Phytoremediation Capability and Growth Parameters of some Tree Species Irrigated with Treated Sewage Water
B- Mineral and Heavy Metals Content of Trees, Soil and Phytoremediation Capability of Planted Trees

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ABSTRACT

An experiment was carried out at Serapium plantation located in northeastern Egypt on March 2019, to study the phytoremediation capability and mineral content [Nitrogen (N), Phosphorus (P) and Potassium (K)], of three tree species *Tectona grandis* , *Gmelina arborea* and *Azadirachta indica* irrigated with treated sewage water after six years of planting in two sites at Serapium plantation, one of the two sites was planted for first time (afforestation in site1) and the other was replanting (reforestation in site2) . Results showed after a period of using treated sewage water irrigation that the concentration of heavy metals in soil was not severe at the two sites. Phyto-Extraction capacity of *Tectona grandis* was the superior for Zinc (Zn), Iron (Fe) and lead (Pb), respectively. Noticeable, that all the studied species are considered hyperaccumulators, allusion to their Phyto-Extraction Ratio.

Key words: phytoremediation, *Tectona grandis* , *Gmelina arborea* , *Azadirachta indica* ,sewage water and Phyto-Extraction Ratio.

INTRODUCTION

Heavy metals are elements that have metallic properties with an atomic number >20. They are naturally soil components . Cd, Cr, Cu, Hg, Pb, and Zn are the most pollutant elements in highly concentrations. Some of these are necessary for plant growth, like Zn, Cu, Mn, Ni, Fe, and Co, in their normal levels, while others such as, Cd, Pb, and Hg their biological role in plants still unknown. Heavy metals have a long residence time in soil. Moreover, they affect harmfully on plant growth, ground cover and soil microflora . Also, they have to be removed physically not chemically (Gaur and Adholeya, 2004 and Roy *et al*. 2005).

Phytoremediation is the processes of using selected plants to clean up the organic and inorganic contaminants from contaminated environment to improve the quality of environment. This processes involves many mechanisms like, phytostabilization, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatilization for organic components , and phytostabilization, rhizofiltration, phytoaccumulation and phytovolatilization mechanisms for inorganic elements.

Plants have the advantage of highly specific and efficient metabolisms sequestrate micronutrients from the environment. The mechanisms of translocation and store micronutrients from soil are the same that plant use to uptake, translocation, and storage of toxic elements that have the same characteristic of micronutrients. Root system can uptake nutrients and toxic elements even if they in very low levels in the soil with the help of some factors such as, chelating agents, pH and redox reactions (Bieby *et al.* 2011). Moreover, plant phyto-extraction ratio is considered an important factor on choosing phytoremediation capable species (Zhao *et al.*, 2003).

Moreover, wastewater is considered a source of nutrients as well as a source of heavy metals. Using wastewater for long time may lead to accumulate heavy metals in soil which in an insoluble or combined form (Mohammed and Abdullahi, 2010).

There are many plant species that have a high capability of metals accumulation. These plant species can concentrate heavy metals, like Cd, Zn, Co, Mn, Ni, and Pb for 100 to1000 times more than other plant species that haven't this property. Timber tree species are considered as one of the most important species in this field plus wood production (Erdei, *et. al*, 2005; Cho-Ruk, *et al*., 2006 and Ang *et al.*, 2010). So, these plant species that can accumulate high concentrations of heavy metals without reduction in growth rate are called hyperaccumulators (Baker *et al.*, 2000). Moreover, the accumulation of heavy metals in these plant tissues at various concentrations showing no toxicity symptoms. At the same time, they reduce the contamination of soil and wastewater (Yasar *et al.*, 2010 ; Zarati *et al.*, 2016). *Tectona grandis* and *Gmelina arborea* produce a high quality wood . Moreover, they have a phytoremediation ability as they showed a great efficiency in contaminated soils with crude oil at low concentrations, (Ogheneriborue *et. al*. 2007).

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The aim of this study is to find out the ability of the studied species to accumulate heavy metals and minerals in their parts. Also, to study the effect of using treated sewage water in irrigation for a long time on soil properties under these species.

METHODOLOGY

Three tree species namely, *Tectona grandis* (Linn.) , *Gmelina arborea* (Roxb.) and *Azadirachta indica* (A. Juss.) were planted since November, 2013 in Serapium plantation in two sites: Site 1 : virgin soil, Site 2: soil was planted for ten years before by sisal (*Agave sisalana*), then it removed and soil was prepared for planting. At both sites, the three species were planted at the same time at (2.5X2 m) space and irrigated with treated sewage water using drip irrigation system. After six years of planting, chemical analysis of soil under tree species and tree parts (leaves, wood and bark) was determined.

