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IMPACT OF LONG-TERM USE OF TREATED WASTE EFFULNTS ON NUTRATION STATUS AND HEAVY METALS ACCUMULATION IN IRIGATED SOIL AND SOME GROWING WOODY TREE SPECIES.

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ABSTRCT

Egypt is an arid country, which covers an area of about one million Km^2 of which only 4% is occupied by its population. The population has tripled during last 50 years from 19 million in 1947 to about 83.5 million in 2012.of whom about 99% are concentrated in the Nile valley and Delta. The population is estimated to be about 100 million by the year 2025**.** One of the important issue in the future is to redistribute the population over a large area. To reach this objective, it is essential to reclaim new lands in order to provide the required food for the new communities.

The current study was conducted at Egyptian& China Friendship Forest (El-Sadat City, Minufiya Governorate, about 100 Km North West of Cairo), to asses the suitability of the sewage effluent treated through stabilization ponds from the stand point of the Egyptian Code (501/2005). In addition the impact of long-term use of that effluent on the nutrition status and heavy metal accumulation in irrigated sandy soil as well as some growing forest tree species. i.e. Cupressus sempervirens, Pinus halepensis., Corymbia citriodora and Eucalyptus camaldulensis. The results of chemical analyses of the waste effluents and tissue of tree organs indicated that:

1-There is no great seasonal variation in the most wastewater constituents along the study year, and fall in category B in the code, with which no problem could be expected upon utilization for irrigation, especially in the light soil with deep ground water.

2-Utilization that effluents for irrigation along 12 years improved nutrition status of the sand soil and increased the level of heavy contents compared with that of the virgin one. That increases differed among the different elements, being due to the concentration of each in the effluent, its physic-chemical properties and the growing plant species. However, some nutrients in the effluents fail to produce the growing plants with its recommended value with which other nutrient sources is required. On the other hand the level of all heavy metal in the soil being below the maximum permissible limit.

3-The rate of heavy metals accumulation in the growing plants differed more or less according to the growing plant species and their organs as well as sort of the element itself. The results of this study draw the attention of the benefit of using such sources of water in forest trees irrigating.

4-The study proved that the application of the principles and standards of the Egyptian Code 501/2005 can be used successfully sewage waste to irrigate woody trees in desert areas and cities surrounded by desert without an environmental or health problems.

Keywords: Reuse wastewater- heavy metals- contaminated soil- hyper accumulation trees.

INTRODUCTION

The steady increase in the amount of water used and waste water produced by urban community and industries throughout the world possess potential health and environmental problem. Egypt seeking safe, environmental sound and cost, efficient ways to treat and dispose of waste water. At the same time, increased attention is being focused on the role that forest traditionally a rural based sector, can play in improving the urban and beret urban environment. One opportunity to option those two concerns is the use of municipal water to irrigation forests, forest plantations greenbelt and amenity trees.

Currently, Egypt produces an estimated 5.5 – 6.5 BCM of sewage water per year, of that amount 2.7 BCM is treated, but only about 0.7 BCM per year is utilized for agriculture mainly in direct reuse in desert area in irrigation some forest trees. Now the guide line (Egypt code 501/2005) had adopted to regulate the treated waste water reuse in agriculture.

The agriculture requirements exceed 80% of total demand of water Abdel-Shafy and Aly, (2002). In view of the expected increase in water demand from other sources, such as municipal and industrial water supply, the development of Egypt's economy strongly depends on its ability to conserve and manage its water resources. Meanwhile, water demand is continually increasing due to population growth, industrial development, and the increase of living standards. The per capita share of water dropped dramatically to less than 1000m3/capita, which is classified as "water poverty limit". It is projected that the value decrease to 500 m^3 $capita^{-1}$ in the year 2025, Abdel-Wahaab,(2003) and El-Gohary, (2013).

Most cultivated lands are close to the Nile banks, its main branches, and canals. Currently the inhabited area is about 5.3 million ha and the cultivated agriculture land is about 3.3 million ha. The per capita crop are declined from 0.17ha in 1960, 0.08 ha in 1996 to about 0.04 ha in 2012 World Bank, (2007). The sharp decline of the per capita of both cultivated land and crop area resulted in the decrease of the per capita crop production. This affects directly security at individual, family, community and country levels World Bank,(2009).

In Egypt, acute shortage of water necessitates the development of new water sources. The supplies of sewage water effluent progressively increased with increasing population. Currently, Egypt produces 5.5 – 6.5 B.C.M. of sewage water per year, of that amount, about 2.987 B.C.M. per year is treated, but only 0.7 B.C.M. per year is utilized for agriculture, mainly in direct reuse in desert areas or indirect reuse through mixing with agricultural drainage water, Abdel-Shafy and Abd-Sabur, (2006).

