American-Eurasian J. Agric. & Environ. Sci., 21 (3): 178-187, 2021
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2021.178.187

Bioavailability of Trace Elements and Heavy Metals in of Some Forestry Species Leaves under Desert Conditions of Egypt

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Abstract: Demonstration tree trial was established to create or establish biodiversity of the green cover in a virgin desert soil, having never been under cultivation. The quality of the soil was poor being shallow and stony which is not suitable for arable crop production. Irrigation took place either by secondary treated wastewater or the Nile water for comparison as well as compost was applied at planting. Plants representing 20 genera (10 tree species and 10 shrubs), were selected to provide a range of plants of food, industrial and amenity value. The tree species comprised: *Bombax, Chorisia, Casuarina, Eucalyptus, Populus, Cupresus, Malus, Pyrus, Vitus, Prunus* and *Carica* while the shrubs were *Rosa, Acalypha, Dodonea, Lantana, Myoporum, Duranta, Adhatoda, Hibiscus, Nerium* and *Seneio*. Another target of the experiments was to determinehebioavailability of trace elements and heavy metals in of the forestry species leaves irrigated with secondary treated wastewater. The results showed that all of the heavy metal concentrations were 10 - 100 times smaller than the limit values in Decree 44/2000. The quality of the canal water is good for crop irrigation, with no constraints due to salinity or chloride content. Its chemistry is in marked contrast to the quality of the treated wastewater. Nerium and Ponsiana leaves contained the greatest Fe concentration >350-400 ppm while most of tree species leaves content was inadequate, 20 ppm. Mn concentration analysis showed that Tichoma and Eucliptus could accumulate around 100 ppm compared with the other species, while, Duranta accumulated the greatest Cr and Co concentration than the other species. Nerium was the greatest accumulator of Cd than the other species. Overall, the trial has provided a useful guide to the species that are likely to survive the very hostile stony and calcareous soil conditions. It may also indicate the expected performance of the bioverification of the forestry species chosen under such hard conditions of desertification. Forest species were greatly variable for the bioavailability of trace elements and heavy metals in of the forestry species leaves irrigated with secondary treated wastewater.

Key words: Biodiversity · Forestry · Desert soil · Bioavailability · Heavy metals

INTRODUCTION

There is a high demand in Egypt for tree-related products but currently there is no large-scale tree production in Egypt (other than fruit) as the demand for and economic returns on, food crop production are so much greater on fertile land with readily available source of irrigation. Nevertheless, the use of treated wastewater for trees is attractive as there are no human food chain implications (real or perceived) and the growing of trees may increase in the future in areas where reduced quality of irrigation water makes crop production marginal or

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where arable crop production is not viable. An additional benefit of using treated wastewater in this way is that there is limited or no potential for disease transmission to the public, although field labourers are potentially exposed. In arid and semi-arid countries, water is becoming scarce resource to consider any sources of water, which might be used economically and effectively to promote further development. Rapid increases in population and industrial growth have led to use low quality water such as drainage and saline water as well as wastewater for irrigation.Irrigation of forest species with wastewater for fuel and timber production is an approach which helps to overcome health hazards associated with sewage farming. Establishment of the green belts around the cities by forest trees under wastewater irrigation also helps revive the ecological balance and improves environmental conditions by self-treatment of wastewater through the application of forest irrigation. The treated wastewater contains organic matter and nutrients that can improve soil and crop productivity. Currently, wastewater is being used for the restoration of degraded land and growth of commercial and environmental crops [1]. After primary treatment, the wastewater becomes safe for irrigation of non-food crops, such as tree plantations, greenbelts and forestlands [2, 3]. Previous studies indicated that using treated wastewater for irrigation improved the soilproperties and some growth parameters of forest trees, such as biomass potential, biomass allocations, specific gravity of the wood, fiber length and volumetric shrinkage [4, 5]. The treated wastewater contains organic matter and nutrients that can improve soil and crop productivity.

MATERIALS AND METHODS

The experimented tree species were selected to represent a range of tree production and amenity scenarios relevant to Egypt, such as: windbreaks, green belts; fruit production; and for industrial uses (e.g. charcoal, construction timber, paper pulp).

