IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 7, July 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

Assessment of Macro - Nutrients and Heavy Metals Accumulation in Soil and Four Biofuel Crop Plants under Long- Term Irrigation with Wastewater

***Om Mohamed A. Khafagi, **Abdel Aziz M. Ragab, and *Heba M. El- Sayed**

*Botany and Microbiology Department, Faculty of Science (Girls Branch), Al- Azhar University, Cairo, Egypt
**Water and Environment Research institute Agriculture Research Center Giza, Egypt

Abstract: This study was conducted to assess the effect of long- term irrigation with wastewater on macro - nutrients and heavy metals accumulation in soil and four biofuel crop plants. The study area of the present work was located at The Old Haggagia village, Fakous, El Sharkia Governorate, as two field plots (25 m x 15 m / each) were established. The first plot received its irrigation water from a small Nile canal, and the second from a wastewater small outlet drain from the major drain of Bahr El Baqar .This site is under wastewater irrigation for more than 50 years. Four crop plant species were chosen for this study, being economically important as potential biofuel producing crops, namely; canola (*Brassica napus*), Jojoba (*Simmondsia chinensis*), Jatropha (*Jatropha curcas*) and castor bean (*Ricinus communis*) plants. Also, they are all known as heavy metals hyper accumulators. Six month old seedlings of Jojoba and Jatropha were transplanted into each of the two field plots, and seeds of canola and castor bean were planted at the same time in both sites. These four oil crop plants were tested to evaluate their phytoremediation potential of heavy metals contaminated sites. For this purpose, soil, the aboveground parts and roots of the plants were analyzed for their content of Cu, Cr, Co and Mn. The content of Cu, Cr, Co and Mn increased significantly in soil under wastewater irrigation as compared with soil under Nile water irrigation . This trend was also noticed in plants grown in soil irrigated with wastewater as compared with the plants grown under Nile water irrigation.

The concentrations of the different heavy metals in the soil showed the descending order: Mn > Cr > Cu > Co, concentrations of these heavy metals in the soil irrigated with wastewater indicated extremely high to high enrichment values, according to the published background concentrations of the trace elements**.** The results indicate varied efficiencies of the four plant species to extract Cu, Cr, Co and Mn from the polluted soil. The uptake values of these heavy metals by the selected plants were determined, and the result showed that *R. communis* had the highest uptake value than other plants.

Keywords: Wastewater irrigation - Phytoremediation – Phytoextraction –Heavy metals – hyperaccumulators- Phytoremediation parameters (Concentration index – Uptake of heavy metals– Translocation Factor – Bioaccumulation Factor).

Introduction

Heavy metals are abundant in the environment, as a result of both natural and anthropogenic activities, and humans are exposed to them through various pathways **(Wilson and Pyatt, 2007).** Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety **(Muchuweti et al., 2006).** This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metals accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals **(Rattan et al., 2005).**

Phytoremediation is the use of green plants to remove pollutants from the environment or to render them harmless **(Salt et al., 1998)**. Phytoremediation has been used to clean-up soil contaminated by organic and inorganic pollutants, including heavy metals. For these elements phytotechnologies represent an in situ low-impact approach that has received increasing interest due to its cost effectiveness and environment-friendly nature (**Pedron et al., 2009).**

Among the different technologies, the most relevant in heavy metal remediation are: phytostabilization, which consists of the immobilization of metals in soil or roots, thus reducing their mobility in the environment, and phytoextraction, that removes metals from soil through uptake and subsequent translocation from roots to the aboveground portion of the plant (**Barbfieri, 2000 and Pivetz, 2001).**

Phytoextraction mainly concerns with the removal of heavy from soil by means of the uptake capabilities of plants. Phytoextraction utilizes the roots of plants to absorb, and concentrate toxic metals from the soil to the above-ground harvestable plant tissues. The concentration process results in a reduction of contaminated mass and also a transfer of the metal from soil to plants **(Blaylock and Huang, 2000)**. Phytoextraction is based on the use of hyper accumulator plants with exceptional metal-accumulating capacity. These plants have several beneficial characteristics such as being fast growing, producing high biomass, the ability to accumulate metals in their shoots, an exceptionally high tolerance to heavy metals and must have the ability to translocate an element from roots to shoots at high rates **(Blaylock and Huang, 2000)**. Four economically important crop plant species were chosen for this study, being important as potential biofuel producing crops, namely; canola (*Brassica napus*), (**Rashid et al., 2016**), Jojoba (*Simmondsia chinensis*) (**Sánchez et al., 2016a)**, Jatropha (*Jatropha curcas*) (**MOPNG, 2007)** and castor bean (*Ricinus communis*) (**Comar et al., 2004**) plants. Also, and at the same time, they are all known as heavy metal hyper accumulators and could be used as phytoremediators of contaminated sites.

Materials and Methods

The Study Area: The study area of the present work is located at The Old Haggagia village, Fakous, El Sharkia Governorate, as two field plots were established. Each plot was (25x 15 m) 375m^2. The first plot is located at the entrance of the village, and receives its irrigation water from a small Nile canal called Khaleeg Om Hendi; this site will be considered as the control. The second site is located at the end boundary of the village, and receives its irrigation water from a small drain, called Bahr El Manaher, that is a small outlet from the major drain of Bahr El Baqar This site is under wastewater irrigation for more than 50 years.