Primary treated wastewater has been used since 1912 in agriculture (El-Gabal El-Asfar Farm, 1200ha). Egypt is now witnessing a wide range of new project aiming at expanding the green stretch in the desert by introducing forest plantations using treated sewage water to produce timber trees of high economic value. Forest trees may be more tolerant than many other plants to irrigate with wastewater. Cultivation green belt or forest species around cities under wastewater irrigation helps to make ecological balance and improve environmental quality by self-treatment of wastewater through application and forest irrigation Shinha, (1996) and Singh and Bhati, (2005).

This practice not only reduces the toxicity of soil and plays an important role in safeguarding the environment, because woody species may utilize wastewater and uptake heavy metals through extensive root systems and retain them for a long time Madejon et al., (2006), but also creates opportunities for commercial biomass production and sequestration of excess minerals in the plant system Sharma and Ashwath, (2006). However, the ability of trees to survive and grown under condition of wastewater irrigation seems to be variable among species because wastewater usually contains undesirable constituents as salts, trace organic compounds…etc.

Again, application of sewage water improves the physical-chemical properties and nutrient status of the soil and an increases crop productive as it supplies N, P, K and also available micronutrient than the crop requires. On the, other hand wastewater may contain amount of potentially harmful components such as heavy metals pathogens El-Wakeel and Abd-Elnaim (1986a); Rattan et al., (2005) and El-Nashar (1999).

The effect of microbial pathogens are usually short term and vary in severity depending on the potential for human, animal or environmental contact, Toze (2006). While the heavy metals have longer term impact that could be a source of contamination and be toxic to the soil and plant El-Wakeel and El-Mowlhi (1988a). Hence, if wastewater is to be recycled safely for irrigation, the problems associated with usin it needed to be known Sharma et al., (2007).

According to differences in climatic, vegetation socio-economic conditions and also in quality of soil and wastewater between regains and even within different time periods in one region, utilizing only the applicable guidelines to other regions of the world would be a mistake and in long-term would damage the soil and water resources.

The Egyptian Code (501/2005) classifies wastewater into three grades (designated A, B and C), depending on the level of treatment and specifies the maximum contaminates consistent with each grade, and the crops that can and importantly, cannot be irrigated with each grade of treated wastewater.

In Egypt the forest trees irrigating with treated wastewater locate in 14 Governorates and 2 district with more them 30.000 ha of marginal desert land allocated 63 forests. The designed daily discharge effluents of WWTPs used for irrigation are about 1.9 million m^3 Abdel-Shafy et al., (2003). The cultivated area is about 5.000 ha FAO, (2005) and fallow land area is about 25,000 ha.

The use of treated wastewater should be considered an integral component in country's national water strategic plan. However, the constraint facing use of treated wastewater are; health, impacts and environmental safety linked to soil structure deterioration, increase salinity and excess of nitrogen and heavy metals toxicity. The present study was devoted to assess the suitability of the treated wastewater of El-Sadat wastewater treatment stabilization pond for irrigation from the stand point of Egyptian Code 501/2005 and its impact on nutrients and heavy metals accumulation in cultivated soil and some growing forest tree species.

Therefore, the present study was conducted to evaluate the impact of long-term application of treated waste effluents on nutrition status and heavy metals accumulation in irrigated soil and some growing woody tree species.

MATERIALS AND METHODS

This study was carried out at Egypt &China Friendship Forest located at El-Sadat City, Minufya Governorate, about 100 Km North West of Cairo City, Egypt (Situated 31° 51\ N 30° 36\ N longitude). This forest was planted in sandy soil, irrigated with treated wastewater since 1998. Drip irrigation system was constructed to serve the irrigation farm. Four wooden tree species namely, Cupressus sempervirens, Pinus halepensis ., Corymbia citriodora and Eucalyptus camaldulensis. grown in the farm since 1998, were tested. However, some area within the farm are still virgin to give a wide range for comparison and follow up the impact of long term sewage application on soil and trees.

Sampling:

Representative samples from the used irrigation sewage effluent, irrigated soil and growing woody tree species were periodically collected from the studying area as follows.

Waste effluent:

The collected samples were filtered and stored in polyethylene bottles and kept near freezing (4 C°) to be analyzed in the laboratory.

Soil:

Five soil profiles were chosen to represent the both virgin (non cultivate) soil and that planted with four different varieties of woody trees, soil samples were taken under each selected tree species from three depths (0-30, 30-60, and 60-90cm) by digging profiles. Soil samples were air dried, ground, thoroughly mixed and passed through a 2 mm sieve and kept for analysis.

Trees:

Four, wooden tree species were planted in 1998 as 4 replicates, each represent 25 seedlings, planted 3X3 m in between 2 summary. Four trees from each species were totally blighted and its organs were separated – i.e. (leaves, branches and roots) For chemical analysis 3 samples of each tree organs were taken (5g. of each) and oven dried at 70 C°, ground and stored for analysis.

