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EFFECT OF IRRIGATION WITH TREATED SEWAGE WATER ON HEAVY METAL UP-TAKE AND ACCUMULATION IN CULTIVATED PLANTS

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ABSTRACT : The aim of this research is to study the effect of irrigation with treated sewage water (SW) on heavy metals up-take and accumulation in plants cultivated in different soil types (have been irrigated since many years ago with SW) comparing to various irrigation water sources.

The results showed that heavy metals (Pb, Cd, Ni and Co) were highly accumulated in silty loam soil over loamy sand soil of pots cultivated with wheat and radish. Accumulation and concentration of heavy metals tend to be in the following order, Pb > Ni > Co > Cd. Mean of total accumulation and concentration showed that, soil irrigated with sewage or ground waters (GW) were highly contaminated with heavy metal than other irrigation water sources.

The mean of total concentration of each pollutant in wheat grains and radish leaves showed the following descending order in both heavy and light soils, Ni > Pb > Co > Cd. Irrigation with SW caused the highest Cd, Pb and Co accumulation as well as GW which increased Ni accumulation in the treated plants. Contrary, agriculture drainage water (ADW) and treated sewage water (TSW) showed the lowest Ni, Pb and Cd accumulation. Cadmium, Pb, Ni and Co availability concentration factor (CF) to plants was affected mainly with irrigation water sources, heavy metal chemistry, and concentration in the soil and the growing plant.

Key words : Soil, plant, treated sewage water, heavy metals.

INTRODUCTION

Every year, River Nile brings large amounts of water (55.5 billion m^3 / year, according to 1959 Nile Waters Agreement between Egypt and Sudan), 86.1 % of this water withdrawal used in agricultural purpose which is available to irrigate not less than 95% of the agricultural area (7790400 fed. according to FAO, 1996) which means that there is 5 % deficiency. By the year 2000, another 2208000 fed (28.3 % of total agricultural area) are planned to be reclaimed (Toshky, Ewainat and the East of El-Tafrea). Accordingly, the total estimate of 69.4 billion m^3 /year is needed, increasing the deficiency of water requirement to 32.3 %. The additional water resources is expected, as reported by Abu-Zeid, 1992, to be available from :

1. Ground water (7.8 billion m^3/ year).
2. Increasing use of agricultural drainage water (7.0 billion m^3/ year)
3. The increase in treated waste water (El-Gabal El-Asfar Station, 1.1 billion m^3 / year)

These sources could add nearly 16 billion m^3 / year which is available to decrease the deficiency percentage of water requirement. But these sources have many constrains. The main constrain is water pollution.

In the past, the pollution was small enough that its effect on water quality has generally been within acceptable limits. A total of 59 industrial out falls as well as total of 79 agricultural drains are located along entire course of the River are discharging into the Nile (FAO 1996). It creates big complicated pollution problems.

The human activities also caused a strong impact on the occurrence of heavy metals in the surface water. Industrial societies use large quantities of metals, which would otherwise not be readily available. The release of metal wastes into environment occurs in many forms including direct discharge of industrial waste water, and agricultural run off and seepage into ground water from waste disposal sites.

Heavy metals can then be taken up and concentrated to extremely high level by plant tissues during the growing season, which consequently accumulate in fruits (Alloway, 1995). Furthermore, the impact of the heavy metal on plant physiological processes, respiration, photosynthesis, carbon allocation and stomatal function are affected (Darrall, 1989). The growth, chlorophyll content, transpiration rate and relative water content are affected by heavy metals, (Gadallh, 1996). Accordingly, this experiment was conducted to evaluate the effect of using treated sewage water and different irrigation water sources on heavy metals contamination in different soil types that were irrigated for many years with sewage water.