Field trial experiment: The field trial experiment was established by the 1st of October, 2014. Five randomized soil samples were collected, mixed to form a compiled soil sample from each site. From those compiled samples three soil samples were collected. Three irrigation water samples were, also, collected from each of the two study sites (three replicates / sample). Soil and water samples were analyzed to assess the chemical constituents and the most common accumulating heavy metals in each, to be monitored and focus on through the investigation.

Plantation: Fifty seedlings of Jojoba (*Simmondsia chinensis*) and fifty seedlings of Jatropha (*Jatropha curcas*) were transplanted by 26 th of December, 2014 into each of the two field plots. Both Jojoba and Jatropha seedlings were six month old, about 90 – 120 cm height. Seeds of canola (*Brassica napus*) and castor bean (*Ricinus communis*) were planted at the same time in both sites. Irrigation was started, in both plots, directly after plantation and was continued every 20 days as recommended by the conventional agricultural management. The cultivation period lasted about five months for canola plant, and lasted about 12 months for Jojoba, Jatropha and castor bean plants. Samples from each of the tested plant species, as well as from irrigation water and soil were collected, at different stages, throughout the experimental period.

Water samples were taken from each of the wastewater drainage and River Nile canal that represented the sources of irrigation water of the studied sites, and kept in plastic bottles in a cool place. Analyses of water were determined according to the standard methods of **Chap man and Pratt**

(1961). Wastewater recorded the following values: pH = 7.53, EC = 1.48, SAR = 2.61, soluble cations (Ca, Mg, Na and K) = 5.44, 4.80, 5.88 and 0.09 $mmolL^{-1}$, respectively and soluble anions (HCO_3,Cl & SO_4) = 1.45, 10.68 and 4.08 $mmolL^{-1}$, respectively. The macro – nutrients (N, P & K) were 4.84, 0.50 and 3.60 $mmolL^{-1}$, respectively and the concentration of heavy metals (Cu, Cr, Co and Mn) were 3.83, 0.97, 1.16 and 13.29 ppm, respectively; while in Nile water pH = 7.14, EC = 1.03, SAR = 2.13, soluble cations (Ca, Mg, Na and K) = 3.51, 3.67, 4.00 and 0.08 $mmolL^{-1}$, respectively and soluble anions (HCO_3,Cl & SO_4) = 1.95, 6.38 and 2.92 $mmolL^{-1}$, respectively. The macro – nutrients (N, P & K) = 3.21, 0.27 and 3.24 ppm, respectively and the concentration of heavy metals (Cu, Cr, Co and Mn) = 0.74, 0.51, 0.25 and 1.80 ppm, respectively. Soil samples were collected from depths of 0-30 cm and 30-60 cm, and placed carefully in closed tin to be used for further analyses. The soil samples were air-dried, ground, passed through a 2 mm sieve and thoroughly mixed. Soil physical and chemical properties were determined according to the standard methods of **(Piper, 1950)**, **Page et al. (1982)** and **Clark et al. (1986)**. The pH was measured in 1: 2.5 soils: water extract using a pH meter. Total soluble salts (EC) were determined in the saturated soil paste, and available macronutrients (Na, P and K) were determined as outlined by **Black (1965)** by using DTPA - NH_4HCO_3 method (**Soltanpour**, **1985**). The trace elements (Cu, Cr, Mn and Co) in soils were extracted by digestion with a mixture of HCl and HNO_3. The mixture was heated until complete digestion **,** then diluted with deionized water to a known volume (**Jackson, 1967**).These metals were measured by atomic absorption (model Perkin Elmer 400) and expressed as mg /kg .Plant samples were analyzed for N, P and K nutrients according to **Cottenie et al., (1982).** Trace elements Cu, Cr, Co and Mn were determined according to (**Christain, 1969)** using atomic absorption (model Perkin Elmer 400). The bioaccumulation factor and translocation factor were calculated according to **Kiekns and Camerlynck (1982)**. The statistical analyses of the obtained data were done according to the method described by **Snedecore and Cochran (1989).**

Results and Discussion

Soil Chemical Characteristics:

The data presented in **Table 1** show the values of soil EC, pH, OM, moisture content and texture classes of the soils. The EC values increased significantly in the soil under wastewater irrigation in both layer 0-30 cm and 30-60 cm as compared with soil under Nile water irrigation; and increased in the 30 – 60 cm depth than in the 0-30cm depth in both soils irrigated with either Nile water or with wastewater. **Shalaby et al., (1996)** reported slight increase in soil EC as affected by application of either sewage effluent waste (S.E.W.) or fertilizer factory waste (F.W.); and they reported more than 42 % increase in soil EC with the addition of oil and soap waste (O.S.W.) as compared with the soil irrigated by tap water. They attributed that to the high alkalinity and acidity of (O.S.W.) and (F.W.), respectively. The soil pH values increased significantly in soil under wastewater irrigation than in soil under Nile water irrigation, and also in the 30-60 cm layer than in the 0 - 30 cm layer **(Table 1)**.

