is the main source of heavy metals in agricultural soil in Egypt.

Concentration of heavy metals in waste water samples had wide variation from month to the other. Once the metals have been concentrated and extracted by the plants they can be easily removed from the site (**Vervake *et al*., 2006)**.

There are several plants mechanisms employed in reaction to exposure to contamination. These include phytoextraction, rhizofiltiration, phytovolatliz, Phyto-stabilization, phytotransformation and phytodegradation and aerial contaminant removal **(Yang *et al,* 2005)**. Once the metals are available to the plant, they must be transported across the membrane of root cells, loaded into and translocate through the xylem and detoxified and stored within cells of the plant in a particular section (roots, leaves, stems). Nickel has shown 60-70% storage in cell walls rather than vacuoles (**Yang *et al.*, 2005**). There are three mechanisms that accompany heavy metal toxicity in plants; autoxidation and Fenton reaction production of reactive oxygen species blocking essential functional groups in the biomolecules and storage of essential metals ions from the biomolecules **(Nouairi *et al*., 2006)**. Several factors affect metal uptake and distribution in plants, including physiochemical properties of contaminants, temperature, soil properties and plant characteristics **(Gardea *et al*., 2005).** Plants are able to exude materials from roots to acidify soil and increase solubility and transports of contaminants **(Suresh and Ravishankar, 2004)**. **Do Nacimiento *et al.* (2006)** showed a shoot selectivity of Ni > Cd = Pb without EDTA and Ni > Pb > Cd with EDTA.

This study was aimed at monitoring some heavy metals status in irrigation water, soil media and grown tree species in a natural woody forest irrigated with treated contaminated wastewater, with special reference to make a comparative study with un-contaminated woody trees as a control.

MATERIALS AND METHODS

This study was carried out on two selected areas, *i.e.,* 1) Egyptian Chinese Friendship Woody Forest that were planted in 2001 at Sadat city, Menoufiah Governorate, 88 km northern- west of Cairo City and 2) Egyptian Japanese Woody Forest at Wadi Al-Natrun, Beheira Governorate, 150 km northern-west of Cairo City, Egypt. Such two areas represent a portion of the Northern African Sahara Region. The grown woody trees in the first area were directly irrigated with primary treated wastewater (an oxidation pond via drip irrigation), while the second one irrigated with the natural underground water. In general, soil texture of the selected two areas is loamy sand (sand = 80.33%, silt = 17.23% and clay = 2.44%). The two areas have an arid climate with a rare winter rainfall, some meteorological data for 2009 and 2010 are presented in Table (1).

Table (1): Meteorological data of Sadat City and Wadi Al-Natron Stations.

Area	Season	Temperature ^{0}C (mean)	Relative humidity %	ET_0
Sadat	Spring 2009	9.26	70.67	3.19
	Autumn 2009	23.33	65.89	4.19
	Spring 2010	15.20	65.29	3.23
	Autumn 2010	26.30	70.10	4.60
Wadi Al-Natron		24.21	59.22	4.19

Woody stands in the first area are included four tree species, *i.e.*, *Morus alba*, *Acacia salegna*, *Khaya senegalensis* and *Populus nigra*. Soil characteristics at each species were studied at soil depths of 0-20, 20-40 and 40-60 cm. A comparison study was undertaken on the studied heavy metals absorb by *Acacia* trees under the same experimental conditions of the un-polluted area of Wadi Al-Natron. Thus, the essential materials in this investigation are the growing woody trees, their supporting soil, irrigation water samples from either oxidation pond at Sadat city or natural underground water at Wadi Al-Natron. The chosen investigated tree species of *Morus alba*, *Acacia saligna*, *Khaya senegalensis* and *Populus nigra* in the first area are belonging the families of *Moraceae, Mimosaceae, Meliaceae and Salicaceae,* respectively, while the second area comprises *Acacia saligna*.

Irrigation water samples were collected four times during the studied periods (spring and autumn of 2009 and 2010 seasons), transported immediately to the laboratory for analysis. Soil samples supporting investigated tree species were collected from both areas for analysis. Plant samples were taken from each area for analysis. Tables (2-5) showed some chemical properties and heavy metal concentrations in the studied irrigation waters and soils, which were determined according to the methods outlined by **Jackson (1973)**. Soil particle size distribution and $CaCO_3$ were determined according to **Piper (1950).** Soil organic matter was determined according to the method outlined by **Black *et al.* (1965**). Concentrations of Cd, Co, Ni and Pb in the used irrigation water as well as their available concentrations in soil were extracted according to **Soltanpour (1985)**, and were measured using the Inductively Coupled Plasma Spectrometry (Plasma 400). Translocation factor of heavy metals was determined by dividing the total concentration in both stems and leaves by concentration in plant roots **(Do Nacimiento *et al.*, 2006**). The obtained data were statistically analyzed by using the soft ware of SPSS statistical package of Social Science Version 13.

Table (2): Water chemical characteristics of the oxidation pond (Sadat) and natural underground water samples (Wadi Al-Natron) during studied seasons.

Area	Season	pH	EC (dS m^{-1})	SAR	Hardness*
Sadat	Spring 2009	6.60	1.55	5.38	175
	Autumn 2009	7.40	1.76	3.90	295
	Spring 2010	6.90	1.67	3.78	295
	Autumn 2010	6.60	1.77	4.36	295
Wadi Al-Natron		7.20	1.20	11.9	80

*Hardness = $(Ca^{+2} + Mg^{+2})$ m mol_c L^{-1} x 5

Table (3): Water concentrations of heavy metals (means ± Sd) of a primary treated wastewater (Sadat) and natural underground water samples (Wadi Al-Natron) during the studied seasons.