The soil was ripped to a depth of 1 m down the slope in the planned line of planting. This broke up the limestone pediment at about 30 cm below the surface, but created a very loose and stony substrate for planting. The background chemical composition of soil is listed in Table (1). Furrows for planting and irrigation were made at 2.5 m spacing down the slope and the area was divided into three section 23 m long for each of the three treatments. Canal water was drawn by tanker from the Bahig Canal and all of the trial was irrigated twice before planting to reduce surface salinity. The trees were planted in the spring (28 April - 5 May 2018) in the furrows. Rows of trees were alternated with rows of shrubs, so that the trees would have sufficient space to reach maturity when the shorter-lived shrubs could be removed in a few years time. For the large trees, fifteen were planted in each full row whereas for the ornamentals and seedling trees, these were planted at 90 per full row.Compost was added to the planting hole (2-3 $kgtree^{-1}$), as required by the trial design. Irrigation with canal water was carried out over the summer period twice per week to all plots, with the frequency of irrigation being reduced to once per week in the winter, depending on rainfall. When treated wastewater became available, this was applied to two blocks and the other continued to receive canal water, in accordance with the trial design. Establishment of the plants was monitored and whilst some species grew readily, others were unable to establish in the very difficult soil conditions. Consequently, those species which failed were replaced with other species. The new species included: Ficus, Tichoma, Ponsiana, Olivea, Pican, Eryobotia (Table 2). The layout of the trial after replanting is shown in Fig. (1). This comprises 17 rows of plants, each row being divided into three treatments. The whole trial area is surrounded by a windbreak of a single row of Causurina on two sides and Eucalyptus on the other two sides. These species are commonly used in Egypt for this purpose.

Monitoring Programme: The monitoring requirements for this trial are modest and can be easily undertaken. The trees are inspected regularly for establishment and growth performance. Leaf samples were taken from each species on each plot during the summer and were analysed for heavy metal contentand monitor nutrient status. Soil samples are to be taken periodically to assess changes to the chemical quality of the soil and for any residual bacteria or parasites. In the longer term, when the fruit trees commence production, the yield and quality of the fruit will also need to be assessed. Samples of treated wastewater from were taken during crop cycles and analyzed for a range of agronomic and environmental parameters. five replicate samples of treated wastewater were taken in October 2019 and analysed for heavy metals and a range of other parameters according to [6].

Table 1: Background chemical composition of soil

				Total concentration (mg kg^{-1} dm)											
pH	$CaCO_3$ (%)	EC (dS m^{-1})	OM (%)	N	P	K	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr	Co
8.21	42.3	0.75	1.20	2205	6	3263	19246	192.9	22.3	8.82	12.5	0.25	1.7	14.0	52.5

Table 2: Original selection of tree and shrub species

Species	Use	
Trees		
Bombax	Amenity and industrial: packing boxes, charcoal	
Chorisia	Amenity:	
Casuarina	Agriculture and industrial: windbreak, trapantin oil, glue, ratting	
Eucalyptus	Industrial: paper	
Populus	Industrial: paper/match	
Cupresus	Industrial: trapantin oil, glue, ratting	
Malus	Fruit: apple	
Pyrus	Fruit: pear	
Vitus	Fruit: grape	
Prunus	Fruit: almond, etc.	
Carica	Fruit: pawpaw	
Ornamental shrubs		
Rosa	Myoporum	Hibiscus
Acalypha	Duranta	Nerium
Dodonea	Adhatoda	Seneio
Lantana		

Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas	Cas
	Irrigated with treated wastewater																	
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
	Irrigated with treatead wastewater, compost applied																	
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
	Irrigated with canal water, compost applied																	
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Cas	Ros	Myo	Bom	Dod	Dur	Fic	Adh	Ner	Pop	Hb	Tic	Pon	Myo	Oli	Pic	Oli	Ery	Euc
Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc	Euc

Fig. 1: Layout and tree selection for treatead wastewater and compost (plant code is initial 3 letters of plant genus)

RESULTS AND DISCUSSION

Secondary Treated Wastewater Quality: The results of the chemical analyses were directly comparable to the overall results typical concentrations although TSS and BOD were greater in and could be attributed to the fact that the treated wastewater had been stored for several weeks after the end of the summer irrigation period and so contained algae.

All of the heavy metal concentrations were 10 – 100 times smaller than the limit values in Decree 44/2000 (Tables 3 and 4). Secondary treatment transfers much of the remaining heavy metal load from primary treated wastewater to sludge and so, despite the potential for increasing concentrations in wastewater in the future (because of the relaxation in industrial treated wastewater quality standards to sewer under Decree 44/2000) [7], it is unlikely that heavy metal concentrations in treated wastewater for reuse will be of environmental concern.