Table 1. Soil electrical conductivity (EC), pH, organic matter (%), moisture content (%) and textural classes of the studied soil

Soil type	Depth cm	EC ds/m	pH	O.M %	Moisture content %	Texture Classes
(Soil I) under Nile water	0-30	4.29 a	7.48 a	1.40 a	8.39 a	Clay Loam
(Soil II) under Wastewater		6.60 b	8.30 b	2.03 b	14.43 b	Clay
LSD at 0.05		0.72	0.24	0.19	4.53	------
(Soil I) under Nile water	30-60	3.88 a	7.57 a	1.69 a	25.88 a	Clay
(Soil II) under Wastewater		25.99 b	8.10 b	2.86 b	45.31 b	Clay

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 5 Issue 7, July 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

LSD at 0.05		2.43	0.24	0.16	10.63	------

Kiziloglu et al., (2007) indicated that wastewater irrigation and preliminary treated-wastewater irrigation significantly affected soil chemical properties especially at 0 - 30 cm soil depth after one year. Application of wastewater increased soil salinity, organic matter, exchangeable Na, K, Ca, Mg, plant-available P, and micro elements deceased soil pH. Soil OM content was significantly higher in soil under wastewater irrigation than that of Nile water irrigation in both soil layers. Also, the OM content was higher in the deeper layer than in the upper layer **(Table 1).** According to **Brar et al., (2000**) OM increased to 60 cm depth. **El-Lawendy et al., (2000**) found that the increase in the soil history of being irrigated with treated sewage effluent was associated with the increase in its OM content. In all soil profiles, OM content was the highest at the surface layer (0-15cm) and decreased downward .Similar findings regarding the effect of irrigation with wastewater on soil OM content were reported by (**El-Motaium and Badawy ,2000; Carlos et al., 2005 and Jun-feng et al., 2007). Aghabarati et al., (2008)** indicated that a seven-year application of municipal effluent increased OM % (0-60 cm soil layer) as compared to soil irrigated with well water.

The soil moisture content increased significantly in wastewater irrigated soil over that of the Nile water irrigated soil for both soil layers **(Table 1).** Regarding soil texture, the data presented in **Table 1** revealed that the upper layer (0 – 30 cm) was sandy loam in soil irrigated with Nile water and sandy clay in soil under wastewater irrigation. Meanwhile, the lower soil layer (30 – 60 cm) was sandy clay under Nile water irrigation and loamy clay under wastewater irrigation. These differences in soil texture were significant.

While the soil content of N and K was higher in soil under wastewater irrigation as compared with that of soil under Nile water irrigation, the opposite was true regarding soil P content (**Table 2**).

Table 2. Heavy metals and macro elements content of soil samples collected during the cultivation period

Soil type	**Depth cm**	**Heavy metals (mg kg^{-1})**				**Macro-elements (mg kg^{-1})**		
		Cu	**Cr**	**Co**	**Mn**	**N**	**P**	**K**
(Soil I) under Nile water irrigation	**0-30**	14.55 a	34.04 a	10.59 a	100.13 a	83.81 a	9.29 a	268.06 a
(Soil II)under Wastewater irrigation		100.57 b	148.66 b	58.12 b	481.55 b	125.16 b	5.52 b	450.45 b
LSD at 0.05		23.19	21.57	4.23	69.74	38.76	0.74	67.16
(Soil I) under Nile water irrigation	**30-60**	14.64 a	18.50 a	6.33 a	101.74 a	100.95 a	7.47 a	194.11 a
(Soil II)under Wastewater irrigation		113.29 b	114.90 b	71.04 b	467.41 b	138.06 b	4.78 b	505.03 b
LSD at 0.05		8.25	33.64	8.10	91.09	25.58	1.72	111.91

The values of the macro elements N, P and K showed significant increase in N and K content and significant decrease in the P content of soil under wastewater irrigation as compared with these of Nile water irrigation in both soil layers 0-30 cm and 30-60 cm **(Table 2).**

Heavy metals content in soil

The soil content of the studied heavy metals, Cu, Cr, Co and Mn under both irrigation types are shown in **Table 2.** Spectacular and remarkable increase in soil content of these tested heavy metals was recorded in both soil layers (0-30 cm and 30-60 cm) under irrigation with waste water over their contents in soil of Nile water irrigation. The increase the values of the studied heavy metals under wastewater irrigation as compared with their comparable values under Nile water irrigation reached several folds. The soil Cu content amounted 18.13 mg kg^{-1}, and 118 mg kg^{-1} by the end of plantation time. Meanwhile , the content of Mn in Nile irrigated and wastewater irrigated soil reached, respectively 143.57 mg kg^{-1} and 514.30 mg kg^{-1} , comparable magnitudes of increase in Cr and Co content in waste water irrigated soil over their corresponding values under Nile water irrigation were also noticed **(Table 2).** The vertical distribution of the increase in their concentration due to sewage water irrigation varied from one element to another. Most of the accumulation of Cu and Cr occurred in the top 30 cm. The increase of Cr in the surface 30 cm soil only by sewage water irrigation was also observed earlier (**Singh et al., 1989).** According to the report of **National Academy of Science** (**1972**), increasing periods of irrigation with sewage effluent increase the contents of the different elements in soil to ample but not toxic levels.

Soil contamination with heavy metals is a serious global environmental problem **(Wang et al., 2001**) posing risks to human, animals, microbes, and plants and contaminating surface and soil ecosystem through natural processes and anthropogenic activities.

Macro – nutrients in plants

As for available nutrient (N , P , & K), the data presented in **Tables 3 - 6** revealed significantly higher contents of these macro nutrients in roots and shoots of all the tested plants under Nile water irrigation as compared with these value of the corresponding plants under wastewater irrigation . For example, the value of N, P and K in root of *B. napus* plants grown in soil irrigated with Nile water recorded 2.32 %, 0.99 % and 1.18 %, respectively, and reached 2.0, 0.67 % and 0.93 %, respectively under wastewater irrigation. Significant variations in the accumulation of nutrients and heavy metals in the above- and below-ground parts of Egyptian clover were recorded in both polluted and unpolluted sites **(Galal, 2016)**. Clover plants accumulated higher concentrations of N, P and K in their roots higher than in shoots in both polluted and unpolluted sites. The concentrations of these nutrients were lower in the leaves, but higher in the roots under the effect of pollution.