MATERIALS AND METHODS

Two soil types (have been irrigated since many years ago with sewage water), loamy sand and silty loam soil were collected from the rhizosphere zone of El-Gabal El-Asfar and Tahanoub agricultural area, Qalubia governorate. Each soil type was air dried, ground and passed through 2-mm sieve to remove rocks, plant residues, and other large particles. Soil sample of 5.0 kg was sub-divided and placed in polyethylene bags. Some physical, chemical properities, soil texture and organic matter percentage of the investigated soils are presented in Tables 1 and 2.

Table 1. Chemical characteristics of soil samples.

Collected soil	pH	EC	Soluble cations (meq/l)				Soluble anions (meq/l)			O.M*	SP**
	(1:2.5) Suspen	dsm^{-1} at 25 C	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}	%	%
Silty loam	7.5	2.1	2.43	4.43	0.4	21.2	7.75	14.79	5.92	3.27	60.00
Loamy sand	7.5	1.31	7.03	2.27	0.78	3.91	5.75	3.36	4.88	1.97	19.33

* Organic matter ** Saturation percentage

Table 2 . Particle size distribution of soil samples.

Soil sample	Particle size distribution of the studied soil		
	Clay (<0.002)	Silt (0.002-0.02)	Sand (>0.02)
Silty loam	23.10	65.70	11.20
Loamy sand	10.42	5.98	83.60

Wheat (*Triticum aestivum*) was seeded in winter and radish (*Raphanus sativus*) in summer during 2003/2004 & 2004/2005 growing seasons. Wheat and radish were thinned to 3 and 5 plants per pot after 21 or 15 d from sowing, respectively.

Different irrigation water sources, Nile water (NW), ground water (GW), and agricultural drainage water (ADW) were collected monthly during winter and summer seasons from Tahanoub, while sewage water (SW) and treated sewage water (TSW) were collected from El-Gabal El-Asfar Station. Heavy metals content (Cd, Pb, Ni and Co) during winter and summer seasons of the different irrigation water sources are presented in Table 3.

Table 3. Heavy metals concentrations (ml / l) in different irrigation water sources at Qalubia governorate during winter and summer seasons.

Irrigation Sources*	Heavy metal concentration (mg/L)							
	winter season, 2003/2004				summer season, 2004/2005			
	Cd	Pb	Ni	Co	Cd	Pb	Ni	Co
NW	0.001	0.066	0.569	0.003	0.315	0.344	0.313	0.014
GW	0.001	0.060	0.747	0.005	0.431	0.360	0.537	0.006
ADW	0.004	0.062	0.525	0.010	0.449	0.309	0.591	0.021
SW	0.006	0.189	0.627	0.012	0.008	0.708	0.313	0.019
TSW	0.004	0.149	0.504	0.007	0.002	0.618	0.248	0.012
Permissible limits*	0.01	5.000	0.200	0.050	0.01	5.000	0.200	0.050

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, SW= sewage water and TSW= treated sewage water

** Permissible limits in irrigation water, National Academy of Science (1972).

During the experiment, fertilizers (urea 46 %, and super-phosphate 16 %) were added to the pots with the rate of 0.6 and 0.35 g/pot of wheat and 0.6 and 0.9 g/ pot of radish, respectively. Irrigation was practiced to keep soil almost at their field capacity for a period of growoing season.

Soil samples were collected at the beginning and the end of the growing seasons from pots, air dried, sieved through 2 mm and average of heavy metal concentrations were calculated. Plants were harvested after 160 and 75 d. for wheat and radish, respectively.

Heavy metals, Cd, Pb, Ni and Co determination was conducted according to Shaole *et al.* (1997) and Allen *et al.*, (1997).

RESULTS AND DISCUSSION

Heavy Metals Accumulation in The Grown Soils

Data presented in Tables (4 - 7) show that, accumulation amount and accumulation % of Cd, Pb, Ni and Co changed significantly according to element character, soil type and irrigation water sources in the two growing seasons for both wheat or radish.