The use of primary and secondary treated wastewater in irrigation can improve the quality of the soil and plant growth because they are considered as natural conditioners through their nutrient elements and organic matter. However, the direct application of wastewater on agricultural land is limited by the extent of contamination with heavy metals, toxic organic chemicals and pathogens [8-14].

Table 3: Analysis of biotower treated wastewater (storage tank) (mg l^{-1})

pH	DO	TSS	BOD	COD	O&G	TDS	Alk
8.3	7.8	67	59.6	158.4	-	1164	352
TKN	NO_3	NH_3	Cl	PO_4	Na	Ca	Mg
18.6	0.094	13.0	444	3.1	584	396	170
SAR	K	Cd	Cr	Cu	Pb	Ni	Zn
6.2	40	0.0015	0.0074	0.003	0.0414	0.0124	0.041

Table 4: Quality criteria for treated wastewater reuse (Decree 44/2000)

		Maximum concentration (pH 6-9)		
Parameter	Unit	Primary	Secondary	Advanced
Biological oxygen demand	mg l^{-1}	300	40	20
Chemical oxygen demand	mg l^{-1}	600	80	40
Suspended solids	mg l^{-1}	350	40	20
Oil and grease	mg l^{-1}	-	10	5
Parasite eggs	count l^{-1}	5	1	1
Faecal coliform	MPN 100 ml^{-1}	-	1, 000	100
TDS	mg l^{-1}	2, 500	2, 000	2, 000
SAR		25	20	20
Chloride	mg l^{-1}	350	300	300
Boron	mg l^{-1}	5	3	3
Cadmium	mg l^{-1}	0.05	0.01	0.01
Lead	mg l^{-1}	10	5	5
Copper	mg l^{-1}	-	0.2	0.2
Nickel	mg l^{-1}	0.5	0.2	0.2
Zinc	mg l^{-1}	-	2	2
Arsenic	mg l^{-1}	-	-	0.1
Chromium	mg l^{-1}	-	-	0.1
Molybdenum	mg l^{-1}	-	0.01	0.01
Manganese	mg l^{-1}	0.2	0.2	0.2
Iron	mg l^{-1}	-	5	5
Cobalt	mg l^{-1}	-	0.05	0.05

Notes:- No standard

Table 5: Canal water quality at Nubaria and Burg El Arab off-takes (annual means) (Units: mg l^{-1} or as indicated)

Parameter	Nubaria	Burg El-Arab	Mean
Temperature (°C)	23.1	21.0	22.0
pH	8.2	8.2	8.2
Turbidity (NTU)	9.6	9.3	9.5
Conductivity (µS cm^{-1})	1019	1199	1109
Total dissolved solids (105°C)	622	740	681
Total dissolved solids (180°C)	581	683	632
Volatile solids (550°C)	54	70	62
Total suspended solids	5	5	5
Cl^-	110	161	135
Alkalinity as $CaCO_3$	165	160	163
Total hardness as $CaCO_3$	243	274	259
Temporary hardness as $CaCO_3$	165	160	163
Permanent hardness as $CaCO_3$	78	114	96
SO_4	167	186	176
SiO_2	2.7	3.1	2.9
NO_3-N	3.63	3.46	3.55
NO_2-N	0.046	0.031	0.038
NH_4-N	0.28	0.28	0.28
PO_4-P	0.620	1.821	1.220
Ca	56.1	59.6	57.8
Mg	25.3	30.5	27.9
Na + K	116.3	142.1	129.2
Dissolved oxygen	5.53	5.55	5.54
Chemical oxygen demand	41.9	48.4	45.2
Biological oxygen demand	9.8	9	9.3
Algae count per litre	9.2×10^5	1.2×10^6	1.1×10^6
Total plate count per ml	316	450	383
Total coliforms per 100 ml	1272	478	875
Faecal coliforms per 100 ml	243	117	180

Table 6: Survival of trees and shrubs after two seasons (number planted and percent survival)