Analysis:

Following Black *et al.,* (1965) and Page (1984), the soil samples were analyzed for particle size distribution, CaCO3, O.M, pH, soluble cation and anions. Available N, P, K, Fe, Mn, Zn, Cu, B, Co. Cr, Ni and Pb were also determined according to American Public Health Association APHA, (1992). The sewage effluent was analyzed for pH, EC, main cations and anions, soluble N, P, Fe, Mn, Zn, Cu, B, Co, Cr, Ni and Pb. Also plant sample were wet digested according to Chapman and Pratt (1961), soluble N in water, available N in soil and total-N in woody trees, determined by Kjeldahel technique Jackson (1973). (P, Fe, Mn, Zn, Cu, B, Co, Cr, Ni, and Pb) in water, soil and woody trees determined by Inductively Coupled Plasma Spectrometry (ICP) (Ultima 2 JY Plasma), K was determined by flame photometer.

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RESULTS AND DISCUSSION

Quality Aspects of the Waste Effluents:

The values (maximum, minimum and average vales) of some chemical characteristic of the used waste effluents are given in Table 2. The results of the field measurements and laboratory analysis indicated that there is no great seasonal variation, in most of wastewater constituents along the study year.

Table 2: Characteristics of sewage effluent used for irrigation.

Items	**Unit**	**Minimum**	**Maximum**	**Average**	**Recommended value Egyptian cod (501/2005)**
pH		7.8	8.1	8.0	6.5-8.4
EC	dS m^{-1}	1.4	1.6	1.5	3.0-7.0
Adj SAR		6.4	7.4	6.8	> 9.0
CO_3	meq L^{-1}	n.d	n.d	n.d	-----
HCO_3	meq L^{-1}	4.1	5.8	4.86	> 9.0
Cl	meq L^{-1}	8.71	10.25	9.3	> 10.0
SO_4	meq L^{-1}	1.03	2.14	1.81	-----
Ca	meq L^{-1}	2.64	3.57	3.08	-----
Mg	meq L^{-1}	1.31	1.90	1.75	-----
Na	meq L^{-1}	10.12	10.70	10.49	-----
K	meq L^{-1}	0.48	0.85	0.65	-----
N	mgL^{-1}	14.9	21.63	19.07	> 30.0
P	mgL^{-1}	5.51	7.49	6.29	
Fe	mgL^{-1}	0.392	0.543	0.423	> 5.0
Mn	mgL^{-1}	.138	0.205	0.161	> 0.20
Zn	mgL^{-1}	0.232	0.291	0.260	> 2.0
Cu	mgL^{-1}	0.106	0.147	0.125	> 0.20
B	mgL^{-1}	0.373	0.550	0.447	> 3.0
Co	mgL^{-1}	0.011	0.016	0.015	> 0.05
Cr	mgL^{-1}	0.011	0.017	0.014	> 0.10
Ni	mgL-1	0.011	0.022	0.015	> 0.20

Value of wastewater reaction (pH) ranged from 7.8 to 8.1 i.e. all figures fell in slight alkaline side.

Regarding salinity, as expressed by EC, the values ranged from 1.4 to 1.6 dS m^{-1} with an average of 1.5 dS m^{-1}. This indicates the ability of the used effluents to cause increasing salinity problems upon utilization for irrigation. However, the level of sodicity parameter adjust R Na ranged from 6.4 to 7.4 (average 6.8) which is considered safe according to FAO, (1985**)** (recommended by Egyptian code 501/2005).

The limit of concern is boron (0.373-0.550) and averaged of 0.447. Noteworthy, most of the potential tree variety of farm is semi- tolerant to tolerant for boron and no particular problem is anticipated. Moreover, B is very mobile, particularly in sandy soil, and leaching is an effective to remove it out of soil profile.

The levels (in average) of available N, P and K in waste effluents being about 19.07, 6.29 and 0.65 mg l^{-1} respectively. For woody trees at full growth, the amount of irrigation water is anticipated to be 10.000 m^3 ha^{-1} $year^{-1}$ with which about 190.0, 60.0 and 250.0 kg ha^{-1} are expected to be supplied. Regarding the recommend fertilizer levels it seems that the values of added N and P not adequate for growing trees with which supplementary amount are required.

Regarding the effluent contents of heavy metals, all of which are within the recommended value for 1ong term use (Egyptian code 501/2005). However, taking into consideration the alkaline pH of the effluent and studied areas, it is expected that solubility of these element, will be quite low. Nevertheless, it should be stressed that, since the amount of irrigation water must be within the tree species water requirement and the frequency of irrigation based on the water holding capacity of sand soil, with low water use efficiency, the long-term environmental risk could be expected as a result of leaching of nutrients and eventually pollution of groundwater particularly by NO_3-N.

Irrigation impact on soil properties (nutrients and heavy metals levels).

The data cited in Table 3 a, b and c show the impact of sewage water utilization, up to 10 years in irrigation on some nutrients and heavy metals contents and their disruption in sandy soil.