Location:

This experiment was carried out in 2019 at Serapium plantation that located in northeastern Egypt 30^{o}, 29', 15.55" N, and 32^{o},14',25.43" E , within the governorate of Ismailia, roughly 16 km. south of Ismailia town, Egypt. Tree species were planted in two sites:

Site1: (virgin soil), located at far south west part of the plantation.

Site 2: (replanted soil), located at north east of site 1, (Fig.1).

Samples:

Samples of sewage water, soil and plant parts were collected in 2019 to determine and study the content of heavy metals and minerals.

- **Water samples:** samples of treated sewage water that used for irrigation by the beginning of the experiment (2013) and by the end of experiment (2019) were collected and analyzed (Table 1).
- **Soil samples:** samples at three depths (30cm, 60 cm and 90 cm) under each tree were collected before planting and after 6 years of planting for the two sites. Soil samples were prepared for chemical analysis (Black *et al.*, 1965). Atomic absorption spectrophotometer was used for determination of heavy metals that extracted by DTPA (Lindsay and Norvell, 1978), soil chemical analysis at the beginning of the study are presented in (Tables 2 and 3).
- **Tree species samples:** samples of tree parts (leaves, wood and bark) were collected from each tree species. Each tree part was air dried, then, oven dried at 70C^{0} to constant weight, then grinded and prepared for chemical analysis.

For Fe, Zn, Cd and Pb analysis, the atomic absorption spectrophotometer was used and heavy metal concentrations were determined by mg /kg dry matter.

Bioconcentration Factor (BCF) or Phyto- Extraction Ratio **(PER):**

Phyto- Extraction Ratio defined as the ratio of heavy metal concentration in tree to that in soil, was applied to evaluate the plants' capability to absorb heavy metals from the soil (Barman *et al.,* 2000).

Phyto- Extraction Ratio (PER) = (Metal conc. in tree part) / Metal conc. in soil (McGrath and Zhao, 2003; Ang *et al.*, 2010)

Or BCF = (Metal conc. in plant tissue) / (Initial conc. of metal in substrate ,soil)

Experiment design:

10 trees from each species were selected randomly for each planted site in CRD design. Means were calculated for each parameter, and tested at Least significant differences (LSD) at significant level of $P < 0.05$ using one-way analysis of variance (ANOVA), to compare the metals concentration for sites and for each tree species (Snedecor and Cochran, 1968) .

Fig 1. Location of Serapium plantation and experimental sites

Table 1. Water analysis in 2013 , 2019 and FAO recommendation values of heavy metals

parameter	pH	EC Dsm^{-1}	SAR	N	P	K	Fe	Zn	Cd	Pb	Ni	Co	Cr
				Elements mg L-1									
Water analysis in 2013													
	6.6	1.65	4.87	12.0	10.0	4.9	4.50	1.39	0.004	0.08	0.03	0.01	0.006
Water analysis in 2019													
	6.4	1.6	4.03	28.08	16.0	20.72	0.16	0.42	--	0.02	---	----	0.002
FAO 1992	6.0- 6.5	0.7-3.0	0.2- 0.7	1 - 40	5.5	10-40	5.00	2.00	0.01	5.00	0.20	0.05	0.10

Table 2. Analysis of soil before planting 2013 (Site1)

Depth	EC (1:2)	pH 1:2.5	N	P	K	Fe	Zn	Cd	Pb
	dS/m			ppm					
0-30	0.34	7.8	154	4597	550	760	57	0.14	65.8
30-60	0.56	7.8	244	2924	440	833	45.5	0.15	70.2
60-90	0.68	7.8	224	2370	181	704	47.1	-	-

Table 3. Analysis of soil before planting 2013 (Site2)

Depth	EC (1:2)	pH 1:2.5	N	P	K	Fe	Zn	Cd	Pb
	dS/m			ppm					
0-30	0.20	6.8	910	7307	360	767	128	0.20	70
30-60	0.57	7.4	896	2681	150	732	62	0.20	70
60-90	0.20	7.1	986	1502	90	672	66		

RESULTS AND DISCUSSION

Chemical analysis:

1- Plant Chemical Analysis.

1-1-Mineral Elements:

Statistical analysis of chemical analysis data showed no significant differences among mineral components means between (site1) and (site2) , for N, P and K elements for the three tree species . Where, the highest values of N, noticed in (site1) for all tree species. As, P and K, for *Gmelina arborea* and *Azadirachta indica* (Table 4).

This result is agreed with the findings Elena *et al.* (2011) since, they found no significant differences in N foliar content between grass irrigated with wastewater and grass irrigated with drinking water as a control. In the contrary, Hayssam *et al*.,(2012) who found that NPK concentration was increased in leaves and shoots by irrigation with treated sewage water. Singh and Bhati (2005) and EL-Sayed (2005) found the same trend.