	Compost+Canal		Compost+Treated wastewater		Treated wastewater		Overall
Species	No. planted	% survival	No. planted	% survival	No. planted	% survival	% survival
Original plantings that survived initially							
Bombax	5	20	5	60	5	80	53
Casuarina	22	100	22	95	22	95	97
Eucalyptus							53
Populus	5	0	5	0	5	0	0
Rosa	18	0	18	0	18	0	0
Dodonea	29	93	39	97	39	95	95
Myoporum (1st row)	26	81	26	81	26	100	87
Myoporum (2nd row)	22	100	24	88	24	100	96
Duranta	23	30	23	78	33	52	53
Adhatoda	25	68	21	71	28	46	62
Hibiscus	26	73	22	67	24	86	75
Nerium	30	100	26	77	29	66	81
Replacement species							
Ficus	5	80	5	100	7	71	84
Tichoma	23	83	15	93	30	50	75
Ponsiana	5	100	5	80	5	60	80
Olivea (2 rows)	5	0	5	0	5	0	0
Pican		0		0		0	0
Eryobotia	5	0	5	0	5	0	0
Mean survival		58		62		56	58

Canal Water Quality: The irrigation supply in the West Nubaria area originates from the River Nile and is transferred via the Nubaria and Nasr Canals. Water quality in the Nubaria Canal is monitored on a regular basis at the potable water off-takes for Nubaria and Burg El Arab. These monitoring points are respectively upstream and downstream of the off-take for the Nasr Canal and therefore the quality of this water is representative of the chemistry of the water irrigated in the West Nubaria area. The annual mean water quality data are summarised in Table 5. The quality of the water is good for crop irrigation, with no constraints due to salinity or chloride content. Its chemistry is in marked contrast to the quality of the treated wastewater from the biotower. Total dissolved solids and alkalinity are about half of that in the treated wastewater, whereas COD, chloride and nitrogen are about 25% of that in the treated wastewater. The sodium absorption ratio is about 3.2 in the canal water compared with SAR 6.2 in the treated wastewater.The nutrient content of the canal water is small, having only 4 mg N, 1.2 mg PO_4 and 10 mg K l^{-1} compared with 18 mg N, 3.4 mg PO_4 and 40 mg K l^{-1} in the treated wastewater. The potassium concentration of the canal water was estimated on the basis of its general chemistry since Na and K were reported as combined values.The microbial quality of the canal water is typical, having small numbers of faecal coliform bacteria, suggesting some contamination from sewage or animals, although the numbers are below the limit for irrigation. Parasite eggs were not reported.

Tree Species Survival: After two growing seasons, the survival of the trees and shrubs was assessed survival of any species continued in growing was not less than 53 % (Eucalyptus, Bombax and Duranta) and as high as 97% (Casuarina). Overall survival rate was 76 % (excluding the failing species) which is high, considering the hostile soil conditions. The large specimens, such as Bombax, that were planted were particularly vulnerable but managed acceptable rates of establishment. The performance of Eucalyptus and Olivea was disappointing and significantly, none of the fruit trees survived, with the exception of Ficus. Most of the shrub species survived with the exception of Rosa. Leaf samples were taken from each species on each plot during the summer and were analysed for heavy metal content. The overall survival of trees and shrubs, indicates that the use of compost at planting is particularly beneficial to establishment, but the benefit of secondary treated wastewater compared with canal water would appear to be marginal. Overall, the trial has provided a useful guide to the species that are likely to survive the very hostile stony and calcareous soil conditions. It may also indicate the expected performance of the bio verification of the forestry species chosen under such hard conditions of desertification Table (6). The high survival rate of Casuarina demonstrates why this is the most common species of tree grown in Egypt under a wide range of conditions, principally for wind break but it is also a useful timber tree. The performance of Eucalyptus and Olivea was disappointing

Table 7: Concentrations of heavy metals in tree and shrub leaves (mg kg^{-1} DM)

Treatment	Fe	Mn	Zn	Cu	Cr	Co	Cd	Pb	Ni
Treated wastewater	148.3	39.8	19.5	3.57	0.28	0.14	0.11	0.77	0.16
Treated wastewater + compost	132.3	35.3	20.3	3.46	0.59	0.90	0.16	0.64	0.23
Canal + compost	160.9	39.4	17.8	3.00	0.24	0.98	0.25	0.61	0.25