Area	Season	Heavy metal contents (mg L^{-1})			
		Cd	Co	Ni	Pb
Sadat	Spring 2009	0.009±0.001	0.016±0.001	1.467±0.000	0.011±0.000
	Autumn 2009	0.003±0.001	0.0111±0.001	1.660±0.000	0.075±0.001
	Spring 2010	0.000±0.000	0.053±0.001	3.506±0.001	4.123±0.000
	Autumn 2010	0.144±0.001	0.064±0.001	1.781±0.000	40.098±0.000
Wadi Al-Natron		0.003	0.076	0.989	0.007

Table (4): Chemical properties of soil supporting tree species as affected by irrigation water in both areas during the studied seasons.

Area	Season	Tree species	Depth (cm)	2009				2010			
				pH	Organic matter %	ECe (dS m^{-1})	$CaCO_3$ %	pH	Organic matter %	ECe (dS m^{-1})	$CaCO_3$ %
Sadat City	Spring	*Morus alba*	0-20	6.60	1.90	0.21	2.80	5.60	2.00	1.80	2.00
			20-40	6.90	1.70		2.60	5.70	1.10		2.00
			40-60	6.90	1.00		2.40	5.70	0.50		1.80
	Autumn		0-20	6.40	1.80	0.13	0.20	6.60	2.90	0.19	2.40
			20-40	7.00	1.80		1.80	6.80	1.80		2.20
			40-60	7.60	1.00		1.40	7.00	1.00		1.80
	Spring	*Khaya senegalensis*	0-20	6.60	2.10	0.21	1.40	6.00	2.20	1.80	3.40
			20-40	6.60	1.90		1.30	5.60	2.00		3.20
			40-60	6.90	1.70		1.20	5.40	0.80		3.00
	Autumn		0-20	6.60	2.00	0.13	2.40	7.00	2.30	0.19	1.80
			20-40	6.90	1.10		2.20	7.00	2.20		1.40
			40-60	7.00	1.60		1.80	7.20	0.50		1.60
	Spring	*Acacia saligna*	0-20	6.30	2.00	0.21	2.00	6.70	2.00	1.80	3.00
			20-40	6.90	1.70		1.70	6.70	1.80		2.80
			40-60	7.00	1.70		1.70	6.60	0.90		2.40
	Autumn		0-20	6.60	5.60	0.13	1.90	6.90	2.20	0.19	2.00
			20-40	5.60	5.60		1.90	6.90	2.00		2.20
			40-60	5.40	5.40		1.90	6.70	0.90		2.00
Vadi Al-Natron	Spring		0-20	7.60	1.40	1.53	4.50	7.60	1.50	1.50	4.60
			20-40	7.54	1.10		4.22	7.50	1.10		4.20
			40-60	7.04	1.10		3.55	7.00	1.10		3.50
Sadat City	Autumn	*Populus nigra*	0-20	6.60	2.30	0.21	2.30	6.00	1.80	1.80	2.00
			20-40	6.90	2.10		2.10	5.60	1.80		1.90
			40-60	7.20	1.20		1.20	5.60	0.90		3.00
	Spring		0-20	7.00	1.90	0.13	1.90	6.00	2.00	0.19	2.40
			20-40	7.40	1.90		1.60	6.00	1.90		3.80
			40-60	7.60	1.30		1.30	6.00	0.90		1.60

Table (5): Heavy metal concentrations (means ± Sd) in cultivated soil at both studied areas during the tested periods.

Sites	Tree species	Depth (cm)	Heavy metal concentrations (mg kg^{-1} soil)			
			Cd	Co	Ni	Pb
Sadat City	*Morus* alba	0-20	0.704±1.104	0.411±0.366	8.315±9.309	5.7747±8.440
		20-40	0.001± 0.001	0.031±0.032	1.786±1.901	0.722±0.532
		40-60	0.083±0.022	0.076±0.011	11.323±7.623	4.861±7.496
	Khaya senegalensis	0-20	0.089±0.152	0.173±0.233	3.617±2.620	4.434±7.605
		20-40	0.012±0.016	0.036±0.041	6.379±6.842	1.694±2.417
		40-60	0.002±0.002	0.024±0.031	6.821±5.326	0.170±0.080
	Acacia saligna	0-20	0.089±0.152	0.173±0.233	4.445±2.842	4.434±7.605
		20-40	0.160±0.275	0.098±0.098	6.379±6.842	1.694±2.417
		40-60	0.057±0.002	0.098±0.113	6.821±5.326	2.197±3.596
Wadi Al-Natron		0-20	0.000	0.058	1.109	0.175
		20-40	0.000	0.125	1.633	0.083
		40-60	0.000	0.128	2.528	0.000
Sadat City	*Populus nigra*	0-20	0.012±0.019	0.185±0.267	8.310±14.283	6.853±11.936
		20-40	0.002±0.003	0.023±0.027	1.160±1.713	3.151±5.429
		40-60	0.051±0.089	0.112±0.157	6.334±9.796	3.087±5.257

RESULTS:

I. Statistically relationships between heavy metal concentrations, atmospheric temperature, irrigation water salinity and soil pH:

a. Atmospheric temperature:

Table (6) reveals a negative correlation between Cd, Co and Pb concentrations in roots of *Acacia, Khaya and Populus*, and atmospheric temperature. On the other hand, it reveals a positive correlation with Ni concentration in root of *Khaya* and all metal concentrations in *Morus* root and atmospheric temperature.