Wheat pots

In silty loam and loamy sandy soil, data presented in Tables 4 and 5 indicate that irrigation with NW showed the lowest relative accumulation % of Cd and Co followed by GW, TSW and ADW comparing with SW irrigation water source. Relative accumulation % of Cd and Co with NW ranged between 20.0 – 55.3, and 11.4 – 44.2 at the 1st season and 39.8 – 61.4, and 31.6 – 55.6 at the 2nd season in silty loam and loamy sand soil, respectively. Also, irrigation with NW decreased the accumulation % of Pb compared with sewage water followed by GW, ADW and TSW. Irrigation with TSW showed the lowest Ni accumulation % ranging between 64.77 -62.09 or 54.23-52.31, in silty loam or loamy sand soil at the 1st and 2nd seasons, respectively.

Radish pots

In silty loam and loamy sand soils, data presented in Tables 6 and 7 indicate that soils irrigated with ADW and GW increased the relative accumulation % of Cd and Ni more than SW, but it decreased when irrigated with TSW. Irrigation with ADW decreased Pb accumulation % lower than SW being 38.1 and 30.4 or 35.3 and 28.1%, followed by NW, GW and TSW in silty loam or loamy sand soil at the 1st and 2nd seasons, respectively. In addition, irrigation with GW and TSW showed the lowest Co accumulation % than other irrigation with water sources which ranged between 58.3 – 51.7 %, and 55.5 – 50.7 %, at the 1st season and 55.6 – 72.29 and 50.5 – 70.71 at the 2nd season in silty loam or lomy sand soil, respectively.

From the above results, it is indicated that, irrigation with SW caused the highest significant contamination level of Cd and Co in silty loam or lomy sand soil, this may be due to the nature of SW which contains high amount of organic matter as compared with the other irrigation water sources which lead to the formation of organo-metal complex and causes accumulation (Denny and Wilkins, 1987).

Increasing Cd, Co and Pb accumulation in soil irrigated with ADW more than GW or NW may be attributed to the higher pH value of ADW than GW or NW in both summer and winter seasons (Marzouk, 2003), which negatively related to the mobility and leachability of these elements in the soil profile (Yujun *et al.*, 1996). In EPA (USA-Environment Protection Agency),1995 report, it was stated that high Pb level can result in more salinity soil. The highest accumulation % of Ni was observed when soil was irrigated with GW than SW. This may be attributed to the high level of Ni in water, especially in summer (Abbdein, 1986, Liu *et al.*, 1994, Badran, 1999 and Marzouk, 2003). On the contrary, Ni contamination in soil irrigated with GW was significantly lower than SW, that could be attributed to OM content, which is higher in SW than GW which positively related to Ni adsorption (accumulation), and considered as the main factor influencing metal adsorption (Sheila, 1994).

From the previous results regarding Cd, Pb, Ni and Co concentration and the mean of accumulation % of total heavy metals content (Tables 4 - 7), it is concluded that :

1. Generally, all of studied heavy metals were highly accumulated in silty loam soil over lomy sand soil in both wheat and radish pots which could be attributed to the high organic matter % of silty loam soil (Table 1). These results are in agreement with Yujun *et al.*, 1996, who stated that soil organic constituents usually have smaller surface areas than inorganic soil, therefore, the total soil surface area was expected to decrease in light soil than heavy soil which may contribute to heavy metal adsorption.

2. Accumulation and concentration of heavy metals tend to be in the following order, Pb > Ni > Co > Cd. This was in agreement with King, 1988 and Eugenia 1996, who found that overall soil types the relative retention of metals was in the following sequence, Pb> Ni> Co > Cd. Also, concentration and accumulation % of Pb, Ni, Co, and Cd is higher in radish pots (summer season) than wheat pots (winter season) that may be closly related to their concentration in irrigation water according to Mowafy *et al.*, 2005, who mintioned that total concentration of heavy metals (Cd, Ni, Pb and Co) in all Egyptian irrigation water sources were higher in sumer than in winter. As well as, there are more than 26 factories discharge their industrial wastes into surface water in Qalubia governorate, as reported by Ahmed,1986. Increasing Pb accumulation in soil over other elements may be attributed to that Pb element strongly adsorbed by soils and forms insoluble crystalline compounds over other heavy metals, (Santillian Medrano and Jurinak 1975).