Data in Table 3 a reveal the grand averages of minerals distribution along the investigated soil profiles, irrespective with growing woody tree species. Results indicate that, the values of all elements increased in the surface layer and sharply decreased, with different magnitude, with depth, and this being in accordance with the contents of organic contents and soil particles. However, it seems that the increasing rate of any metals being due to the difference in their concentration in the sewage effluent addition to the differences in physic- chemical properties of this element. El Wakeel and El-Mowelhi (1988a)., Brown et al., (1997), Hassan et al (2002) and Rana et al (2010).

Regarding, the grand average values (in ppm)of the study elements along the investigated soil profiles as affected by long term use of sewage effluent, being in the following order: N (77.78) > K (60.58) > P (8.61) > Fe (6.03) > Mn (1.469) > Zn (0.991) > Pb (0.253) > B (0.203) > Cu (0.191) > Ni (0.110) > Cr (0.052) > Co (0.019).

It is worthy to mention that the long term irrigation with sewage effluent increased (with different magnitude) the level of all elements. Comparing the grand average values of these elements in the treated soil compared with that under the virgin one (Table 3 a)., it is quite evident the increasing folds were in the following decreasing order: P (48.7) > N (23.4) > Pb (13.3) > Mn (9.6) > Zn (4.5) > Ni (92.50) > Fe (2.4) > B (1.9) > Co (1.8) > Cu (1.6) > K (1.4) > Cr (1.3).

Taking the growing woody trees species into consideration, data in Table (3 b and c) show the increasing levels of the available elements in the treated soil compared with that in the virgin one differed more or less according to the growing tree species. For example, the increasing folds of available N values show the following order: (33.5) > (23.5) > (20.5) > (19.5), under *Pinus halepensis; Corymbia citriodora; Cupressus sempervirens* and *Eucalyptus camaldulensis* respectively, however for P the order was (55.1) > (53.1) > (48.8) > (41.3) for *Pinus halepensis, Eucalyptus camaldulensis, Corymbia citriodora, Cupressus sempervirens*, respectively.

In the other word, according to data in (Table 3 b), it can be said that some woody trees species are more effective for absorbing nutrient and/ or heavy metals more or less than others. These results are in agreement with those of Shinha (1996), El- Nashar (1999), Rattan et al (2005), and Tabari, and Salehi, (2009).

In General. the highest values of the available element in the planted, soils compared to that under virgin one being as follow: N and P under *Pinus halepensis*; B, Ni. Cr, and Pb under *Cupressus sempervirens*; K and Fe under *Corymbia citriodora*; and Mn, Zn, Cu,and Co under *Eucalyptus camaldulensis*. However the lowest levels were found for: N and Cr under *Eucalyptus camaldulensis*, P and Co under *Cupressus sempervirens*, K, Fe, Mn, Zn and Cr under *Pinus halepensis* and B, Cu and Pb under *Corymbia citriodora*.

Generally, the levels of all metals under the sewage water irrigated soil Table 3 (a, b and c) being below the maximum recommended limits, Adriano, (1986), Aubert and Pinta, (1997), Kabata et al., (2001) and WHO (1989).

Mineral Contents in Growing Woody Tree Species.

The data in Table 4a elucidate that, the level of mineral contents in tested woody tree species differ more or less according to plant species, year seasons, and sort of mineral. Generally the date reveal that, no greet variation of N, P, or K averages within the different woody trees species. The highest values of Fe, Mn, Zn, Cu, Cr, Ni and B were elucidated in *Cupressus sempervirens*, Co in *Corymbia citriodora*, and Pb in *Eucalyptus camaldulensis*, heaver the lowest ones were given for Fe, Mn, Zn and Ni in *Pinus halepensis* Cr and Pb in *Corymbia citriodora* and Cu in *Eucalyptus camaldulensis*.

Regarding the time of the year all elements concentration reveled the following Spring> Summer> Winter>Autumn. With respect the overall distribution of different elements in growing woody trees (irrespective species) it showed the following order: N (1.094) > K (1.091) > P (0.123)% > Fe (765.4) > Mn (42.75) > B(38.55) > Cu (24.08)> Zn (22.096) > Cr (16.51) > Ni (12.04) > Co (4.30) > Pb (0.087) mg kg^{-1}.

With respect to the level of metals distribution in the different organs, data in Table 4b show the following leaves > branches > roots. The optained results are in agreement with those obtained by Poraas (2000) and El-Khateeb *et al.* (2012).

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CONCLUSION.

Wastewater reuse for forest plantation irrigation has several benefits safe and low cost of treatment and disposal of wastewater, rehabilitation of fragile ecological zones, reduce discharge of wastewater into the water streams and sea, and use of nutrients in wastewater for productive purposes. Therefore, wastewater could be considered as an alternative source of water for irrigation.