Table 3. Contents of the macro elements N, P, and K (%) in roots and shoots of *Brassica napus* plant grown in the two studied sites

Source of irrigation water	Roots macro-elements content (%)			Shoots macro-elements content (%)		
	N	P	K	N	P	K
Nile water canal (control)	2.32 a	0.99 a	1.00 a	2.61 a	0.48 a	1.02 a
Wastewater drain	2.00 b	0.67 b	0.92 b	1.56 b	0.33 b	0.94 b
L.S.D at .05	0.04	0.05	0.04	0.02	0.08	0.03

Table 4. Contents of the macro elements N, P, and K (%) in roots and shoots of *Simmondsia chinensis* plant grown in the two studied sites

Source of irrigation water	Roots macro-elements content (%)			Shoots macro-elements content (%)		
	N	P	K	N	P	K
Nile water canal (control)	2.58 a	1.10 a	0.51 a	3.68 a	0.85 a	1.03 a
Wastewater drain	1.77 b	0.53 b	0.35 b	2.36 b	0.69 a	0.48 b
L.S.D at .05	0.42	0.14	0.08	0.64	0.24 n.s	0.19

Table 5. Contents of the macro elements N, P, and K (%) in roots and shoots of Jatropha curcas plant grown **in the two studied sites**

Source of irrigation water	Macro - elements content %					
	Root			Shoot		
	N	P	K	N	P	K
Nile water canal (control)	2.02 a	1.05 a	1.33 a	3.86 a	1.30 a	1.53 a
Wastewater drain	1.30 b	0.49 b	0.65 b	1.32 b	0.64 b	0.41 b
L.S.D at .05	0.29	0.31	0.14	0.24	0.52	0.20

Table 6. Contents of the macro elements N, P, and K (%) in roots and shoots of *Ricinus communis* plant grown in the two studied sites

Source of irrigation water	Roots macro-elements content (%)			Shoots macro-elements content (%)		
	N	P	K	N	P	K
Nile water canal (control)	2.25 a	0.92 a	1.18 a	2.45 a	1.11 a	1.13 a
Wastewater drain	1.32 b	0.61 b	1.12 a	1.73 b	0.60 b	1.12 a
L.S.D at .05	0.23	0.11	0.36 n.s	0.21	0.28	0.22 n.s

Heavy metals content in plant

The content of Cu, Cr, Co and Mn in roots and shoots of the four plant species of the present investigation are shown in **Tables 7 - 10**. Conclusively, it could be stated that the concentration of Cu, Cr, Co and Mn increased significantly and greatly in both roots and shoots of the four plant species grown in soil under irrigation with wastewater as compared with those grown in soil irrigated with Nile water. Such increase in the tissue content of the tested heavy metals under wastewater irrigation may reach many and many folds- their concentration in plants of the control site (Nile water irrigation). Considering the content of the tested heavy metals in roots and shoots, it is obvious that these trace elements, generally, tended to accumulation greatly in the roots rather than in shoots under both types of irrigation water. For instance, the concentration of Cu, Cr, Co and Mn reached 92.07, 41.11, 11.57 and 119.42 ppm in roots, and 32.26, 35.71, 8.93 and 122.68 ppm in shoots of *B. napus* plants under wastewater irrigation.

Conclusively, it could be noticed that these above mentioned trends of heavy metals bioaccumulation, regarding their response to irrigation water type, the stage of growth and the partitioning between the roots and shoots, noticed in *B. napus* plants were also noticed with the other three plant species namely, *Simmondsia chinensis*, *Jatropha curcas* and *Ricinus communis* plants (**Tables 7 - 10**).

Table 7. Contents of Cu, Cr, Co and Mn (mg kg^{-1}) in roots and shoots of *Brassica napus* plant grown in the two studied sites

Source of irrigation water	Root heavy metals content (mg kg^{-1})				Shoot heavy metals content (mg kg^{-1})			
	Cu	Cr	Co	Mn	Cu	Cr	Co	Mn
Nile water canal (control)	18.57 a	7.70 a	1.22 a	24.32 a	6.72 a	7.36 a	1.66 a	26.04 a
Wastewater drain	92.07 b	41.11 b	11.57 b	119.42 b	35.26 b	35.71 b	8.93 b	122.68 b
L.S.D at .05	11.35	5.96	3.09	8.21	3.00	3.92	0.70	6.84

Table 8. Contents of Cu, Cr, Co and Mn (mg kg^{-1}) in roots and shoots of *Simmondsia chinensis* plant grown in the two studied site

Source of irrigation water	Root heavy metals content (mg kg^{-1})				Shoot heavy metals content (mg kg^{-1})			
	Cu	Cr	Co	Mn	Cu	Cr	Co	Mn
Nile water canal (control)	4.53 a	3.93 a	3.10 a	18.43 a	7.57 a	4.33 a	2.97 a	9.80 a
Wastewater drain	13.02 b	29.61 b	30.73 b	44.59 b	19.39 b	34.30 b	8.47 b	26.67 b
L.S.D at .05	2.15	2.78	6.80	6.12	2.40	3.18	1.07	5.31