However, all the studied elements were below the toxic limits of agricultural soil except the loamy sand soil irrigated with SW, which contained the highest amount of Pb.

From the mean total of relative accumulation % of total heavy metals content, it is concluded that irrigation with NW or TSW during summer and winter seasons caused the lowest accumulation % of total heavy metals in the different soil types pre-irrigated with SW.

Table 4 . The effect of irrigation water sources on decreasing heavy metal accumulation in different soil types pre-irrigated with sewage water at 2003 - 2004 wheat growing season.

Soil type	Irrigation water sources[1]	Heavy metal concentration (ug/g dw)																Mean of total acc. %
		Cd				Pb				Ni				Co				
		concn[2]		acc.[3]	relative[4]	concn[2]		acc.[3]	relative[4]	concn[2]		acc.[3]	relative[4]	concn[2]		acc.[3]	relative[4]	
		begin	end	amount	acc. %	begin	end	amount	acc. %	begin	end	amount	acc. %	begin	end	amount	acc. %	
Silty loam	NW	1.108	1.111	0.003 f	20.0	147.35	150.22	2.870 f	39.4	41.570	42.169	0.599 c	95.4	23.870	24.044	0.174 e	55.2	52.5
	GW	1.108	1.112	0.004 e	26.7	147.35	150.59	3.240 d	44.5	41.570	42.343	0.733 a	123.1	23.870	24.085	0.215 c	68.3	65.7
	ADW	1.108	1.119	0.011 b	73.3	147.36	151.03	3.680 e	50.5	41.570	42.098	0.528 d	84.1	23.870	24.159	0.289 b	91.7	74.9
	SW	1.108	1.123	0.015 a	100.0	147.35	154.63	7.280 a	100.0	41.570	42.198	0.628 b	100.0	23.870	24.185	0.315 a	100.0	100.0
	TSW	1.108	1.118	0.010 c	66.7	147.35	153.24	5.890 b	80.9	41.570	41.977	0.407 g	64.8	23.870	24.073	0.203 d	64.4	69.2
Loamy sand	NW	0.583	0.584	0.001 g	16.7	78.320	79.260	0.940 j	32.1	37.000	37.366	0.366 h	84.1	13.750	13.802	0.052 j	44.1	44.3
	GW	0.583	0.584	0.001 g	16.7	78.320	79.380	1.060 i	36.2	37.000	37.444	0.444 e	102.1	13.750	13.816	0.066 h	55.9	52.7
	ADW	0.583	0.586	0.003 f	50.0	78.320	79.530	1.210 h	41.3	37.000	37.273	0.273 i	62.8	13.750	13.844	0.094 g	79.7	58.5
	SW	0.583	0.589	0.006 d	100.0	78.320	81.250	2.930 e	100.0	37.000	37.435	0.435 f	100.0	13.750	13.868	0.118 f	100.0	100.0
	TSW	0.583	0.586	0.003 f	50.0	78.320	80.280	1.960 g	66.9	37.000	37.236	0.236 j	54.3	13.750	13.809	0.059 i	50.0	55.3
Permissible limit[5]		5.000				100.000				100.000				50.000				

1 = NW=Nile water GW= Ground water ADW=Agricultural drainage water SW= sewage water and TSW= treated sewage water

2 = heavy metal concentration = (concn at the beginning + concn at the end)/2

3 = heavy metal accumulation amount = concn at the end - concn at the beginning.

4 = relative heavy metal accumulation percentage = accumulation amount in the soil / accumulation amount in SW soil * 100.

5 =Toxic limits : permissible limits for agricultural soil, Anderson *et al.*, (1973) and Tictjen, (1975).