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تأثير إستخدام المياة العادمة المعالجة فى الرى على المدى الطويل على الحالة الغذائية وتراكم العناصر الثقيلة فى التربة وبعض الأشجار الخشبية.

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تؤدى الزيادة السكانية المستمرة إلى الزيادة فى الإستهلاك المائى لسد الإحتياجات المنزلية والصناعية وبالتالى زيادة المخلفات الناتجة عنها وما يصحبها من مشاكل صحية وبيئية فى ظل ندرة المياه وخاصة فى المناطق الجافة وشبة الجافة الأمر الذى أدى إلى دراسة هذه المشكلة ومحاولة الحد من آثارها السيئة على الصحة والبيئة عموماً. وكان من أهم تلك الإتجاهات هو إعادة إستخدام هذه المياه ذات الصلاحية المحدودة فى الزراعة ووضع اللوائح والقوانيين المنظمة لهذا الإستخدام طبقاً لدرجة المعالجة التى تم إجراؤها فى الكود المصرى 2005/501 الذى وضع الأسس والمعايير للإستخدام المباشر لمياه الصرف الصحى فى رى الأشجار الخشبية فى الأراضى الهامشية وخاصة فى المحافظات ذات الظهير الصحراوى ومن تلك المدن مدينة السادات بمحافظة المنوفية التى أجريت فيها هذه الدراسة لبيان تأثير إستخدام هذه النوعية من المياه على الحالة الغذائية وتراكم العناصر الثقيلة فى التربة وبعض أصناف الأشجار الخشبية على المدى الطويل وأوضحت الدراسة التى تم إجراؤها على الغابة المصرية الصينية التى يتم ريها منذ عام 1998 بهذه النوعية من المياه ما يأتى :-

1. إن نوعية المياه المستخدمة تضع فى القسم (ب) طبقاً للكود المصرى 2005/501 والذى معه يمكن إستخدام هذه المياه بنجاح فى رى الأشجار الخشبية دون حدوث أى أضرار سلبية وخاصة فى هذه المنطقة ذات التربة الرملية عميقة القطاع الأرضى وانه ليس هناك إختلاف ملموس فى مكوناتها على مدار العام .
2. أدى إستخدام هذه النوعية من المياه فى رى بعض أصناف الأشجار الخشبية على مدى حوالى إثنى عشر عاماً إلى إرتفاع قيم العناصر الغذائية وإلى تراكم بعض العناصر الثقيلة فى التربة دون تخطى الحدود القصوى المسموح بها لهذه العناصر . وأن الزيادة فى تراكم أى من هذه العناصر بالتربة كان متأثراً بدرجة تركيزة فى مياه الرى وعمق قطاع التربة وكذلك نوعية الأشجار النامية .
3. إختلف محتوى الأشجار النامية من العناصر الغذائية والثقيلة بإختلاف نوعية النبات وأجزاؤه (جذر - ساق - أوراق) وكذلك بإختلاف فصول السنة. وكذلك نوعية العنصر فى حد ذاته.
4. أثبتت الدراسة أنه بتطبيق أسس ومعايير الكود المصرى 2005/501 يمكن إستخدام مخلفات الصرف الصحى بنجاح فى رى الأشجار الخشبية فى المناطق الصحراوية والمدن ذات الظهير الصحراوى دون حدوث مشاكل بيئية أوصحية.

Table 1: Some physical and chemical properties of the virgin (non-cultivate) soil.

Soil depth (cm)	OM %	$CaCO_3$ %	Particle size distribution %				Texture class	SP %	pH	EC dSm^{-1}	Soluble anions meq l^{-1}				Soluble cations meq l^{-1}				SAR	Soil class
			Sand		Silt	Clay					CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{+2}	Mg^{+2}	Na^+	K^+		
			Coarse	Fine																
0 – 30	0.03	3.00	80.55	14.35	2.40	2.70	Sandy	18.00	8.00	3.86	0.00	1.71	13.05	38.39	14.70	9.45	27.99	1.01	5.10	NS NA
30 – 60	0.03	3.30	75.30	19.2	2.70	2.80	Sandy	19.00	8.30	7.46	0.00	0.95	47.70	58.52	49.35	21.95	34.94	0.93	5.9	SNA
60 – 90	0.02	3.35	79.30	12.01	3.48	5.21	Sandy	19.0	8.40	10.10	0.00	1.90	64.80	64.54	44.10	26.25	61.40	0.69	10.4	SA
Average	0.03	3.20	78.38	15.18	2.86	3.57	Sandy	18.60	8.20	7.14	0.00	1.52	41.85	53.32	36.05	19.22	41.44	0.88	8.13	

NSNA= non saline non alkaline soil SNA=saline non alkaline soil SA= saline alkaline soil.

Table 1: Cont. DTPA extractable elements (mg kg^{-1}).