Table (6): Simple correlation coefficients between atmospheric temperature and heavy metal concentrations in root of the tree species during studied periods.

Heavy Metal	Tree species			
	Morus alba	*Acacia saligna*	*Khaya senegalensis*	*Populus nigra*
Cd	0.597	-0.276	-0.010	-0.281
Co	0.519	-0.277	-0.343	-0.287
Ni	0.078	-0.058	0.108	-0.234
Pb	0.734	-0.284	-0.248	-0.169

b. Irrigation water salinity:

Table (7) reveals that there is a negative correlation between soil metal concentrations under *Khaya* and *Populus* and the irrigation water salinity, while soil supporting *Morus* shows a negative correlation between water salinity and its Pb concentrations only. On the other hand, soil supporting *Acacia* at the first area shows a negative correlation between soil Pb and Co concentrations and irrigation water salinity.

Table (7): Simple correlation coefficients between irrigation water salinity (EC) and heavy metal concentrations in soil supporting the tree species during studied periods.

Heavy Metal	Tree species			
	Morus alba	*Acacia saligna*	*Khaya senegalensis*	*Populus nigra*
Cd	0.545	0.070	-0.130	-0.180
Co	0.390	-0.394	-0.396	-0.192
Ni	0.298	0.294	-0.141	-0.060
Pb	-0.047	-0.086	-0.119	-0.120

Morus metal root concentration shows a positive correlation with irrigation water salinity, where *Acacia* Ni root concentration, *Khaya* Cd and Ni root concentration and *Populus* Pb- root concentration show a positive correlation with irrigation water salinity (Table 8).

Table (8): Simple correlation coefficients between irrigation water salinity (EC) and heavy metal concentrations in root of the tree species during studied periods.

Heavy Metal	Tree species			
	Morus alba	*Acacia saligna*	*Khaya senegalensis*	*Populus nigra*
Cd	0.128	-0.106	0.100	-0.110
Co	0.612	-0.103	-0.168	-0.116
Ni	0.286	0.088	0.307	-0.062
Pb	0.826	-0.183	-0.078	0.004

c. Soil pH:

Table (9) reveals a positive correlation between soil pH at 40-60 cm depth and *Morus* root Co concentration, positive correlation with Cd, Co, Ni and Pb concentration in *Acacia* root and negative correlation between *Khaya* and *Populus* root metal concentrations and soil pH.

Table (9): Simple correlation coefficients between pH values at 40-60 cm depth and heavy metal concentrations in root of the tree species during studied periods.

Heavy Metal	Tree species			
	Morus alba	*Acacia saligna*	*Khaya senegalensis*	*Populus nigra*
Cd	-0.456	0.170	-0.930	-0.703
Co	0.519	0.143	-0.990	-0.660
Ni	-0.399	0.151	-0.838	-0.660
Pb	-0.260	0.165	-0.981	-0.732

II. Heavy metal contents in oxidation pond and natural underground waters:

The concentration of heavy metals (Cd, Co, Ni and Pb) in irrigation water samples collected from the oxidation pond and natural underground water, Table 3, showed an always seasonal difference as regards different elements in the oxidation pond water (P <0.001). Generally metal concentrations were noticeably higher during 2010 than 2009. Also, concentrations of Cd, Co, Ni and Pb, as mean values during autumn 2010 at Wadi Al-Natron area, were 0.003, 0.076, 0.989 and 0.007

mg L^{-1}**,** respectively. Moreover, nickel concentrations at the same area was recorded the highest value, which exceeded the FAO critical limit of fresh water.

III. Heavy metal concentrations in the studied soil:

a. Available cadmium (Cd):

Regarding soil supporting *Acacia* at Sadat City area as compared to Wadi Al-Natron area, Table 5, the mean values of Cd were zero in all soil depths. Available Cd concentration on the surface layer (0-20 cm) of soil supporting *Morus* showed the highest concentration where ($P < 0.05$), while in the subsurface layer (20-40 cm) soil supporting *Acacia* showed the highest significant Cd concentration ($P < 0.05$) and at the deep layer (40-60cm) showed insignificant differences between soil supporting different species ($P > 0.05$).

b. Available cobalt (Co):

Concerning soil supporting *Acacia* at Sadat City area as compared to Wadi Al-Natron area, Table 5, the mean values of Co were 0.058, 0.125 and 0.128 mg kg^{-1} on the surface 0-20cm, subsurface 20-40cm and deep 40-60cm layers, respectively. Statistically, there was insignificant differences for Co concentrations in soil supporting different species ($P > 0.05$) at the surface 0-20cm layer. Also, Co concentrations showed the highest significant Co values ($P < 0.05$) in the surface 0-20cm layer soil supporting *Acacia*, while there was insignificant difference between soil supporting different species ($P > 0.05$) at the deep 40-60 layer.

c. Available nickel (Ni):

With respect to soil supporting *Acacia* at Sadat City area as compared to Wadi Al-Natron area, Table 5, Ni contents were 1.109, 1.633 and 2.528 mg kg^{-1} for the surface 0-20cm, subsurface 20-40cm and deep 40-60cm layers, respectively.