Cd = Cadmium Pb= Lead Ni= Nickel Co=Cobalt

The figuers followed by the same letters are insignificant.

Table 5 . The effect of irrigation water sources on decreasing heavy metal accumulation in different soil types pre-irrigated with sewage water at 2004 - 2005 wheat growing season.

Soil type	Irrigation water sources[1]	Cd concn[2] begin	Cd concn[2] end	Cd acc.[3] amount	Cd relative[4] acc. %	Pb concn[2] begin	Pb concn[2] end	Pb acc.[3] amount	Pb relative[4] acc. %	Ni concn[2] begin	Ni concn[2] end	Ni acc.[3] amount	Ni relative[4] acc. %	Co concn[2] begin	Co concn[2] end	Co acc.[3] amount	Co relative[4] acc. %	Mean of total acc. %
		Heavy metal concentration (ug/g dw)																
Silty loam	NW	1.125	1.127	0.002 f	33.3	154.53	155.04	0.510 f	41.5	42.668	42.992	0.324 c	83.3	24.362	24.476	0.114 e	61.0	54.8
	GW	1.129	1.132	0.003 d	50.0	156.29	156.82	0.530 e	43.1	43.084	43.567	0.483 a	124.2	24.295	24.460	0.165 c	88.2	76.4
	ADW	1.139	1.144	0.005 b	83.3	154.98	155.56	0.580 d	47.2	43.049	43.329	0.280 e	72.0	24.579	24.759	0.180 b	96.3	74.7
	SW	1.130	1.136	0.006 a	100.0	165.00	166.23	1.230 a	100.0	42.755	43.144	0.389 b	100.0	24.545	24.732	0.187 a	100.0	100.0
	TSW	1.122	1.126	0.004 c	66.7	161.87	162.84	0.970 b	78.9	42.384	42.625	0.241 g	62.0	24.330	24.479	0.149 d	79.7	71.8
Loamy sand	NW	0.588	0.589	0.001 f	33.3	81.000	81.220	0.220 j	33.3	37.695	37.883	0.188 h	68.9	13.938	13.991	0.053 j	55.8	47.8
	GW	0.588	0.589	0.001 f	33.3	81.360	81.600	0.240 i	36.4	37.906	38.210	0.304 d	111.4	13.893	13.968	0.075 h	78.9	65.0
	ADW	0.592	0.593	0.001 f	33.3	80.970	81.220	0.250 h	37.9	37.961	38.132	0.171 i	62.6	14.003	14.086	0.083 g	87.4	55.3
	SW	0.591	0.594	0.003 d	100.0	85.980	86.640	0.660 c	100.0	37.825	38.098	0.273 f	100.0	14.017	14.112	0.095 f	100.0	100.0
	TSW	0.587	0.589	0.002 e	66.7	83.810	84.250	0.440 g	66.7	37.488	37.631	0.143 j	52.4	13.904	13.969	0.065 i	68.4	63.6
Permissible limit[5]		5.000				100.000				100.000				50.000				

1 = NW=Nile water GW= Ground water ADW=Agricultural drainage water SW= sewage water and TSW= treated sewage water

2 = heavy metal concentration = (concn at the beginning + concn at the end)/2

3 = heavy metal accumulation amount = concn at the end - concn at the beginning.

4 = relative heavy metal accumulation percentage = accumulation amount in the soil / accumulation amount in SW soil * 100.

5 =Toxic limits : permissible limits for agricultural soil, Anderson *et al.*, (1973) and Tictjen, (1975).

Cd = Cadmium Pb= Lead Ni= Nickel Co=Cobalt

The figuers followed by the same letters are insignificant.

Table 6 . The effect of irrigation water sources on decreasing heavy metal accumulation in different soil types pre-irrigated with sewage water at 2003 - 2004 radish growing season.