Table 9. Contents of Cu, Cr, Co and Mn (mg kg^{-1}) in roots and shoots of *Jatropha curcas* plant grown in the two studied site

Source of irrigation water	Root heavy metals content ($mg\ kg^{-1}$)				Shoot heavy metals content ($mg\ kg^{-1}$)			
	Cu	**Cr**	**Co**	**Mn**	**Cu**	**Cr**	**Co**	**Mn**
Nile water canal (control)	3.46 a	3.28 a	0.17 a	5.82 a	3.56 a	2.72 a	0.25 a	7.99 a
Wastewater drain	28.82 b	42.19 b	3.33 b	44.72 b	29.96 b	21.04 b	2.60 b	81.80 b
L.S.D at .05	6.07	7.01	0.38	6.40	10.87	8.64	1.05	42.94

Table 10. Contents of Cu, Cr, Co and Mn ($mg\ kg^{-1}$) in roots and shoots of *Ricinus commo unis* plant grown in the two studied site

Source of irrigation water	Root heavy metals content ($mg\ kg^{-1}$)				Shoot heavy metals content ($mg\ kg^{-1}$)			
	Cu	**Cr**	**Co**	**Mn**	**Cu**	**Cr**	**Co**	**Mn**
Nile water canal (control)	2.87 a	7.17 a	1.59 a	2.87 a	2.07 a	6.07 a	1.62 a	7.57 a
Wastewater drain	45.83b	112.67b	13.30b	220.83b	221.50b	64.00b	20.67b	86.23b
L.S.D at .05	3.13	12.38	5.08	31.84	49.48	3.31	2.58	12.65

Mireles et al., (2004*)* stated that there was no consistent pattern of metal accumulation, but as expected, most metals (Cr, Mn, Fe, Co, Ni, Cu, Zn and Pb) in roots were present at high level, while their content decreased in stems and leaves of alfalfa plants irrigated with wastewater. Ni, Cu and Zn ranges however, overlapped those considered toxic**.**

Similar data and conclusion were reported by many other authors including; **El-Motaium and Radway (2000), Rattan et al. (2005) and Rimawi et al. (2007).**

Phytoremediation parameters

Phytoremediation parameters can be used to evaluate the potential of the different plant species in the phytoremediation process of heavy metals polluted sites. Among these parameters is the concentration index, translocation factor, bioconcentration factor, heavy metals uptake.

Concentration index (Ci): is the ratio of concentration of an element in enriched plant to the concentration of that element in a normal plant (**Kiekns and Camerlynck, 1982)**. The concentration index (Ci) of the four tested heavy metals (Cu, Cr, Co and Mn) in roots and shoots of the four plant species under the current study are presented in **Table 11**.

Table 11 .The concentration index of *Brassica napus, Jatropha curcas, Simmondsia chinensis, Ricinus communis*

Plant species	Concentration index							
	Root				Shoot			
	Cu	Cr	Co	Mn	Cu	Cr	Co	Mn
B.napus	4.82	5.03	8.57	5.00	5.91	5.02	6.33	4.97
J. curcas	5.04	10.06	9.41	6.95	6.48	8.71	6.32	6.98
S.chinensis	3.78	5.22	7.01	3.46	3.55	5.41	3.46	3.30
R. communis	9.44	8.39	8.92	29.44	37.93	7.66	8.32	8.52

The highest Ci for Cu, Cr, Co and Mn was recorded in *R. communis* plants; meanwhile, the lowest Ci for the tested metals was attained by *S. chinensis* plants. The higher Ci of an element indicates high tolerance of the plant to high levels of that element with the plant tissue, and the lower phytotoxicity of that element within the plant tissue. In other words, *R.communis* plant proved to be the most tolerant to high concentrations of Cu, Co and Mn, meanwhile, *S. chinensis* (Jojoba) seemed to be the most sensitive plant species.

The presented data also, revealed that *J. curcas* attained the highest Ci regarding Cr in roots and shoots and Co in roots only Considering the tolerance level of the tested trace elements, the studied plant species follow the order *R. communis* > *J.curcas* > *B. napus* > *S. Chinensis*. The great variability among plant species in their ability to take-up trace metals from the same soil medium of natural ecosystem is well known **(Abdel – Sabour and Aly, 2000**). When plants grow under a chemical stress, e.g., in a polluted environment, their response to metal contents may change drastically.

Uptake of heavy metals

Plant uptake of heavy metals is an important criterion for plant selection in phytoextraction since it provides some estimation of the amount of heavy metals that can be removed from a contaminated site as well as the time needed for site remediation The dry weight of any plant plays an important role in the uptake of the different metals from the soil. The data revealed high significant effect of the site on the uptake of Cu, Cr, Co and Mn by the different parts of the tested plant species under investigation. The lowest uptake value was found in *S. chinensis* plants grown in the soil irrigated with wastewater because they produced the lowest biomass **(Table 12). Begonia *et al*. (2002)** on their investigation of wheat plants (*Triticum aestivum L.)* grown in soil amended with four concentrations (0, 500, 1000& 2000 mg Pb/ Kg soil) of lead, stated that root Pb uptake increased with increasing levels of soil Pb.