1-2- Heavy metals:

Statistical analysis of chemical data for the tree species indicated highly significant differences between concentration of Fe, Zn and Pb among tree parts of the three tree species (leaves, wood and bark). As illustrated in Fig. (2), *Gmelina arborea* displayed the highest concentration of Fe (433.24 mg / kg), followed by *Tectona grandis* (229.89 mg / kg), then *Azadirachta indica* (209.85 mg / kg). Where, *Tectona grandis* had the highest Zn content, then *Gmelina arborea* and *Azadirachta indica* (73.42 mg / kg, 63.68 mg / kg and 48.5 mg / kg, respectively). Moreover, the highest concentration of pb was obtained in *Gmelina arborea* (8.08 mg / kg), then *Tectona grandis* (4.41 mg / kg) and *Azadirachta indica* (4.19 mg / kg). On the other hand, chemical analysis of plant samples showed that Cd concentration was very low to be detected for all the three tree species.

Furthermore, the statistical analysis of heavy metals concentrations (Fe, Zn and pb) was showed significant differences among (leaves, wood and bark) except for Zn in *Gmelina arborea* and *Azadirachta indica*, and pb content in *Tectona grandis* as presented in (Table 5 and Fig. 3). For all tree species, leaves had the highest concentration of Fe, then wood and bark. At the same time, the highest Fe content was found in *Gmelina arborea* leaves (432.94 mg / kg), followed by *Tectona grandis* leaves (394.84 mg / kg), then, *Azadirachta indica* leaves (292.94 mg / kg). When, wood had the highest Zn content, then bark and finally leaves. Noticeably, *Tectona grandis* wood displayed the highest concentration of Zn (70.6 mg / kg), followed by *Azadirachta indica* wood (68.3 mg / kg) ranked by *Gmelina arborea* wood (49.2 mg / kg). On the other hand, there were highly significant differences between Pb concentration in tree parts of *Gmelina arborea* and *Azadirachta indica* , yet *Tectona grandis* showed no significant differences among its parts. For all species, leaves recorded the lowest value of Pb, compared to that in bark and wood, that exhibited higher concentration, except for *Azadirachta indica* that showed the highest concentration of Pb in their leaves.

The result of Pb concentration in plant parts of *Gmelina arborea* and *Tectona grandis* was agreed with (Rabeda *et al.*, 2015; Tangahu *et al.*, 2011). Also, Evangelou *et al.* (2013) Alagić *et al.* (2013) found that the high concentration of Pb was in stem more than leaves. Moreover, according to Akansha and Shukla (2018), Pb concentration was higher in leaves more than bark on their study on *Ficus virens* and *Azadirachta indica*. They concluded that the leaves are best accumulators than bark.

Table 4. Significant differences of NPK concentration of the three tree species at the two sites

Tree species	N		P		K	
	Site1	**Site2**	**Site1**	**Site2**	**Site1**	**Site2**
Gmelina arborea	12200 ns	11733.3 ns	3433.33 ns	2400 ns	3866.7 ns	9533.3 ns
LSD 0.05	23530.70		2832.94		9567.90	
Tectona grandis	15566.67 ns	9100 ns	2000 ns	4066.7 ns	5100 ns	6233.3 ns
LSD 0.05	9591.58		3894.73		9778.6	
Azadirachta indica	15333.33 ns	10766.67 ns	3600 ns	933.3 ns	8333.3 ns	6766.7 ns
LSD 0.05	17400		4514.99		15047.3	