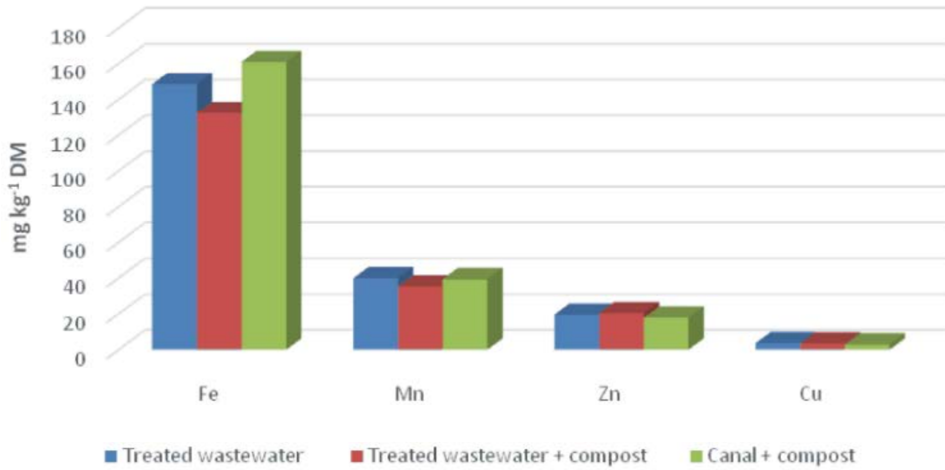


Fig. 2: EEffect of treated wastewater and canal waters trace elements concentrations in tree and shrub leavesspecies (mg kg^{-1} DM)

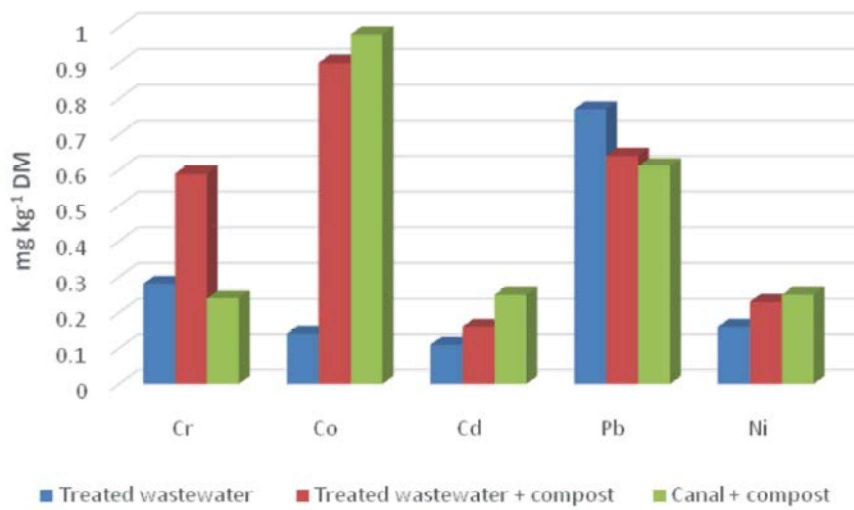


Fig. 3: EEffect of treated wastewater and canal waters on heavy metals concentrations in tree and shrub leavesspecies (mg kg^{-1} DM)

andsignificantly, none of the fruit trees survived, with the exception of Ficus. Most of the shrub species survived with the exception of Rosa.Theoverall survival of trees and shrubs, after replanting, was greatest on the compost treatment irrigated with treated wastewater (62%), with marginally lower survival rates under the compost only (58%) and treated wastewater only (56%) treatments. This indicates that the use of compost at planting is particularly benefcial to establishment, but the benefit of treated wastewater compared with canal water would appear to be marginal.

Bioavailability of Trace Elements and Heavy Metals in of Forestry Species Leaves: The mean concentrations according to treatment are given in Table (7) All of the concentrations were very small and no treatment related effects are discernible. Of the essential trace elements, copper concentrations appear particularly deficient under all treatments (Table 7 & Figs. 2 and 3). The results do not agree with the findings of [13] who found that concentrations of in contrary heavy metals (Cd, Ni, Pb and Fe) tended to accumulate in root more than that in leaves and shoots with few exceptions.