Table 12. The uptake of Cu, Cr, Co and Mn (mg/plant) by *Brassica napus* , *Simmondsia chinensis, Jatropha curcas and Ricinus communis*

Plant species	Sites	Uptake of Cu, Cr, Co and Mn (mg/plant)											
		Root				Shoot				Plant			
		Cu	Cr	Co	Mn	Cu	Cr	Co	Mn	Cu	Cr	Co	Mn
B.napus	Nile water	0.07	0.03	0.005	0.09	0.46	0.51	0.11	1.80	1.84	1.10	0.21	3.67
	Wastewater	0.19	0.09	0.02	0.25	0.66	0.67	0.17	2.30	2.65	1.60	0.43	5.05
S.chinensis	Nile water	0.01	0.01	0.01	0.06	0.04	0.02	0.01	0.05	0.10	0.07	0.05	0.23
	Wastewater	0.02	0.04	0.04	0.05	0.02	0.04	0.01	0.03	0.08	0.15	0.09	0.17
J.curcas	Nile water	0.25	0.24	0.01	0.42	1.15	0.88	0.08	2.59	2.78	2.38	0.17	5.47
	Wastewater	0.37	0.53	0.04	0.57	1.05	0.74	0.09	2.86	2.80	3.02	0.28	6.04
R.communis	Nile water	0.24	0.59	0.13	0.24	0.23	0.67	0.18	0.84	0.96	2.56	0.62	2.02
	Wastewater	1.19	2.91	0.34	5.71	9.59	2.77	0.89	3.73	18.49	12.22	2.35	21.23

The translocation factor (TF)

The values of the TF of Cu, Cr, Co and Mn in the four plant species of the present study under both Nile water irrigation and wastewater irrigation are presented in **Table 13.** Translocation factor value of more than one, for an element attained by certain plant, means that this plant can absorb, mobilize and translocate high amounts of that element from the soil to the root and then to the aerial part of that plant. Consequently, this plant species could be used for phytoextracting this element from the contaminated sites. As indicated from **Table 13**, generally, it could be noticed that all TF value for all the tested heavy metals exceeded one with all the tested plant species, except in *B. napus*. Phytoextraction usually involves the uptake of toxic heavy metals from contaminated soils and their accumulation in harvestable parts of plant species. Plants being considered as hyper accumulators must have the potential to tolerate the metals and transfer them from roots to above-ground parts of the plant species **(Nawab et al, 2016)**.

Table 13. Translocation factor (TF) of Brassica *napus, Jatropha curcas, Simmondsia chinensis, Ricinus communis* grown in two sites

Plant species	Sites	Translocation factor (TF)			
		Cu	Cr	Co	Mn
Brassica	Nile water	0.36	0.96	1.36	1.07
	Wastewater	0.38	0.87	0.77	1.03
Jatropha	Nile water	1.02	0.83	1.59	4.13
	Wastewater	1.26	1.00	1.21	3.03

ISSN (Online) 2348 – 7968
www.ijiset.com

Simmondsia	**Nile water**	1.67	2.11	3.16	1.56
	Wastewater	1.49	1.94	2.07	1.33
Riccinus	**Nile water**	1.69	0.85	6.73	3.70
	Wastewater	4.83	0.79	3.62	4.21

Bioaccumulation Factor (BAF)

The BAF determines the ability of a plant to uptake a metal from soils. The BAF was used to assess the capacity of the studied plants to uptake metals from the soil. The data given in Table 14 present the values of BAF of Cu, Cr, Co and Mn by the four plant species of the present investigation. Plant species that attain BAF and TF greater than one are suitable for phytoextraction of heavy metals (**Pilon-Smits , 2005).**

Generally, the highest BAF values for most of the tested heavy metals (1.85 and 2.46) were recorded in *R. communis* followed by *B. napus*, while the lowest were for *S. chinensis* followed by *J. curcas*. It is worth to recall here that all TF values for the four tested heavy metals exceeded one with all the tested plant species, except in *B. napus* (**Table 14**).

In order for a plant to be considered hyper accumulators, it must have the potential to uptake and tolerate the metals and transfer them from roots to aerial parts of the plant **(Blaylock. and Huang, 2005).** On the basis of these two criteria (BAF and TF) / or at least one of them, the four plant species of the current study could be considered as hyper accumulators for one or more of the tested heavy metals. For instance, *R. communis* could be a "strong" hyper accumulator, followed by *J. curcas*, *S. chinensis* and *B. napus*. For the heavy metals of the current study. The uptake of metals by plants depends upon their mobility and availability in sediments.

Plants evolved several effective mechanisms for tolerating high concentrations of metals in soil. In some species, tolerance is achieved by preventing toxic metals uptake into root cells. These plants, coined excluders, have little potential for metal extraction. A second group of plants, accumulators, does not prevent metals from entering the root. Accumulator species have evolved specific mechanisms for detoxifying high metal levels accumulated in the cells. These mechanisms allow bioaccumulation of extremely high concentration of metals. In addition, a third group of plants, termed indicators, show poor control over metal uptake and transport processes. In these plants, the extent of metal accumulation reflects metal concentration in the rhizosphere. Indicator species have been used for mine prospecting to find new ore bodies **(Raskin et al., 1994).**

Table 14. The bioaccumulation factor of Cu, Cr, Co and Mn by *Brassica napus Simmondsia chinensis, Jatropha curcas and Ricinus communis*