Soil depth (cm)	N	P	K	Fe	Mn	Zn	Cu	B	CO	Cr	Ni	Pb
0 – 30	4.00	0.12	108.36	2.88	0.30	0.028	0.20	0.72	n.d	0.06	n.d	n.d
30 – 60	4.00	n.d	75.41	2.44	0.08	0.20	0.18	0.90	n.d	0.04	n.d	n.d
60 – 90	2.00	n.d	63.26	2.48	0.08	0.18	0.12	0.62	n.d	0.02	n.d	n.d
Average	3.33	0.03	82.34	2.60	0.15	0.22	0.16	0.75	n.d	0.04	n.d	n.d
normal range in soil a.b.d.	--	--	--	--	--	50-100	15-40	--	10-15	--	15-30	15-30
*WHO upper limit range	--	--	--	--	--	400	100	--	-	--	5.500	2-200

a= Adriano 1986 b= Aubert and **Pinta, 1997 c= Kabata 2001 *= Source, WHO,1989.**

Table 3a. Effect of long term application of sewage wastewater on some nutrients and heavy metal content in soil planted with different woody trees species.

Profile of utilize in year	Soil depth cm	mg kg^{-1}*											
		N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Co**	**Cr**	**Ni**	**Pb**
Control (0)	0-30	4.000	0.170	53.400	2.880	0.300	0.280	0.120	0.122	0.011	0.060	0.015	0.025
	30-60	4.000	0.120	36.110	2.480	0.080	0.200	0.120	0.107	0.011	0.040	0.011	0.015
	60-90	2.000	0.120	29.300	2.280	0.080	0.180	0.110	0.094	0.011	0.020	0.011	0.011
Average		3.333	0.137	39.603	2.547	0.153	0.220	0.117	0.108	0.011	0.040	0.012	0.017
Irrigated *	0-30	103.820	11.450	80.030	9.480	2.530	2.061	0.226	0.278	0.031	0.086	0.168	0.444
	30-60	71.560	7.980	55.100	5.940	1.137	0.644	0.191	0.183	0.016	0.040	0.109	0.152
	60-90	57.960	6.410	46.620	2.660	0.740	0.267	0.155	0.148	0.011	0.031	0.052	0.080
Average		77.780	8.613	60.583	6.027	1.469	0.991	0.191	0.203	0.019	0.052	0.110	0.225
Folds of control		22.334	62.024	0.530	1.366	8.580	3.503	0.634	0.885	0.758	0.308	7.892	12.255

*** Each figure represents the average value of 3 replicates X 4 season X 4 woody tree species = 48 replicates.**

Table 3b: Average of the effect of sewage wastewater irrigation on some nutrients and heavy metal distribution in soil cultivated with different woody trees species.

Woody Trees Species	Soil depth cm	mg kg^{-1} *											
		N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Co**	**Cr**	**Ni**	**Pb**
Control	0-30	4.000	0.170	53.400	2.880	0.300	0.280	0.120	0.122	0.011	0.060	0.015	0.025
	30-60	4.000	0.120	36.110	2.480	0.080	0.200	0.120	0.107	0.011	0.040	0.011	0.015
	60-90	2.000	0.120	29.300	2.280	0.080	0.180	0.110	0.094	0.011	0.020	0.011	0.011
Average		3.333	0.137	39.603	2.547	0.153	0.220	0.117	0.108	0.011	0.040	0.012	0.017
Cupressus sempervirens	0-30	89.200	8.430	79.000	9.730	2.700	2.223	0.194	0.274	0.026	0.102	0.172	0.484
	30-60	62.200	7.800	51.600	5.820	0.963	0.940	0.179	0.229	0.015	0.034	0.118	0.222
	60-90	53.540	5.730	45.460	2.730	0.643	0.253	0.163	0.150	0.011	0.026	0.046	0.034
Average		68.313	7.320	58.687	6.093	1.435	1.139	0.179	0.218	0.017	0.054	0.112	0.247
Folds of control		19.494	52.561	0.482	1.393	8.361	4.176	0.531	1.022	0.576	0.350	8.081	13.510
Pinus halepensis	0-30	147.400	14.310	79.000	9.560	2.510	2.093	0.190	0.254	0.030	0.074	0.162	0.466
	30-60	101.340	7.320	51.610	5.980	1.055	0.910	0.170	0.164	0.015	0.046	0.112	0.150
	60-90	77.060	5.730	45.460	2.580	0.768	0.258	0.146	0.146	0.011	0.023	0.070	0.084
Average		108.600	9.120	58.690	6.040	1.444	1.087	0.169	0.188	0.019	0.048	0.115	0.233
Folds of control		31.580	65.732	0.482	1.372	8.420	3.941	0.446	0.746	0.697	0.192	8.297	12.725
Corymbia citriodora	0-30	101.490	12.120	81.660	9.340	2.440	1.868	0.270	0.240	0.033	0.087	0.163	0.431
	30-60	62.720	7.580	60.790	5.990	1.130	0.793	0.218	0.164	0.016	0.040	0.105	0.135
	60-90	48.900	6.140	48.040	2.580	0.740	0.315	0.151	0.144	0.011	0.024	0.051	0.052
Average		71.037	8.613	63.497	5.970	1.437	0.992	0.213	0.183	0.020	0.050	0.106	0.206
Folds of control		20.311	62.024	0.603	1.344	8.370	3.509	0.826	0.697	0.818	0.258	7.622	11.118
Eucalyptus camaldulensis	0-30	77.170	10.950	80.450	9.180	2.460	2.060	0.250	0.303	0.035	0.080	0.173	0.393
	30-60	59.960	9.210	56.410	5.960	1.400	0.780	0.195	0.173	0.011	0.038	0.101	0.104
	60-90	52.330	8.040	47.500	2.750	0.810	0.240	0.161	0.150	0.012	0.026	0.039	0.066
Average		63.153	9.400	61.453	5.963	1.557	1.027	0.202	0.209	0.019	0.048	0.104	0.188
Folds of control		17.946	67.780	0.552	1.342	9.152	3.667	0.731	0.938	0.758	0.200	7.459	10.039