Soil type	Irrigation water sources[1]	Heavy metal concentration (ug/g dw)																Mean of total acc. %
		Cd				Pb				Ni				Co				
		concn[2] begin	concn[2] end	acc.[3] amount	relative[4] acc. %	concn[2] begin	concn[2] end	acc.[3] amount	relative[4] acc. %	concn[2] begin	concn[2] end	acc.[3] amount	relative[4] acc. %	concn[2] begin	concn[2] end	acc.[3] amount	relative[4] acc. %	
Silty loam	NW	1.111	1.125	0.014 c	200.0	150.22	154.53	4.310 e	41.6	42.169	42.668	0.499 e	89.6	24.044	24.362	0.318 c	88.3	104.9
	GW	1.112	1.290	0.017 b	242.9	150.59	156.29	5.700 c	55.0	42.343	43.084	0.741 b	133.0	24.085	24.295	0.210 e	58.3	122.3
	ADW	1.119	1.139	0.020 a	285.7	151.03	154.98	3.950 f	38.1	42.098	43.049	0.951 a	170.7	24.159	24.579	0.420 a	116.7	152.8
	SW	1.123	1.130	0.007 d	100.0	154.63	165.00	10.370 a	100.0	42.198	42.755	0.557 d	100.0	24.185	24.545	0.360 b	100.0	100.0
	TSW	1.118	1.122	0.004 e	57.1	153.24	161.87	8.630 b	83.2	41.977	42.384	0.407 g	73.1	24.073	24.330	0.257 d	71.4	71.2
Loamy sand	NW	0.584	0.588	0.004 e	200.0	79.260	81.000	1.740 i	36.8	37.366	37.695	0.329 i	84.4	13.802	13.938	0.136 h	91.3	103.1
	GW	0.584	0.588	0.004 e	200.0	79.380	81.360	1.980 h	41.9	37.444	37.906	0.462 f	118.5	13.816	13.893	0.077 j	51.7	103.0
	ADW	0.586	0.592	0.006 f	300.0	79.530	80.970	1.440 j	30.4	37.273	37.961	0.688 c	176.4	13.844	14.003	0.159 f	106.7	153.4
	SW	0.589	0.591	0.002 g	100.0	81.250	85.980	4.730 d	100.0	37.435	37.825	0.390 h	100.0	13.868	14.017	0.149 g	100.0	100.0
	TSW	0.586	0.587	0.001 h	50.0	80.280	83.810	3.530 g	74.6	37.236	37.488	0.252 j	64.6	13.809	13.904	0.095 i	63.8	63.3
Permissible limit[5]		5.000				100.000				100.000				50.000				

1 = NW=Nile water GW= Ground water ADW=Agricultural drainage water SW= sewage water and TSW= treated sewage water

2 = heavy metal concentration = (concn at the beginning + concn at the end)/2

3 = heavy metal accumulation amount = concn at the end - concn at the beginning.

4 = relative heavy metal accumulation percentage = accumulation amount in the soil / accumulation amount in SW soil * 100.

5 =Toxic limits : permissible limits for agricultural soil, Anderson *et al.*, (1973) and Tictjen, (1975).

Cd = Cadmium Pb= Lead Ni= Nickel Co=Cobalt

The figures followed by the same letters are insignificant.

Table 7 . The effect of irrigation water sources on decreasing heavy metal accumulation in different soil types pre-irrigated with sewage water at 2004 - 2005 radish growing season.