ns. Non-significant

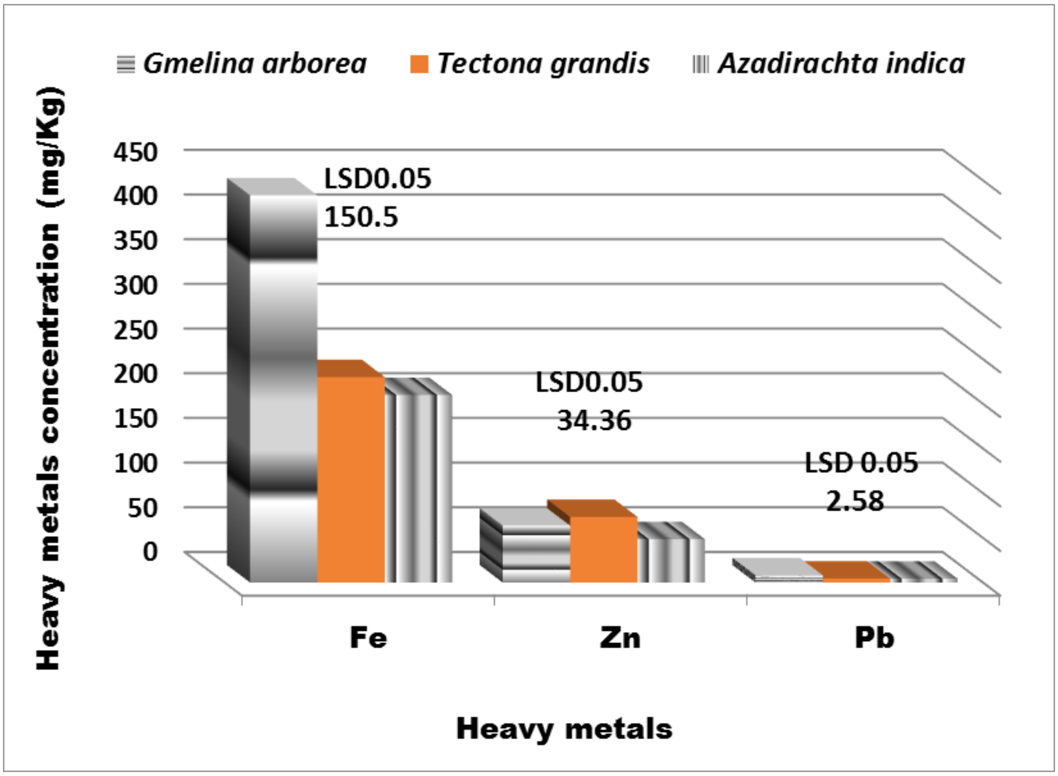

Fig 2. Total plant parts concentration of Fe, Zn and Pb (mg/kg) for the three tree species

Table 5. Heavy metals concentration (mg/kg) of leaves, wood and bark for each tree species in the two sites

Tree species	Fe			Zn			Pb		
	leaves	wood	Bark	leaves	wood	Bark	leaves	wood	Bark
Gmelina arborea	432.94**	209.38**	168.03**	24.1 ns	49.2 ns	39.1 ns	5.18 **	7.19 **	9.59 **
LSD 0.05		114.94			38.9			1.84	
Tectona grandis	394.84**	201.37 **	162.09 **	10.9 *	70.6 *	57.6 *	3.7 ns	5.26 ns	4.5 ns
LSD 0.05		46.41			45.66			1.83	
Azadirachta indica	292.94 *	177.5 *	119.22 *	19.5 ns	68.3 ns	23.8 ns	5.57 **	4.4 **	3.13 **
LSD 0.05		98.01			58.67			0.79	

*significant ** high significant ns. Non-significant

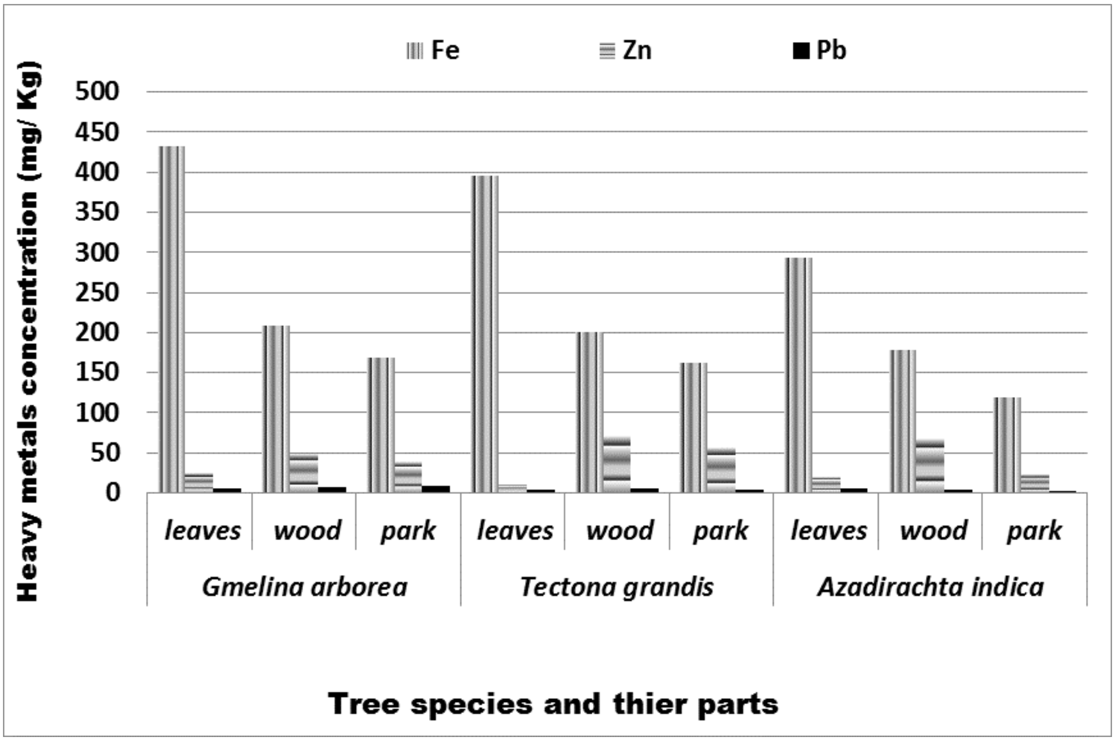

Fig 3. Concentration of Fe, Zn and Pb (mg/kg) of each plant part for the three tree species

2- Soil chemical analysis:

According to soil analysis for site1 and site2 before planting and by the end of experiment there were a slight decrease in soil pH and EC for both sites was detected.