*** Each figure represents the average value of 3 replicates X 4 season = 12 replicates.**

Table 3c: Grand mean effect of sewage wastewater irrigation on some nutrients and heavy metal level in soil cultivated with different with woody trees species during the investigation year.

Woody Trees Species		mg kg^{-1}*											
		N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Co**	**Cr**	**Ni**	**Pb**
Control	Control	3.333	0.137	39.603	2.547	0.153	0.220	0.117	0.108	0.011	0.040	0.012	0.017
Cupressus sempervirens	Grand Average	68.313	7.320	58.687	6.093	1.435	1.139	0.179	0.218	0.017	0.054	0.112	0.247
	Folds of control	19.494	52.561	0.482	1.393	8.361	4.176	0.531	1.022	0.576	0.350	8.081	13.510
Pinus halepensis	Grand Average	108.600	9.120	58.690	6.040	1.444	1.087	0.169	0.188	0.019	0.048	0.115	0.233
	Folds of control	31.580	65.732	0.482	1.372	8.420	3.941	0.446	0.746	0.697	0.192	8.297	12.725
Corymbia citriodora	Grand Average	71.037	8.613	63.497	5.970	1.437	0.992	0.213	0.183	0.020	0.050	0.106	0.206
	Folds of control	20.311	62.024	0.603	1.344	8.370	3.509	0.826	0.697	0.818	0.258	7.622	11.118
Eucalyptus camaldulensis	Grand Average	63.153	9.400	61.453	5.963	1.557	1.027	0.202	0.209	0.019	0.048	0.104	0.188
	Folds of control	17.946	67.780	0.552	1.342	9.152	3.667	0.731	0.938	0.758	0.200	7.459	10.039

*** Each figure represents the average value of 3 replicates X 4 woody trees X 4 seasons = 12 replicates.**

Table 4a: Average metal contents in different woody trees species through the year season.

Tree Species	Season	%			$mg\ kg^{-1}$*								
		N	P	K	Fe	Mn	Zn	Cu	B	Co	Cr	Ni	Pb
Cupressus sempervirens	Spring	1.200	0.161	1.200	1474.0	66.10	43.10	32.60	77.50	3.28	35.08	23.92	0.084
	Summer	1.177	0.134	1.177	1221.0	53.40	29.30	26.60	51.90	3.11	31.39	19.67	0.069
	Autumn	1.045	0.087	1.045	695.0	40.80	26.20	19.00	45.20	2.89	17.06	12.75	0.048
	Winter	1.079	0.125	1.079	802.0	49.90	27.00	22.40	44.70	2.92	24.58	16.36	0.058
Average		1.125	0.127	1.125	1048.0	52.55	31.40	25.15	54.83	3.05	27.03	18.18	0.065
Pinus halepensis	Spring	1.390	0.196	1.390	695.0	43.00	25.10	32.20	48.03	5.86	12.47	10.78	0.095
	Summer	1.060	0.106	1.060	484.2	31.50	17.30	25.00	36.40	5.47	11.22	9.77	0.078
	Autumn	0.653	0.054	0.653	372.9	24.60	11.10	17.40	25.50	2.47	9.20	6.91	0.067
	Winter	1.120	0.094	1.120	471.2	28.10	15.10	20.60	27.20	3.53	9.77	8.83	0.072
Average		1.056	0.113	1.056	505.8	31.80	17.15	23.80	34.28	4.33	10.67	9.07	0.078
Corymbia citriodora	Spring	1.270	0.245	1.270	953.0	53.40	24.30	33.10	43.90	7.64	11.44	8.15	0.084
	Summer	1.170	0.107	1.127	767.2	39.40	21.00	25.50	31.80	6.64	10.28	7.80	0.073
	Autumn	0.860	0.076	0.860	527.0	32.10	15.20	20.30	18.90	4.50	8.88	5.38	0.063
	Winter	0.980	0.096	0.980	583.2	36.10	17.10	22.60	22.00	5.50	9.22	6.32	0.069
Average		1.070	0.131	1.059	707.6	40.25	19.40	25.38	29.15	6.07	9.96	6.91	0.072
Eucalyptus camaldulensis	Spring	1.312	0.176	1.312	1080.0	62.00	32.30	25.40	47.70	4.43	23.15	15.23	0.154
	Summer	1.217	0.119	1.217	778.6	47.30	22.30	24.20	36.14	4.21	20.53	15.23	0.147
	Autumn	0.857	0.089	0.857	593.8	38.20	19.10	18.30	26.30	2.71	14.85	10.74	0.103
	Winter	1.108	0.091	1.108	747.5	40.50	21.50	20.10	33.50	3.69	14.99	14.78	0.125
Average		1.124	0.119	1.124	799.98	47.00	23.80	22.00	35.91	3.76	18.38	14.00	0.132
Seasonal grand average	Spring	1.293	0.195	1.293	1050.5	56.13	31.20	30.83	54.28	5.30	20.54	14.52	0.104
	Summer	1.156	0.117	1.145	812.8	42.90	22.48	25.33	39.06	4.86	18.36	13.12	0.092
	Autumn	0.854	0.077	0.854	547.18	33.93	17.90	18.75	28.98	3.14	12.50	8.95	0.070
	Winter	1.072	0.102	1.072	650.98	38.65	20.18	21.43	31.85	3.91	14.64	11.57	0.081
Average		1.094	0.122	1.091	765.35	42.90	22.94	24.08	38.54	4.30	16.51	12.04	0.087