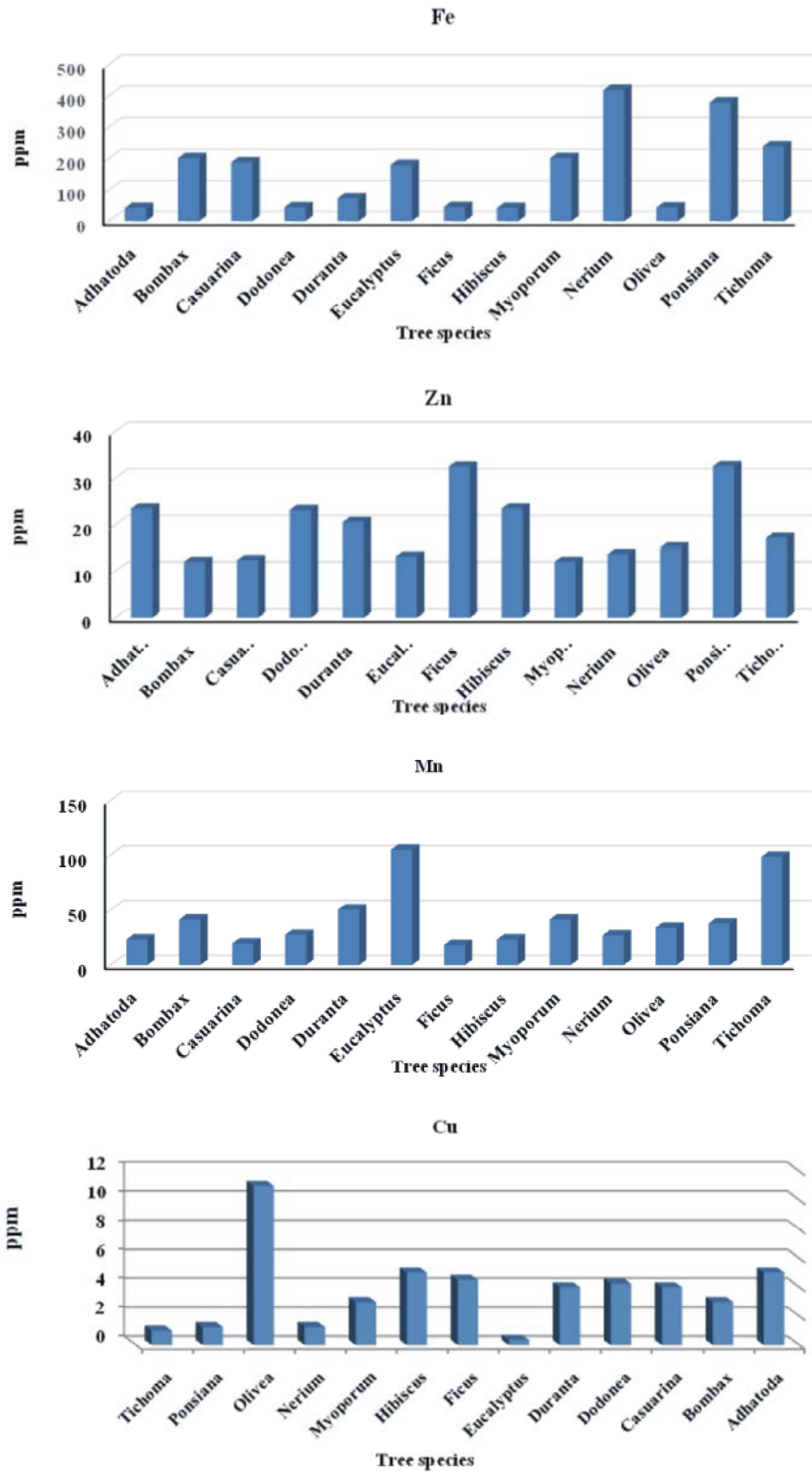
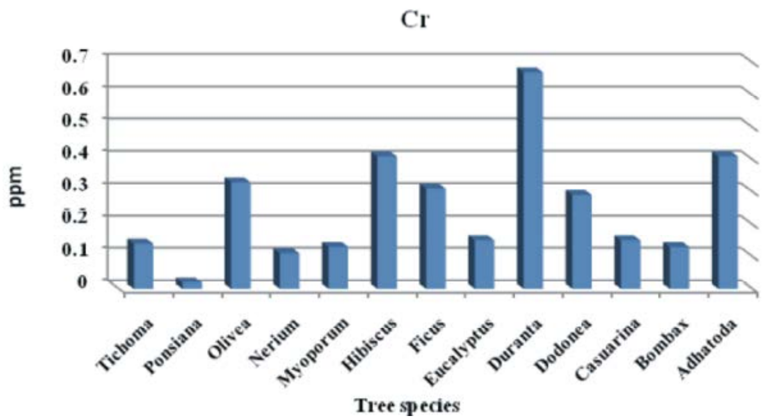