2-1- Mineral Elements:

N P K content of soil under each tree species for the two sites were significant and varied according to statistical analysis presented in Table (6). Whereas, soil under *Azadirachta indica* and *Tectona grandis* showed highly significant differences between Site1 and Site2 in N content, whereas, N content under *Gmelina arborea* showed no significant differences. As for, P and K content non significant differences obtained between the two sites under the three species, except for P concentration under *Azadirachta indica* which was significant.

Furthermore, the highest concentration of N and P were observed in Site2 for all the species, when the highest K content was found in site1. This results in accordance with the findings of Hassan *et al.* (2003) as well as Muamar *et al*. (2014) for N and p on their work to compare soil properties after irrigation with treated sewage water and groundwater. The concentration of NPK in old site may be ascribed to sisal plants which planted before this experiment that needs a moderate nitrogen amount, modest amount of phosphorus and high amount of potassium that is required for strengthen fiber production (Alfred , 1995).

2-2- Heavy metals:

Statistical analysis of heavy metals concentration (Zn ,Fe and Pb) in soil under the tree species showed no significant differences between the two sites, except for Pb concentration in soil under *Azadirachta indica* , which showed significant differences between site1 and site2 (Table 7). Furthermore, Fig. (4) presented the differences of heavy metals concentration in the soil under the three species. Data analysis revealed that no significant differences of heavy metals concentration of Zn and Fe in soil under the tree species. Contrasting by, Pb concentration, significantly different among soils under the three species.

These results are matching with (Abedi-Koupai *et al*. 2006) who found that there were no significant effects of treated wastewater on the amount of soil Fe , Pb, Mn, Ni and Co compared with the beginning stage of sugar beet, corn and sunflower crops growth. Rationally, using treated wastewater in forest irrigation is source of N,P,K and heavy metals (Ghorab *et al.*, 2017). The behave of heavy metal ions in soil may by uptaking by plant root, adsorbed on the surface of soil particle or retained in the soil in soluble (Parker and Parker, 1986). An allusion by Klay *et al.*, (2010), heavy metal content increases with wastewater irrigation

Table 6. Significant differences of NPK concentration (mg/kg) of the soil under the three tree species at the two sites

Tree species	N		P		K	
	Site1	Site2	Site1	Site2	Site1	Site2
Gmelina arborea	252 ns	602 ns	3496.7 ns	3554 ns	469.7 ns	205.7 ns
LSD 0.05	391.38		4512.19		492.82	
Tectona grandis	146.7 **	770.3 **	3296.3 ns	3685 ns	580.7 ns	399.3 ns
LSD 0.05	212.5		4111.92		539.2	
Azadirachta indica	317.3 **	793.3 **	1635.3 *	3885 *	513.67 ns	350 ns
LSD 0.05	230.7		1759.56		445.13	

***significant ** high significant ns. Non-significant**

Table 7. Significant differences of heavy metals concentration (mg/kg) of the soil under the three tree species at the two sites

Tree species	Fe		Zn		Pb	
	Site1	Site2	Site1	Site2	Site1	Site2
Gmelina arborea	1.72ns	1.19 ns	0.18 ns	0.2 ns	0.25 ns	0.15 ns
LSD 0.05	1.22		0.26		0.13	
Tectona grandis	0.84 ns	0.77 ns	0.15 ns	0.15 ns	0.069 ns	0.067 ns
LSD 0.05	0.52		0.14		0.098	
Azadirachta indica	2.29 ns	1.59 ns	0.16 ns	0.7 ns	0.147 *	0.029 *
LSD 0.05	2.4		1.3		0.086	