Also, there was insignificantly difference between Ni concentrations in soil supporting the different tree species ($P>0.05$) at the surface layer (0-20 cm). as for the subsurface layer (20-40 cm) of soil supporting *Acacia* and *Khaya*, the statistical analysis showed a highly significant difference in Ni concentrations ($P<0.05$), while at the deep layer (40-60 cm) there was an insignificant difference between soil supporting the different tree species ($P > 0.05$).

d. Available lead (Pb):

Regarding soil supporting *Acacia* at Sadat City area as compared to Wadi Al-Natron area, Table 5, the mean values of Pb were 0.175, 0.083 and 0.000 mg kg^{-1} for the surface (0-20 cm), subsurface (20-40cm) and deep (40-60cm), respectively. All soil depths supporting the different tree species showed insignificant difference between Pb concentrations in soil supporting various tree species ($P > 0.05$),

IV. Heavy metal accumulations in the different plant organs (root, stem, leaf and fruit) of the investigated tree species:

a. Cadmium concentration:

Table (10) showed that Cd concentration as mean values in *Acacia* cultivated at Wadi Al-Natron were 0.001, 0.002 and 00.000 mg kg^{-1} in tree roots, stems and leaves. At Sadat City area, the root Cd-concentration mean values in both *Acacia* and *Khaya* were similarly low, in contrast *Morus* and *Populus* have similarly the highest Cd concentration in their roots during studied period ($P < 0.05$). There were insignificant differences in Cd-concentrations of tree stems, leaves and fruits of various tree species ($P > 0.05$)

Table (10): Heavy metal concentrations (means ± Sd) in plant organs of the studied tree species during the tested periods.

Area	Tree species	Plant organ	Heavy metal concentrations (mg kg^{-1})			
			Cd	Co	Ni	Pb
Sadat City	*Morus* alba	Root	0.149±0.1025	0.481±0.528	1.950±1.901	5.708±3.540
		Stem	0.117±0.078	0.123±0.129	1.782±1.065	1.105±1.410
		Leaf	0.039±0.065	0.377±0.673	0.377±0.673	12.832±23.144
		Fruit	0.035±0.064	0.373±0.676	2.755±4.985	3.243±5.866
	Khaya senegalensis	Root	0.009±0.010	0.013±0.020	0.440±0.374	0.543±0.860
		Stem	0.049±0.084	0.046±0.078	4.804±8.061	0.874±1.410
		Leaf	0.056±0.102	0.046±0.078	0.046±0.078	0.419±0.751
		Fruit	ns	ns	ns	Ns
	Acacia saligna	Root	0.031±0.055	0.066±0.112	0.750±0.870	2.255±4.034
		Stem	0.025±0.045	0.031±0.052	1.014±1.019	4.677±8.126
		Leaf	0.166±0.300	0.042±0.044	0.042±0.044	0.602±1.081
Wadi Al-Natron		Fruit	0.049±0.089	0.429±0.776	0.352±0.636	0.832±1.505
		Root	0.001	0.000	0.601	0.040
		Stem	0.002	0.000	0.604	0.049
		Leaf	0.000	0.000	0.447	0.094
		Fruit	ns	ns	ns	Ns
Sadat City	*Populus nigra*	Root	0.168±0.298	0.119±0.214	1.181±1.851	0.361±0. 480
		Stem	0.181±0.264	0.634±0.823	8.258±12.795	4.049±6.606
		Leaf	0.011±0.019	0.015±0.019	0.015±0.019	0.011±0.019
		Fruit	ns	ns	ns	Ns

b. Cobalt concentration:

The Co concentration as mean values in *Acacia* cultivated at Wadi Al-Natron, Table 10, were zero in all plant organs. Root

Co concentration of *Morus* at Sadat City area showed the highest concentration, meanwhile its soil has no the lowest value. On the other hand, *Acacia* showed the highest Co contents in the subsurface soil depth (20-40 cm), while its roots have no the lowest concentration (P <0.001). Stem-Co concentrations were showed significant differences between various tree species (P <0.05). Co-concentration as mean values in tree stems could be categorized in an ascending order of *Populus* > *Morus*> *Khaya*> *Acacia*. Leaf-Co concentrations showed wide variations in the investigated tree species (P<0.05). Its concentrations could be categorized in an ascending order of *Morus* > *Khaya* > *Acacia* > *Populus*. Fruit Co concentrations showed insignificant differences between the investigated tree species (P > 0.05).

c. Nickel concentration:

Nickel concentrations as mean values in *Acacia* cultivated at Wadi Al-Natron, Table 10, were recorded 0.601, 0.604 and 0.447 mg kg^{-1} in the tree roots, stems and leaves, respectively. The highest values of Ni concentration were found in the subsurface layer (20-40 cm) of soil supporting both *Acacia* and *Khaya* of Sadat City, with insignificant differences in their root concentrations (P >0.05). There were also no differences in Ni stem concentration between various species (P >0.05). Meanwhile, there were significant differences between tree species for leaves (P<0.05), where Ni concentrations could be arranged in an ascending order of *Morus* > *Khaya* > *Acacia* > *Populus.* As for Ni concentration in fruits, There were insignificant differences between various tree species (P >0.05).

d. Lead concentration:

The obtained data of Pb concentration, Table 10, revealed that its mean values in *Acacia* cultivated at Wadi Al-Natrons area during autumn 2010 were

0.040, 0.049 and 0.094 mg kg^{-1} in tree roots, stems and leaves. *Morus* root seems to absorb Pb more than other organs of tree species (P <0.001). In tree stems, there was insignificant differences between the investigated tree species, (P >0.05). While, leaf Pb concentrations exhibited a wide variation between the investigated tree species (P<0.05), with an ascending order of *Morus* > *Acacia* > *Khaya* > *Populus.* Whereas, there was insignificant difference between tree species for fruits (P >0.05)

V. Sequestration preferences and translocation factors:

The data of different metal sequestration preferences within plant organs in various investigated tree species are presented in Table 11. *Morus* root seems to sequestrate Cd, Co and Ni, while Pb found to be sequestrated more in leaves. *Khaya* stem seems to sequestrate Ni and Pb, while Co found to be similarly sequestrated in stems and leaves.