Soil type	Irrigation water sources[1]	Cd concn[2] begin	Cd concn[2] end	Cd acc.[3] amount	Cd relative[4] acc. %	Pb concn[2] begin	Pb concn[2] end	Pb acc.[3] amount	Pb relative[4] acc. %	Ni concn[2] begin	Ni concn[2] end	Ni acc.[3] amount	Ni relative[4] acc. %	Co concn[2] begin	Co concn[2] end	Co acc.[3] amount	Co relative[4] acc. %	Mean of total acc. %
Silty loam	NW	1.127	1.143	0.016 c	200.0	155.04	166.08	1.040 e	39.1	42.992	43.379	0.387 d	89.8	24.476	24.667	0.191 c	86.8	103.9
	GW	1.320	1.153	0.021 b	262.5	156.82	158.05	1.230 d	46.2	43.567	44.155	0.588 b	136.4	24.460	24.582	0.122 e	55.5	125.2
	ADW	1.144	1.167	0.023 a	287.5	155.66	156.50	0.90 g	35.3	43.329	44.066	0.737 a	171.0	24.759	25.006	0.247 a	112.3	151.5
	SW	1.136	1.144	0.008 g	100.0	166.23	168.89	2.660 a	100.0	43.144	43.575	0.431 c	100.0	24.732	24.952	.0220 b	100.0	100.0
	TSW	1.126	1.134	0.008 g	100.0	162.84	164.85	2.0101 b	75.6	42.625	42.966	0.341 e	79.1	24.479	24.638	0.159 d	72.3	81.8
Loamy sand	NW	0.589	0.599	0.010 f	200.0	81.220	81.670	0.450 i	32.4	37.883	37.978	0.095 i	80.5	13.991	14.045	0.054 h	78.3	97.8
	GW	0.589	0.601	0.012 e	240.0	81.600	82.130	0.530 h	38.1	38.210	38.355	0.145 g	122.9	13.968	14.003	0.035 j	50.7	112.9
	ADW	0.593	0.606	0.013 d	260.0	81.220	81.610	0.390 j	28.1	38.132	38.315	0.183 f	155.1	14.086	14.156	0.070 f	101.4	136.2
	SW	0.594	0.599	0.005 h	100.0	86.640	88.180	1.390 c	100.0	38.098	38.216	0.118 h	100.0	14.112	14.181	0.069 g	100.0	100.0
	TSW	0.589	0.592	0.003 i	60.0	84.250	85.180	0.930 f	66.9	37.631	37.713	0.082 j	69.5	13.969	14.018	0.049 i	71.0	66.9
Permissible limit[5]				5.000				100.000				100.000				50.000		

Heavy metal concentration (ug/g dw)

1 = NW=Nile water GW= Ground water ADW=Agricultural drainage water SW= sewage water and TSW= treated sewage water

2 = heavy metal concentration = (concn at the beginning + concn at the end)/2

3 = heavy metal accumulation amount = concn at the end - concn at the beginning.

4 = relative heavy metal accumulation percentage = accumulation amount in the soil / accumulation amount in SW soil * 100.

5 =Toxic limits : permissible limits for agricultural soil, Anderson *et al.*, (1973) and Tictjen, (1975).

Cd = Cadmium Pb= Lead Ni= Nickel Co=Cobalt

The figures followed by the same letters are insignificant.

Heavy Metal Accumulation In The Grown Plant

Tables 8 -11 showed that Cd, Pb, Ni and Co were detected during the growing seasons in wheat grains and radish leaves which grown in silty loam or loamy sand soil and the concentration differed significantly in various irrigation water sources.

Cadmium content

In wheat grains, Cd content reached the hieghest concentration when wheat was irrigated with SW being 3.077 and 3.231 ug/g dw in plant potted in silty loam soil and 2.376 and 2.495 ug/g dw in those grown in loamy sand soil at the 1st and 2nd season, respectively, and followed by TSW> ADW> NW> GW.

Conversely, in radish leaves, Cd content reached its biegh peak in plants potted in silty loam soil and irrigated with GW with the values of 3.36 and 3.427 ug/g dw, and 2.157 and 2.2 ug/g dw in plants grown in loamy sand soil at 1st and 2nd seasons, respectively, followed by ADW> NW> SW> TSW.