*significant ns. Non-significant

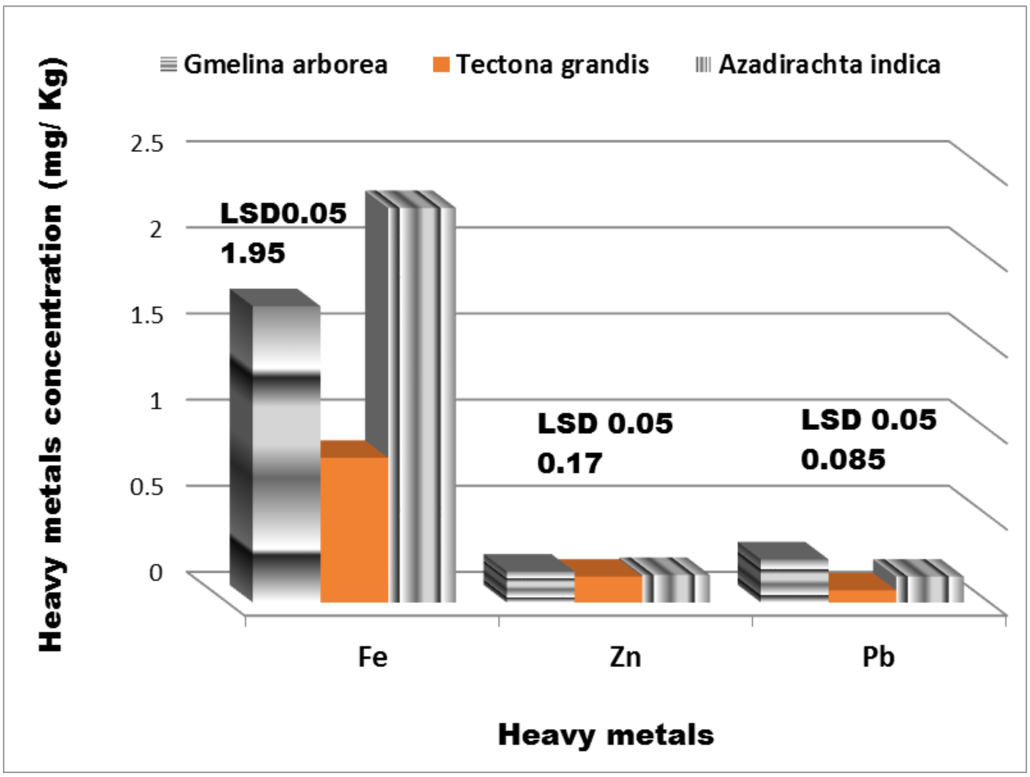

Fig 4. Concentration of Fe, Zn and Pb (mg/kg) for the soil under the three tree species

period, especially for Pb and Cd. So, the source and the quality of treated wastewater effect on soil properties so, with long time of used, changing in soil and ground water properties must be monitoring.

3- Phyto- Extraction Ratio (PER):

It is noticeable, from data presented in fig.(5) , *Tectona grandis* recorded the highest (PER) for Zn (489.47), followed by Fe (273.7), then 63.0 for Pb. Moreover, *Gmelina arborea* came in the second rank (353.8, 251.9 and 32.32) for Zn, Fe and Pb , respectively. As for , *Azadirachta indica* it came at the last in order (303, 91.6 and 27.9 for Zn, Fe and Pb), respectively.

According to Pulford and Watson (2003) and Li (2006), woody trees are used to clean soil, water or air form contamination heavy metals like, Ni, Pb, Zn, Cu and Cd. Moreover, tree species are vary in its uptake capacity. High values of (PER) resulting from this research and indicating to the definition of Metallophytes or Hyperaccumulators plants, according to Prasad *et al*., (2010) ,Singh *et al*., (2016), and Juan, *et al*. (2020)" they are plants which can uptake large amounts of heavy metals from the soil, moreover , they don't keep heavy metals in roots but translocate and accumulate them in the aboveground parts at concentrations 100–1000 multiple higher than non hyperaccumulating species with no toxic effect on their growth rate". Therefore, *Tectona grandis*, *Gmelina arborea and Azadirachta indica* are considered hyperaccumulator plants for Zn, Fe and Pb. Also, according to Lorestani *et al*. (2011) ; Ali *et al*. (2013) ; Manal and Mohamed (2021) only plants with BCF and TF > 1 are considered hyperaccumulators. On the other hand Bamidele and Agbogidi, (2006) they indicated that, *T. grandis* and *G. arborea* are not so, recommended for contaminated soil by crude oil.

4-Heavy metals content along soil depth:

Because of, no significant differences between $site_1$ and $site_2$ of heavy metals concentration in soil under the three species, samples of soil at different depths under the three tree species from $site_2$ were statistically analyzed. Regarding to the results, there were a highly significant differences of heavy metals concentration within soil depth under the three tree species.

Generally, the lowest concentration of Fe, Zn and Pb (mg/kg) was observed on the middle depth (30-60cm) of soil under the three tree species as presented in Table (8). While, the highest concentration of studied heavy metals was found on top depth (0-30cm), followed by the lowest depth (60-90 cm) for *Azadirachta indica* and *Tectona grandis* . This oppose to that detected in the soil under *Gmelina arborea* since the highest concentration of heavy metals was found in the lowest depth (60-90cm), followed by top stratum (0-30 cm).