Table (11): Metal sequestration preferences within plant organs and tree species during studied period.

Tree species	Cd	Co	Ni	Pb
Morus alba	R>S>L	R>L>S	R>S>L	L>R>S
Khaya sengalensis	L>S>R	S=L>R	S>L>R	S>L>R
Acacia saligna	L>R>S	R>L>S	S>R>L	L>R>S
Populus nigra	R>S>L	S>R>L	S>R>L	S>R>L

R=Root S=Stem L=Leaf

Metal sequestration preferences following different order within tree organs of *Acacia*. *Populus* stem seems to sequestrate Co, Ni and Pb, while Cd seems to be sequestrated more in *Populus* roots.

VI. Metal translocation factors:

Data showed that all investigated tree species are able to translocated metals from roots to shoots, where all values of translocation factors are above 1. Cd, Co, Ni and Pb translocation factor values in *Morus* are 1.00, 1.03, 1.10 and 2.44, respectively. The corresponding translocation factor values are 4.50, 1.10, 1.40 and 2.29 in *Khaya* vs 11.66, 2.46, 11.01 and 2.38 in *Acacia* and 1.14, 3.18, 1.18 and 11.84 in *Populus*, respectively.

VII. Relation between metal translocation factors in the tree species and recorded atmospheric temperature in different studied seasons:

The obtained data in Table 12 showed that *Morus* Co and Ni translocation factors were the highest values at the highest temperature. In contrast, an opposite relation shows for *Populus* Cd, Co, Ni and Pb translocation factors, where the highest values were recorded at the lowest temperature.

Table (12): Translocation factors for tree species as affected by atmospheric temperature.

Tree species	Temperature	Cd	Co	Ni	Pb
Morus alba	9.26	0.000	0.50	1.533	1.800
	23.33	0.000	0.50	0.694	0.232
	15.20	0.513	0.76	3.349	6.401
	26.30	0.563	48.00	10.670	0.191
Populus nigra	9.26	121.00	606.00	300.560	254.000
	23.33	1.00	0.00	21.196	1.628
	15.20	1.02	5.04	4.741	15.190
	26.30	0.40	0.00	3.847	1.000
Acacia saligna	9.26	0.00	0.500	0.977	254.000
	23.33	0.00	0.766	9.000	15.105
	15.20	6.18	0.500	2.030	1.628
	26.30	0.50	48.000	1.203	1.280
Khaya senegalensis	9.26	0.000	0.666	1.071	0.666
	23.33	0.555	3.333	0.900	0.225
	15.20	9.423	3.800	19.528	2.490
	26.30	0.000	1.096	3.264	1.096

Meanwhile, *Acacia* metal translocation factors showed different behaviour towards the various studied metals, the highest Co translocation factor showed the highest value at the highest temperature, while the reverse was true for that shows its highest translocation factor at the lowest temperature. On the other hand, there was no a specific trend between temperature and *Khay*a metal translocation factors. The translocation preference patterns were varied according the nature of the investigated tree species, *i.e.,* Pb>Ni>Co>Cd, Cd>Pb>Ni>Co, Cd>Ni>Co>Pb and Pb>Co>Ni>Cd in *Morus, Khaya, Acacia* and *Populus*, respectively.

DISCUSSION:

a. Atmospheric temperature:

From the previous results it could be observes that there was a positive correlation between metal-root concentrations and atmospheric temperature. These findings are in agreement with **Helal *et al.* (1997**) who found that plants grown at 25°C accumulate higher levels of Cd, Ni and Pb than those grown at 15°C; this appears to be caused by a progressive decline in pH and organic matter soil status.

b. Evaluation of water samples:

The variations in apparent correlation between soil metals and salinity values (slight to moderate) might not be attributed to the irrigation source, but to other factors such as fertilizers, fungicides and bactericides. These opinions are more agreement with the findings outlined by **Abo El-Roos *et al.* (1996)** who reported irrigation water salinity affects heavy metals availability to plants, where high salinity causes an increase in their concentrations. The negative correlation between salinity and metal concentrations may be due to different tree root behavior in the rhizospher, soil properties and pollution with other specific ions of heavy metals. The highest degree of hardness may be due to the presence of gypsum and limestone sediments that are rich in calcium **(Said, 2002)**

c. Metal ions in water:

The maximum concentration of Cd, Co and Pb in the oxidation pond samples which observed during autumn 2010 and highest value of Ni observed in 2010 spring season may be due to the increasing industrial activities during this periods ($P<0.001$).