Plant species	Sites	Bioaccumulation factor											
		Root				Shoot				Plant			
		Cu	Cr	Co	Mn	Cu	Cr	Co	Mn	Cu	Cr	Co	Mn
B.napus	Nile water	1.28	0.23	0.12	0.24	0.46	0.22	0.16	0.26	1.74	0.44	0.27	0.50
	Wastewater	0.92	0.28	0.20	0.25	0.35	0.24	0.15	0.25	1.27	0.52	0.35	0.50
S.chinensis	Nile water	0.31	0.12	0.29	0.18	0.52	0.13	0.28	0.10	0.83	0.24	0.57	0.28
	Wastewater	0.13	0.20	0.53	0.09	0.19	0.23	0.15	0.06	0.32	0.43	0.67	0.15
J.curcas	Nile water	0.24	0.10	0.02	0.06	0.24	0.08	0.02	0.08	0.48	0.18	0.04	0.14
	Wastewater	0.29	0.28	0.06	0.09	0.30	0.14	0.04	0.17	0.58	0.43	0.10	0.26
R.communis	Nile water	0.20	0.21	0.15	0.03	0.14	0.18	0.15	0.08	0.34	0.39	0.30	0.10
	Wastewater	0.46	0.76	0.23	0.46	2.20	0.43	0.36	0.18	2.66	1.19	0.58	0.64

The permissible limits of different countries and organizations show variation in concentrations for different heavy metals. These differences may be due to different strategies adopted by these countries and organizations to set permissible limits. The variation in permissible limit may be based on soil characteristics and type. The permissible limits for Cu, Cr, Co and Mn are 135 – 270, nd, nd and nd, respectively according to Singh et al .2010 (c.f. WHO /FAO 2007) mg $g^{-1.}$ The permissible limits for Cu, Cr, Co and Mn are 40.0, nd, nd and nd, respectively in plants according to Singh et al .2010 (c.f. WHO /FAO 2007) mg $g^{-1.}$ **.** The permissible limits for Cu, Cr, Co and Mn are 1.2, 1.0d, nd and 1.5 , respectively in water according to Nazief et al.2006 .(c.f. National Environmental Quality Standard (NEQS)1999) mg $g^{-1.}$**.**

References

Abdel-Sabour, M.F. and Aly, R.O. (2000). Bioremediation of heavy metal contaminated soils in dry land: Case studies in Egypt. Eds. Wise, D.L.; Trantolo, D.J.; Cichan, E.J.; Inyang, H.I. and Stottmeister, U. New York.

Aghabarati, A.; Hosseini, S.M. and Maralian, H. (2008). Heavy metal contamination of soil and olive trees (*Olea europaea* L.) in Suburban Areas of Tehran, Iran. Research J. of Environ, Sci., 2, 5,323-329.

Barbafieri, M., (2000). The importance of nickel phytoavailable chemical species characterization in soil for phytoremediation applicability.Int. J. Phytore-mediate, 2, 105-115.

Begonia, M.F.T.; Begonia, G.B.; Butler, A.; Burrell, M.; Lghoavodha, O. and Crudup, B. (2002). Chelate-assisted phytoextraction of lead from a contaminated soil using wheat (*Triticum aestivum* L.), Bull. Environ. Contam. Toxicol. 68, pp. 705–711.

Black, C. A. (1965). Methods of soil analysis. Soil Sci. Soc. of America. Inc. Pub. Madison, Wisconsin, USA.

Blaylock, M.J. and Huang, J.W. (2005). Phytoextraction of metals. In: I. Raskin and B.D. Ensley, Editors, Phytoremediation of Toxic Metals: Using Plants to clean up the Environment, John Wiley and Sons, New York.53-70.

Brar, M.S., S.S. Mahli, A.P. Singh, C.L. Arore and K.S. Gill. (2000). Sewer water irrigation effects on some potentially toxic trace elements in soil and potato plants in northwestern India. *Can. J. Soil Sci.* 80: 465 – 471.

Carlos, A.; Lucho-Constantino, Francisco Prieto-Garcia, Luz Maria, D. R.; Refugio R.V. and Hector M., P. V. (2005). Chemical fractionation of boron and heavy metals in soils irrigated with wastewater in central Mexico. Agriculture, Ecosystems and Environment, 108, 57-71.

Chapman, H.D., Pratt, P.F., 1961. Methods of Analysis for Soils. Plants and Waters. Agr. Pub., Univ. of California, Riverside.

Christian, G.D. (1969). Medicine, trace elements and atomic absorption spectroscopy. Anal.Ch, 41, 1.244.

Cottenie, A.; M. Verlso; L. Kilkens; G. Velghe and R. Camerlynck (1982). Chemical Analysis of Plants and Soils. Lab. Agroch. State Univ. Gent, Belgium.

El- Motaium, R. A. and Badawy, S. H. (2000). Effect of irrigation using sewage water on the distribution of some heavy metals in bulk and rhizosphere soils and different plant species: Cabbage plants (*Brassica oleracea L.*) and Orange trees (Citrus *sinensis L.*). J. Soil Sci. 40, 1-2 pp. 285- 303.

El-Lawendy, W.I.; Khafagi, O.A. and Abdel-Aal, H. (2000). Characteristics of treated sewage effluent and its impact on soil properties in El-Saff area. Al-Azhar Bull. Sci., 2, 2, 1-11.

El-Motaium, R.A. and Radawy, S.H. (2000). Effect of irrigation using sewage water on the distribution of some heavy metals in bulk and rhizosphare soils and different plant species: Cabbage Plants (*Brassica oleracea* L.) and Orange Trees (Citurs *sinensis* L.) Egypt. J. Soil Sci. 40, 1-2, 285-303.

Galal, T.M. (2016). Impact of environmental pollution on the growth and production of Egyptian clover. International Journal of Plant Production 10(3): 303-316.