Root system is essential for water-nutrient uptake. Moreover, root system architecture differs among plant and tree species. For instance, G. *arborea* produces a fibrous root system with incidental roots, at 1.2 m, depth (Mbakwe, 1989). While, *A. indica* aged 6 years old ,developed moderately long, primary root with a moderate number of lateral roots distributed along its length that, reaches about 1.2m to 1.5 m depth. Moreover, 80% the total root biomass presented in the upper 0.3 m of the soil profile John and Chaturvedi, (1994).

Teak produces a major, long and thick tap root, with numerous lateral roots at 0.4 to 0.6 m depth because of its sensitivity to oxygen deficiencies. So, both of lateral and vertical roots are located in the top 0.3m of the soil (Peter, 1993). According to, Nnyamah and Black (1977), the amount of extracted water from any soil layer depended on rooting density and water content of soil. Regarding to the results of some studies reviewed by Ehleringer and Dawson (1992), some trees in some cases, uptake deep water although, surface water is available. Especially, in areas with low summer rains, plants produce active roots in two zones: near the surface and at the depth.

Results here are agreeable with the findings of Dabral *et al*. (1987) on their study on *Eucalyptus* plantation of 16 years old, they found that lateral roots extended up to 18 m between a soil depth of 0.3 to 0.6 cm. Moreover, Onyewotu *et al.* (1994) and Onyewotu and Stigter (1995) mentioned that most tree roots occurred in the top 0.7 m of the soil. When, El-Lakany and Mohamed (1993a , 1993b) on their study on 6 years old *E. camaldulensis* under drip irrigation ,the depth of the majority of vertical roots, and the maximum depth of vertical roots were greater for the drip irrigated trees compared with sprinkler irrigation. On the oppose with Scholl (1976) that found water uptake of root zone occurred in the top 30 cm of the soil, then moved downward to the next layer from 0.3 m to 1.80 m. Baldwin and Stewart (1987) found that root concentration of *Eucalyptus grandis* irrigated with recycled water was highest in the top 0.3 m of the soil, and decreased with depth. Also, Bi *et al*. (1992) observed on their study on site planted with *Eucalyptus obliqua* and *Pinus radiata*, that most of the root density was in the top 0.2 m of the soil.

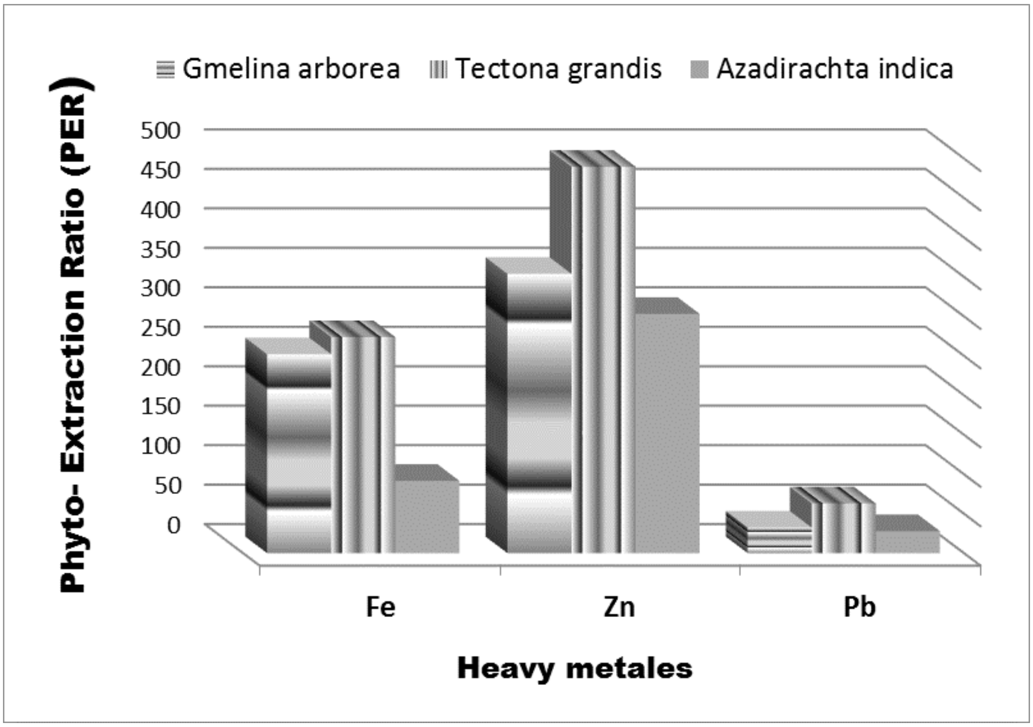

Fig 5. Phyto- Extraction Ratio (PER) of the three tree species

Table 8. Significant differences of heavy metals concentration (mg/kg) on soil depth under the three tree species