Statistical analysis shows significant differences between periodically seasons in water Cd contents. Concerning high Co and Ni concentrations observed during 2010 autumn season in the natural underground water at Wadi Al-Natron area may be associated with natural process of chemical weathering of sedimentary rocks, soil leaching of metal polluted water is an important environmental factor as well as other industrial activities in such region. There is always seasonal difference as regards different elements in wastewater, during 2010 the metal contents is noticeably higher in 2010 than 2009, may be due to the different year industrial activities.

d. Soil characteristics:

Soil pH values at a depth 40-60 cm in soil supporting *Morus* has a negative significant correlation with heavy metal concentrations in plant roots, except with Co that shows a positive correlation with soil pH, may be due to different root interactions in the rhizospher, soil properties and other Co-metal pollution interactions in soil. While, a negative correlation with soil pH may be due to tree root behavior with metal uptake in the rhizospher and rhizospheric interactions that may led to modification of root zone pH value with different metals and tree species. That was true, since plant roots have been supported to contribute with the mobilization of nutrients in some species (**Huang, 1997**).

The highest Cd concentration is observed in the surface layer (0-20 cm) of soil supporting *Morus* during autumn 2010, this may be due to the higher soil organic matter in the surface layer because of plant litter accumulation which reduces Cd mobility, and consequently increasing its concentration in the upper layer of the soil profile.

Concerning the highest significantly Cd concentration that is observed in the subsurface 20-40cm layer of soil supporting *Acacia* at Sadat City area, may be attributed to the relatively high soil pH value that reduces Cd mobility, and consequently increases its concentration in such soil depth. The widely variations in Cd values in the studied soil may be due to different pH values in various soil depths. The highest Ni concentrations in soil supporting *Acacia* at Wadi Al-Natron area at the deep 40-60cm layer during autumn may be due to high organic matter content that reduces metal mobility and increase its concentrations in the soil. Statistically, there was insignificant difference in Ni concentrations between soils supporting different tree species in the surface and deep layers ($P>0.05$), while the highest significant Ni concentrations observed in subsurface layer (20-40cm) of soils supporting *Acacia* and *Khaya* ($P <0.05$). These results may be due to the differences in soil pH values and the occurrence of relatively high organic matter content that reduces the mobility of some metals. The highest Pb concentration in soil supporting *Acacia* at Wadi Al-Natron area was observed in surface 0-20cm layer during autumn, may be due to the presence of plant litter on the surface layer that reduces metal mobility and increases its concentrations in the soil.

e. Heavy metal concentrations in the investigated tree roots and shoot systems.

Cd concentrations in *Populus* were higher in tree root (0.663 mg kg^{-1}) than that in tree stem (0.613 mg kg^{-1}) during spring and the lowest value of Cd in the *Populus* organs observed in the new leaves (0.042 mg kg^{-1}) after 2009 winter dormant season. While, the highest concentration of Cd in *Morus* root was associated with high concentration in surface 0-20cm layer, may be due to the upward migration of soluble metal and slow translocation rate from root to shoot with higher organic matter values in the surface layer. *Acacia* and *Khaya* trees have similar affinity for low Cd root absorb, because of the remarkable degree of uptake of specific metal as well as the mechanism of metal selectivity (**Still *et al.*, 1980)**.

Statistical analysis of Co concentration in tree root of the investigated tree species revealed that Co highest concentration was observed in *Morus* root, but its value in soil supporting *Morus* has not the lowest concentration. In contrast, *Acacia* root has the lowest Co concentration and the highest concentration observed in the subsurface layer (20-40 cm) of soil supporting *Acacia* tree. The highest Co concentration was observed in *Morus* root, while it in supporting soil has not the lowest concentration in the subsurface layer (20-40 cm), may be due to the upward migration of soluble metal. These results showed a different behavior of *Morus* root uptake toward Cd and Co, where the Co content during spring showed higher contents in leaves (1.495 mg kg^{-1}) than that in stem (0.904 mg kg^{-1}) and the lowest value (0.353 mg kg^{-1}) in root. That indicates higher Co translocation rate from tree roots to stems than those of Cd, may be due to the different response of *Morus* towards the essential elements such as Co than that of toxic ones such as Cd, where for most of toxic metals the rate of metal translocation from roots to stems that was much lower compared with the rate of uptake of non-toxic metals **(Huang and Cunningham, 1996**). Co concentrations of *Acacia* at Sadat City area achieved 0.066 times higher in tree root, 0.031 times higher in tree stem and 0.042 times higher in tree leaves than those of the same tree cultivated in Wadi Al-Natron area, due to irrigation with wastewater.

Ni concentrations in various tree leaves take the following descending order: *Morus* > *Khaya* > *Acacia* > *Populus*, these may be due to different rate of Ni translocation from tree stem to leaves in different species, while there was insignificant difference in fruit Ni concentration between *Morus* and *Acacia* (P>0.05). Ni concentrations of *Acacia* at Sadat City area achieved 1.247 times higher in tree root, 1.678 times higher in tree stem and 0.093 times higher in tree leaves than those of the same tree cultivated in Wadi Al-Natron, due to irrigation with wastewater. The highest Ni concentration was observed in subsurface layer (20-40cm) of soil supporting both *Acacia* and *Khaya* tree species, but these values in soil are not associated with any root concentration with significant differences. This may be due to the higher rate of translocation of Ni from tree roots to stems, where the highest concentration was appeared in tree leaves. The likely reason may be due to reduction of Ni concentration in tree root and stem after translocation to leaves as a result of the growth dilution effect. The highest concentration was observed in *Morus* leaves and fruit due to high rate of Ni translocation from stem to leaves as a result of different metal accumulation sites in different plants according to **Vazques *et al.* (1992).**