Heba. M.S. El Sayed. (2018). Phytoremediation of soil affected with wastewater irrigation in Sharkia Governorate, Nile Delta, Egypt. M.Sc. Faculty of Science (Girls Branch).

Jackson, M. L. (1967). Soil Chemical Analysis. Prentice- Hall, Inc. N.J. USA.

Jun – Feng,W.; Gen-xu, W. And Hua,W.(2007). Recycling in the Ioess area of China. Journal of Environmental Sciences 19, 1093 – 1099.

Kiekns, L. and Camerlynck, R. (1982). Uptake of elements by plants. Presented at VDLUFA. Conf. Muster, West Germany.

Kiziloglu, F.M.; Turan, M.; Sahin,U.; Anaoali, I.A. and Okuroglu, M.(2007). Effect of wastewater irrigation on soil and cabbage – plant (*brassica olerecea* var. capital cv. yalova -1) chemical properties. J. of Plant Nutrition and Soil, 170, 1, 166-172.

Mireles, A.; Solis, C.; Andrade, E.; Solar, M.L.; Pina, C. and Flocchini, R.G. (2004).Heavy metal accumulation in plants and irrigated with wastewater from Mexico City. Nuclear Instruments and Methods in physics Research B, 219-220,187-190.

Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D., Lester, J.M., 2006. Heavy metal content of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: implications for human health. Agriculture .Ecosystem and Environment 112, 41-48.

National Academy of Sciences (NAS) (1972). National Research Initiative: Report of the committee on Research Advisory to the U.S. Department of Agriculture. Washington, DC: National Academy press, 1972.

National Environmental Quality Standard (NEQS) for municipal and liquid industries (1999). Compiled and distributed by National Scientific Corporation.

Nazif, W., Perveen, S. and Shah, S. A. (2006). Evaluation of irrigation water for heavy metals of Akbarpura area. J. Agricultural and Biological Science 1, 1, 51-54.

Nawab, J.; Khan, S.; Tahir Shah, M.T.; Gul, N.; Ali, A.; Khan, K. and Huang, Q. (2016). Heavy metal bioaccumulation in native plants in chromite impacted sites: A search for effective remediating plant species. Clean-Soil, Air, Water. 44 (1): 37-46.

1. **Page, A. L.; R. H. Miller and D. R. Keeney (1984).** Methods of soil analysis. Part 2: Chemical and Microbiological Properties. Second edition. Agronomy J. 9: 2, Am. Soc. Agron. Inc., Soil Sci. Soc. Am. Inc. Pub. Madison, Wisconsin, USA.

Page, A. I.; Miller, D. R. and Keeny, D. R. (1982). "Methods of Soil Analysis part II second ed. Chemical and Microbiological properties", 2nd ed, American Society of Agronomy Madison, Wisconsin, **U. S. A.**

Pedron, F., Petruzzelli, G., Barbafieri, M., Tassi. E., **(2009**). Strategies to use phytoextraction in very acidic soil contaminated by heavy metals. Chemosphere, 75, 6,808-814.

Pilon-Smits, E. (2005). Phytoremediation, Annual Review of Plant Biology. 56: 15-39.

Piper, C. S. (1950). Soil and Plant Analysis. Interscience Inc., New York .U.S.A.

Pivetz, B.E., (2001).Phytoremediation of contaminated soil and ground water at Hazardous Sites. Ground Water Issue, Environmental protection Agency EPA/540/s-01/500, and Washington, DC.

Rattan, R.K.; Datta, S.P.; Chhonkar, P.K.; Suribabu, K. and Singh, A.K. (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater: a case study. Agriculture Ecosystem Environmental. 109: 310-322.

Rimawi, Q.; Jiries, A.; Zubi, Y. and El-Naqa, A. (2007).Reuse of mining wastewater in agricultural activities in Jordan. Environ Dev Sustain DOI 10-1007/s 10668-007-9137-9.

Salt, D. E.; Smith, R. D. and Raskin, I. (1998). Phytoremediation. Annu. Rev. Plant physiol. Plant Mol. Biol. 49, 643-668.

Shalaby, M.H.; Gobran, O.A. and Raslan, M.I. (1996) .Chemical properties of soil as affected by pollution of different wastes. Egypt. J. of Soil Sci 36, 1-4, 23-32.

Singh BG, Rao PV, Hiremath SM (1989). Effect of salinity on germination and seedling growth in three varieties of groundnut (*Arachis hypogea L.*). J Res APAU 17: 432 – 433.

Singh, A., Sharma, R. k., Agrawal, M. and Marshall, F. M. (2010a). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. J. Tropical Ecology 51 (2S), 375-387.

Snedecor, G. W. and Cochran, W. G. (1989). "Statistical Methods" 8th Ed. Iowa State Univ., Press Amer. Iowa U.S.A., 325-330.

Soltanpour, P. N. (1985). Use of AB-DTPA soil test to evaluate elements availability and toxicity. Commun. Soil Sci. Plant Anal., 16: 323-338.

Wang, Q.R, Dong Y, Cui Y, LiuX (2001).Instances of soil and crop heavy metal contamination in China. Soil Sediment Contam 10:497–510.

WHO/FAO (**2007)**. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. United States of America, ALINORM 07/30/13.

Wilson, B., Pyatt, F.B., (2007). Heavy metal dispersion, persistence, and bioaccumulation around an ancient copper mine situated in Anglesey. UK. Ecotoxicology and Environmental Safety 66,224-231.