Tree species	Soil depth	Fe	Zn	Pb
Gmelina arborea	0-30 cm	1.23**	0.122**	0.17**
	30-60 cm	1.1**	0.12**	0.166**
	60-90 cm	2.025**	0.31**	0.26**
LSD 0.05		**0.009**	**0.012**	**0.006**
Tectona grandis				
	0-30 cm	0.92**	0.21**	0.095**
	30-60 cm	0.74**	0.09**	0.034**
	60-90 cm	0.755**	0.16**	0.077**
LSD 0.05		**0.018**	**0.015**	**0.007**
Azadirachta indica				
	0-30 cm	2.75**	0.29**	0.107**
	30-60 cm	1.23**	0.12**	0.072**
	60-90 cm	1.84**	0.14**	0.084**
LSD 0.05		**0.014**	**0.014**	**0.001**

**Highly significant

CONCLUSION

Soil under all species in site2 had the highest concentration of N and P, comparing to high concentration of K for site1.

For all tree species, leaves contained the highest concentration of Fe, then wood and bark, comparing to Zn that recorded the highest value in wood, then bark and finally leaves. Moreover, leaves recorded the lowest value of Pb, comparing with bark and wood for all species**.**

Tectona grandis surpasses both of *Gmelina arborea* and *Azadirachta indica* in Phyto- Extraction Ratio (PER) for Zn, Fe and Pb. When, *Gmelina arborea* displayed the highest Phyto- Extraction Ratio, Followed by *Azadirachta indica*. Moreover, we can consider the three tree species in this research are hyperaccumulators for Zn, Fe and Pb based up on their highly Phyto-Extraction Ratio.

Along soil depth, the middle layer (30-60 cm) recorded the lowest heavy metal concentration because of increasing root density at this depth. While, top soil depth (0-30cm) and the lowest depth (60-90cm) recorded the highest heavy metal concentration because of differences between species in root density , formation and also, regarded to drip irrigation system that concentrate water in soil surface .

Regarding to FAO safely concentration range of heavy metals , both of used sewage water and soil after a period of using treated sewage water in irrigation are in safely limit of heavy metals contamination.

Also, if the planted species have good Phyto-Extraction properties we can control soil and ground water contamination by heavy metal safely.

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الملخص العربي

قدرة المعالجة النباتية ومعدل النمو لبعض الأنواع الشجرية المروية بمياه الصرف الصحى المعالج
ب– المحتوى المعدنى والمعادن الثقيلة للأشجار والتربة وقدرة المعالجة النباتية للأشجار المنزرعة

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أجريت هذه التجربة فى غابة سيرابيوم بالإسماعيلية فى مارس ٢٠١٩ .حيث تم زراعة ٣ أنواع شجرية على مياه الصرف الصحى المعالج وهى التيك *Tectona grandis* و الملينا *Gmelina arborea* و النيم *Azadirachta indica* و زرعت الثلاث أنواع فى موقعين بالمزرعة موقع١ وهو أرض تزرع لأول مرة و موقع٢ و كان منزرع من قبل بنبات الأجاف على مياه الصرف الصحى المعالج وتم إزالته وإعادة زراعة الموقع. الهدف من هذا البحث هو دراسة قدرة المعالجة النباتية للأنواع تحت الدراسة والفرق فى المحتوى المعدنى والمعادن الثقيلة فى التربة والنبات بعد فترة من الرى بمياه الصرف الصحى المعالج. أظهرت النتائج تفوق موقع ٢ فى محتوى التربة من النيتروجين والفوسفور على عكس البوتاسيوم الذى كان تركيزه أعلى فى تربة موقع١.الأشجار موضع الدراسة كان لها قدرة عالية على تخزين المعادن الثقيلة فى أجزائها المختلفة ، حيث كانت الأوراق الأعلى فى محتواها من الحديد Fe يليها الخشب ثم القلف . بينما الخشب كان الأعلى فى محتواه من الزنك Zn يليه القلف ثم الأوراق كانت أقل تركيز و التى أيضا احتوت على أقل تركيز من الرصاص. أظهرت النتائج أيضا أن الأنواع الثلاثة تحت الدراسة تعتبر نباتات فائقة التراكم وأن أعلى معدل إستخلاص حيوى Phyto- Extraction Ratio (PER) قد سجل فى التيك *Tectona grandis* يليه الملينا *Gmelina arborea* ثم النيم *Azadirachta indica* لكل من الزنك Zn و الحديد Fe والرصاص Pb . وبدراسة تراكم المعادن الثقيلة على طول عمق التربة حول منطقة الجذور أوضحت النتائج أن عمق التربة الأوسط من (٣٠–٦٠ سم) كان يحتوى على أقل تركيز من المعادن الثقيلة على عكس الطبقة السطحية (٠– ٣٠ سم) والأعمق (٦٠–٩٠ سم) .

الكلمات المفتاحية : المعالجة الحيوية، المعادن الثقيلة ،تيك ، ملينا ، نيم، الرى بمياه الصرف الصحى المعالج.