The highest Ni concentration was found in *Acacia* leaves at Sadat City area during autumn. It can be concluded that these results were generally high due to the high concentration of Ni in irrigation water of natural underground water, which absorbed by plant root, then translocated to the upper stem system, but these values still lower than those irrigated with the oxidation pond at Sadat City area. As illustrated presented in Table (11), the data revealed that the highest concentration of Pb observed in *Morus* root, and its concentration in tree root seems to absorb Pb more than roots of the other three species. That was true, since the Pb concentration in soils supporting the four tree species were similar. *Morus* root of Pb concentration gives a supportive evidence of its capability to absorb Pb despite as well as it was the least mobile element (P <0.001). Statistical analysis showed insignificant difference between Pb concentration in stem and fruit of tree species (P>0.05). Pb concentration in leaves tends to be found in different concentrations in various investigated tree species

(P<0.05). Pb concentrations in leaves showed an ascending order of *Morus* > *Acacia* > *Khaya* > *Populus.*

The ability of *Morus* root to absorb Pb may be due to increasing its solubility by root exudes, which was associated with decreasing soil pH in the rhizosphere **(Mc.Grath, 1997)**. The highest Pb concentration observed in *Morus* leaves (51.215 mg kg^{-1}) during spring indicates high translocation rate from root to stem. These results may also due to the presence of phytochelaties, *i.e.*, carboxylic acid that is abundant in cells of terrestrial. It could be concluded that the Pb concentrations of *Acacia* at Sadat City area achieved 56.375 times higher in tree root, 93.40 times higher in tree stem and 6.404 times higher in tree leaves than those of the same tree cultivated in Wadi Al-Natron area, due to irrigation with wastewater.

f. Metal sequestration preferences and translocation factor:

All metal translocation factors were more than 1, means that metals were successfully transported from tree roots to stems. Metal translocation preferences showed an ascending orders of Pb>Ni>Co>Cd, Cd>Pb>Ni>Co, Cd>Ni>Co>Pb and Pb>Co>Ni>Cd. in *Morus, Khaya, Acacia* and *Populus*, respectively.

g. Relation between metal translocation factors in the investigated species and recorded atmospheric temperature in different study seasons:

Morus Ni and Co highest translocation factors found at the highest temperature degrees, the revere was true for *Populus* Cd, Co, Ni and Pb translocation factors that showed the highest values at the lowest temperature. *Acacia* metal translocation factors showed different behaviour with different metals, the highest Co and Pb translocation factors showed the highest values at the highest and lowest temperatures, respectively. On the other hand, there was no relation between temperature and *Khaya* metal translocation factors. It can be concluded that various tree metal translocation factors have different behaviour with atmospheric temperature. In general, it was found that metal translocation factors are not only affected by atmospheric temperature but also are affected by soil pH, organic matter and irrigation water salinity. Such conditions may be assist naturally to accelerate soil phytoremediation processes at the warm climate of desert regions.

CONCLUSIONS

Generally, *Morus* and *Populus* both acted like Cd extractors, however, the current study shows that *Populus* has been able to remove Cd from the soil, while *Morus* acted like Cd, Co, Ni and Pb extractor, it is classified as un-hyperaccumulators. All metals were successfully transported from tree roots to shoots for all the investigated tree species. Metal sequestration preferences in *Morus, Acacia, Khaya and Populus* could be categorized in the following ascending orders of:

Cd: R>S>L, L>R>S, L>S>R and R>S>L, respectively.
Co: R>L>S, R>L>S, S=L>Rand S>R>L, respectively.
Ni: R>S>L, S>R>L, S>L>R and S>R>L, respectably.
Pb: R>S>L, S>R>L, S>R>L and S>R>L, respectively.

The metal concentration is not only depending on its mechanism of uptake by plant but also on the received metal-contaminated wastewater in the soil. So, metal supplying may be limited under less received wastewater in different seasons and less polluted conditions. Also, it is noticed that Ni concentrations in soil and water of the first area (Sadat City, contaminated wastewater) exceeded the recorded values of Egypt contaminated soil and water, but it exceeds the recorded values of fresh water in the second area (Wadi Al-Natron, natural underground water).

Metal translocation preferences showed different distribution patterns in *Morus*;, *Khaya*;, *Acacia* and *Populus* as illustrated in the descending orders of Pb>Ni>Co>Cd;

Cd>Pb>Ni>Co; Cd>Ni>Co>Pb and Pb>Co>Ni>Cd, respectively. Ni and Co highest translocation factors found at the highest temperature degrees for *Morus* only and both concentrations are more affected by soil pH, organic matter and irrigation water salinity, which may be assist naturally to accelerate soil phytoremediation processes at warm climate of desert regions.

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متابعة التلوث البيئي في غابه شجرية تروي بمياه ملوثة بالمخلفات معالجة بصفة أولية