Fig. 4(a-d): Effect of treated wastewater on Fe, Zn, Mn and Cu concentrations in different plant species laves (mg kg^{-1} DM)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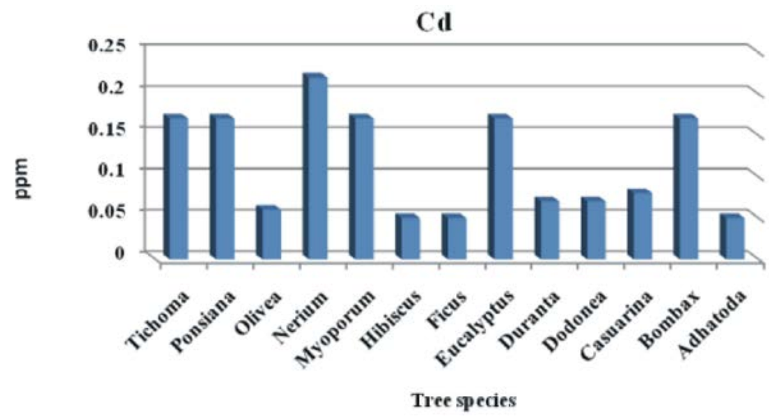
ppm
Tichoma
Ponsiana
Olivea
Nerium
Myoporum
Hibiscus
Ficus
Eucalyptus
Duranta
Dodonea
Casuarina
Bombax
Adhatoda
Tree species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ppm
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Ponsiana
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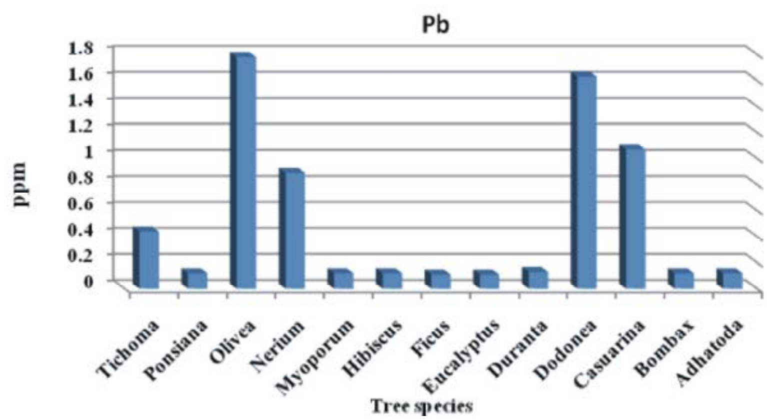
Hibiscus
Ficus
Eucalyptus
Duranta
Dodonea
Casuarina
Bombax
Adhatoda
Tree species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ppm
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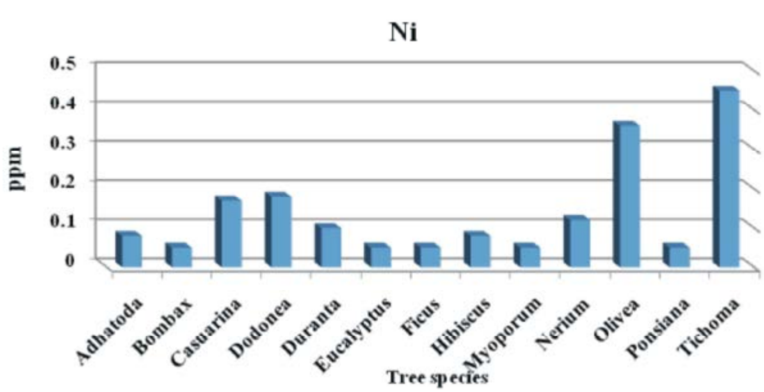
Ponsiana
Olivea
Nerium
Myoporum
Hibiscus
Ficus
Eucalyptus
Duranta
Dodonea
Casuarina
Bombax
Adhatoda
Tree species


Ni
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0.4
0.3
0.2
0.1
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ppm
Adhatoda
Bombax
Casuarina
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Hibiscus
Myoporum
Nerium
Olivea
Ponsiana
Tichoma
Tree species