*** Each figure represents the average value of 3 replicates X 4 woody trees X 4 seasons = 48 replicates.**

Table 4b: Minerals contents in organs of different woody trees species.

Tree Species	Part of tree	%			mg kg^{-1}*								
		N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Co**	**Cr**	**Ni**	**Pb**
Cupressus sempervirens	Leaves	1.396	0.276	0.806	617.00	33.000	18.470	18.840	23.390	4.058	13.480	9.710	0.113
	Branchs	0.966	0.071	0.450	977.00	33.880	18.810	23.080	21.190	4.135	15.000	10.590	0.120
	Roots	0.662	0.662	0.060	1113.00	46.050	42.430	42.430	18.270	4.646	16.950	12.730	0.217
Average		1.008	0.336	0.439	902.33	37.643	26.570	28.117	20.950	4.280	15.143	11.010	0.150
Pinus halepensis	Leaves	1.629	1.629	0.168	698.00	698.000	22.880	14.860	27.510	3.719	16.050	12.810	0.073
	Branchs	1.151	1.151	0.142	824.00	824.000	24.880	14.840	23.450	4.625	17.280	13.260	0.084
	Roots	1.003	1.003	0.095	1044.00	1044.000	29.780	31.170	16.340	5.844	25.280	16.060	0.094
Average		1.261	1.261	0.135	855.40	855.333	25.847	20.290	22.433	4.729	19.537	14.043	0.084
	Leaves	1.325	0.139	0.751	283.80	49.270	17.830	10.720	26.160	4.729	9.020	6.260	0.051
Eucalyptus camaldulensis	Branchs	1.121	0.113	0.492	340.00	90.160	24.030	28.420	20.170	3.188	13.480	13.580	0.041
	Roots	1.103	0.118	0.483	457.80	108.900	28.260	32.720	21.150	4.769	21.720	12.770	0.086
Average		1.183	0.123	0.575	360.53	82.777	23.373	23.953	22.493	5.115	14.740	10.870	0.059
Eucalyptus camaldulensis	Leaves	1.449	0.111	0.523	216.00	22.470	11.200	9.320	32.240	2.625	11.930	10.980	0.031
	Branchs	0.741	0.089	0.447	288.00	38.190	17.460	26.400	26.420	4.442	15.540	11.950	0.051
	Roots	0.632	0.080	0.371	552.00	42.190	19.350	27.340	21.090	5.448	16.780	13.100	0.610
Average		0.941	0.093	0.447	352.00	34.283	16.003	21.020	26.583	4.172	14.750	12.010	0.231
Seasonal grand average	Leaves	1.450	0.539	0.562	279.36	200.685	17.595	13.435	27.325	3.783	12.620	9.940	0.067
	Branchs	0.995	0.356	0.383	401.40	246.558	21.295	23.185	22.808	4.098	15.325	12.345	0.074
	Roots	0.850	0.466	0.252	252.58	577.023	29.955	33.415	19.213	5.177	20.183	13.665	0.252
Average		1.098	0.454	0.399	311.12	341.422	22.948	23.345	23.115	4.352	16.043	11.983	0.131

*** Each figure represents the average value of 3 replicates X 4 woody trees X 3 organs = 36 replicates.**

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