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تهدف هذه الدراسة إلى متابعة التلوث البيئى لتربة رملية طمييية منزرعة بانواع مختلفة من الأشجار الخشبية مثل التوت الأبيض، الأكاسيا سالجنا، الكايا سينيجالنسس (الماهوجني الأفريقي)، الحور الأسود، والتى تروى بمياه ملوثة بالمخلفات تم معالجتها من خلال نظام الرى بالتنقيط. وقد قدرت بعض العناصر الثقيلة (الكادميوم، الكوبلت، النيكل، الرصاص) فى كل من مياه الرى، التربة المروية، الأشجار الخشبية النامية، حيث من المتوقع حدوث معالجة نباتية لقابلية هذه المعادن الثقيلة للتراكم والإنتقال من الأجزاء السفلى للأنسجة النباتية إلى تلك العلوية، آخذا فى الإعتبار تراكم العناصر فى كلا مياه الرى والأرض المروية، ولتحقيق هذا الهدف، تم إختيار موقعين فى مصر هما أ) غابة الصداقة المصرية الصينية في مدينة السادات بمحافظة المنوفية والتى تروي بمياه ملوثة بالمخلفات معالجة بصفة أولية وتشتمل على الأربعة أنواع من الأشجار الخشبية المشار إليها سابقا، ب) الغابة اليابانية-المصرية فى منطقة وادي النطرون بمحافظة البحيرة والتى تروى من المياه الجوفية الطبيعية، كمعاملة مقارنة بالنسبة للأكاسيا سالجنا فقط.

وتشير النتائج المتحصل عليها إلى عادة ما توجد فروق موسمية لتركيز العناصرالمختلفة فى مياه الرى خلال عام ٢٠١٠، حيث سجلت تركيز أعلى من عام ٢٠٠٩. كما تجاوزت تركيزات كلا الرصاص والنيكل في مياه رى منطقة مدينة السادات الحدود المسموح بها فى المياه الملوثة فى مصر.

وأيضا تجاوز تركيز النيكل فى المياه الجوفية الطبيعية بمنطقة وادى النطرون الحدود المسموح به في مياه الرى العذبة. وبالنسبة لمحتوي التربة من تركيزات العناصر الثقيلة المدروسة، تشير النتائج أن تركيز الكادميوم كان قليلا في التربة المنزرعة باشجار الحور الأسود، مقابل تركيز مرتفع في الطبقة تحت السطحية (٢٠-٤٠ سم) للتربة المنزرعة بأشجار الأكاسيا سالجنا. وقد سجل أعلى تركيز للنيكل في الطبقة تحت السطحية (٢٠-٤٠ سم) في التربة المنزرعة بأشجار الأكاسيا والكايا، وعلى الجانب الآخر فان تركيز عنصرى الرصاص والكوبلت فى التربة كان تقريبا متشابها تحت الأربعة أنواع الشجرية المدروسة .

وبخصوص تركيزات العناصر الثقيلة المدروسة فى أنواع الأشجار المختارة، فان هناك إختلافات غير معنوية لتركيزات الكادميوم في سيقان الأشجار المختلفة، حيث أن نمط توزيع تركيزات الكادميوم فى سيقان الأشجار أمكن ترتيبها تنازليا النحو التالي : الحور الأسود > التوت > الكايا > الأكاسيا. تركيزات الكوبلت والنيكل فى الأوراق قد أخذت الترتيب التنازلى التوت الأبيض > الكايا > الأكاسيا > الحور الأسود. كما أن تركيزات الرصاص فى الأوراق قد أخذت ترتيبا تنازليا على النحو التالى : التوت الأبيض> الأكاسيا > الكايا > الحور الأسود. وقد نجحت جميع العناصر المختبرة في الإنتقال من الجذور إلى السيقان فى جميع أنواع الأشجار الخشبية. أظهرت النتائج أن نبات التوت الأبيض كان ذات أفضلية من حيث إنتقال العناصر، كما هو حادث فى الترتيب التنازلى التالي : رصاص > نيكل > كوبلت > كادميوم في التوت الأبيض، مقابل كادميوم > رصاص > نيكل > كوبلت في الكايا، كادميوم > نيكل > كوبلت > رصاص في الأكاسيا، رصاص > كوبلت > نيكل > كادميوم فى ،الحور الأسود. وجد أن أعلى معدل لأنتقال عنصري النيكل و الكوبلت يكون عند أعلى درجات حرارة الهواء الجوي.

وقد وجد أن تركيز عنصرى النيكل والكوبلت، و حيث أن تركيز هذه العناصر في النبات يتأثر بالرقم الهيدروجينى للتربة ، المادة العضوية، ملوحة مياه الري مما قد يساعد في تسريع عمليات المعالجة النباتية للتربة في المناطق الصحراوية الحارة. لذا يمكن التوصية من الناحية التقنية بأن هناك جدوى من استخدام أشجار كل من التوت الأبيض و الحور الأسود للتخلص من العناصر الثقيلة من التربة في فترة قصيرة فقط في حالة إتاحة تيسير المزيد من تلك العناصر الثقيلة بالتربة بإضافة بعض المواد الكيميائية المساعدة على امتصاصها بواسطة النباتات. ومن الضرورى فى حالة إستخدام أشجار التوت الأبيض فى عملية المعالجة النباتية التوصية بالتخلص من جميع الثمار و الأورق، مع دراسة تأثير تراكم العناصر الثقيلة يأوراق التوت على دودة القز كمؤشر حيوي . يمكن تقدير كمية استخلاص النبات للعناصر الثقيلة بالحساب النظري لنسبة إنخفاض تركيز العنصر بالتربة وذلك بمعرفة أقصى تركيز للعنصر بالنبات و حساب عامل التركيز (Concentration Factor) والذى يساوى تركيز العنصر في النسيج النباتى / تركيزه فى التربة. ويمكن تحقيق ذلك وفقا لعدد الأشجار المنزرعة في الفدان، وأيضا يمكن متابعة تركيز عنصر النيكل في المياه الجوفية الطبيعية والتى تستخدم فى رى الغابة المصرية-اليابانية لمنع انتشار التلوث بالنيكل.