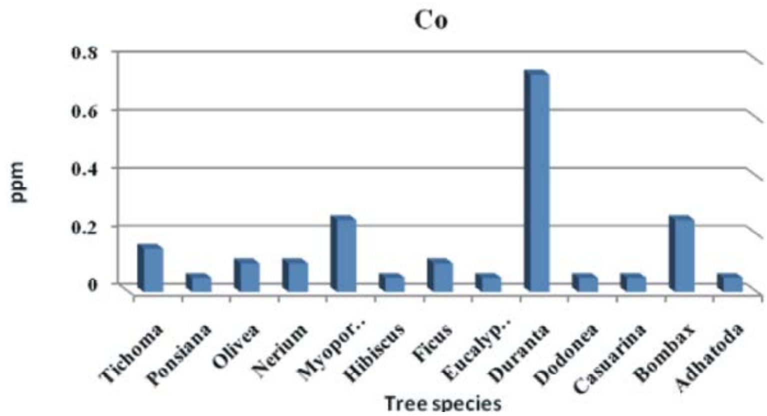

Fig. (4e-i): Effect of treated wastewater on heavy metals Co, Cr, Cd, Pb and Ni concentrations in different plant species laves (mg kg^{-1} DM)

When irrigation time increased from 6 to 18 months the uptake of Cd, Ni, Pb and Fe in the whole plant was increased due to progressive increase of vegetative growth. Also EL-Sayed [12] foundthat irrigation with secondary treated wastewater increased Fe, Zn, Mn, Cu, Pb, Cd, Cr and Ni in leaves, stems and roots of tree species (C. siliqua, A. saligna and A. stenophylla) compared with tap water. The magnitude of increase of the studied heavy metals in the whole plant due to primary treatead wastewater treatment comparedwith tap water after 18 months ranged from 2 to 9 times for all elements and can be arranged in the following order: Cd> Ni>Pb> Fe. Overall, the trial has provided a useful guide to the species that are likely to survive the veryhostile stony and calcareous soil conditions. While the scientific integrity of the trial has been compromised to some extent because of the method of irrigation, it would be useful to continue to irrigate and monitor the trial for a number of years to gather more information on survival and growth performance of the different species.

The results of heavy metal analysis in leaves of species indicated that showed that Nerium and Ponsiana leaves contained the greatest Fe concentration >350-400 ppm while Olivia contained the lowest Fig. (4a). Concerning Zn it is clear from Fig. (4b) that most of tree species leaves content was inadequate, 20 ppm. Mn concentration illustrated in Fig. (4c) show that Tichoma and Eucliptus could accumulate around 100 ppm compared with the other species. Meanwhile, Olivia species could accumulate >10 ppm and the other species seemed to be deficient in this important nutrient (Fig. 4d). Duranta accumulated the greatest Cr and Co concentration than the other species. Cd is the most important heavy metal due its high mobility in tissue but it seems that it is far from the toxic limit for all species. Nerium was the greatest accumulator than of Cd than the other species. The results are explained by many investigators, who found that sewage treatead wastewater had a stimulatory effect on vegetative growth of trees, provided the soil with plant nutrients and organic matter and improved the soil physical characteristics, that reflected on the growth by enhancing the cell elongation and division (Kaneker *et al*. [15] on Acacia nilotica, Hassan [16] on Acacia saligna and Leucaenaleucocephala, Berbec *et al*. [17] on poplar, Guo and Sims [18] on Eucalyptus.

The tree trials results demonstrated that tree irrigated with secondary treated wastewater perform equally as well as, or significantly better than, with canal water. There were no underlying trends in the data, tissue concentrations of zinc and copper were below recommended levels in crops. Heavy metal concentrations were very small and are of no concern to crop quality or animal and human dietary intake. There were no detectable effects of treated wastewater on soil quality.

CONCLUSION

The policy of the reuse of marginal water, which includes treated wastewaters, is well developed and treated wastewater reuse will play an increasingly important role in overall water resource management in the next decades. The responses of a wide range of trees to treated wastewater irrigation is consistent with international experience, with enhanced plant growth and economic yield due to the supply of nutrients and trace elements and benefits to soil conditions from organic matter in the case of compost. The pathogen content of treated wastewater in Egypt is large and treated wastewater and compost need to be treated to minimize the potential risks of disease transmission, particularly to farm labourers who are exposed during manual field operations and who will have low appreciation of hygiene.

It may be concluded from this study that under sandy calcareous desert soils in Egypt Treated wastewater can be used in field crop irrigation. Forest species were greatly variable for the bioavailability of trace elements and heavy metals in of the forestry species leaves irrigated with secondary treated wastewater However, continuous monitoring should be taken in consideration.

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