Lead content

Data (Tables 8-11) revealed that, Pb was higher when wheat and radish were potted in silty loam soil and irrigated with SW than loamy sand during the two growing seasons. Lead accumulattion tend to be in the following descending order according to irrigation water sources, SW > TSW > NW > GW > ADW in wheat grains and SW > TSW > GW > NW > ADW in radish leaves. The lowest Pb concentration was seen in plant potted in loamy sand soil irrigated with ADW, reaching 7.844 ~ 8.236 ug/g dw in wheat grains, and 12.106 ~ 12.227 ug/g dw in radish leaves during the 1st and 2nd seasons, respectively.

Nickel content

Nickel concentration in grains showed different trend from that of Cd and Pb pollutants. In silty loam soils, the highest amount of Ni in wheat grains or radish leaves was detected when plants was irrigated with GW, followed by SW > NW > TSW > ADW in wheat grains and ADW > SW > NW > TSW in radish leaves, respectively.

Cobalt content

Cobalt showed different pattern compared with Cd, Pb and Ni pollutants. In Silty loam or loamy sand soil, SW revealed the highest significant concentration in both wheat grains or radish leaves while irrigation with GW caused the lowest.

However, the mean of total concentration of each pollutant in wheat grains and radish leaves showed the following descending order in both heavy and light soils, Ni > Pb > Co > Cd. This order is positively correlated with the heavy metal concentration in soil which agrees with Said, 1980 and Alloway, 1995.

Heavy Metal Availability To The Grown Plants

Availability to wheat grains

Data presented in Tables 8 and 9 show that Cd, Pb, Ni and Co availability (CF) to wheat plant was affected mainly with irrigation water sources, heavy metal chemistry and concentration in the soil. In silty loam and loamy sand soils the availability of Cd and Co to plants was high when plants were irrigated with SW followed by TSW > ADW > NW >GW in the 1^{st} and 2^{nd} seasons, while were concentrated significantly in grains. The highest CF value of Cd and Co was 2.764 and 0.065 or 4.055 and 0.087 in grains of silty loam and loamy sand soil, in the 1^{st} season, respectively . In the 2^{nd} season, the highest CF of Cd and Co values were 2.851 and 0.066 or 4.214 and 0.090 in grains when the wheat was grown in silty loam and loamy sand soils, respectively. Irrigation with SW and GW caused the highest CF of Pb and Ni ,respectively , while irrigation with TSW caused the lowest values. The highest Pb and Ni CF values were 0.051 and 0.049 or 0.346 and 0.351 in silty loam soils and 0.098 and 0.095 or 0.373 and 0.383 in loamy sand soils, in the 1^{st} and 2^{nd} seasons, respectively.

Availability to radish leaves

Data presented in Tables 10 and 11 indicated that, in silty loam soils, Cd, Pb, Ni and Co were more available to radish plants when irrigated with GW (0.886 and 0.884),than ADW (0.821 and 0.817), NW (0.761 and 0.763) and SW (0.636 and 0.639), while TSW showed the lowest (0.521 & 0.525) in the 1^{st} and the 2^{nd} seasons, respectively. Heavy metal availability (CF value) to radish plant in loamy sand pots showed the same trend as silty loam soil.

From foregoing results, it can be concluded that, there were relative differences in heavy metals uptake between wheat and radish, which may be due to plant cultivar and various factors including surface area of the roots, root CEC, root exudates and rate of evapotranspiration. These factors affect the mass flow of the soil solution in the vicinity of the root and thus the movement of ions to the root absorbing surface (Alloway, 1995). Also, CF values showed that Cd was readily translocated to plant grains more than other pollutants, followed by Ni, Co or Pb. This is in agreement with Chaney and Giordano, 1977, who classified Cd as element which readily translocated to the extent, and Willaert and Verloo, 1992, who showed that acidified fertilizers like $(NH_4)_2$ SO_4, NH_4NO_3 and urea increase water soluble Cd in the soil. Lehoczky *et al.,* 2000, indicated that lettuce leaves Cd concentration was 1.4 – 16 times as much as the total Cd content of soil. That could be attributed to the increased apoplastic Cd binding, (Hart *et al.*, 1998). The high accumulation of Cd in wheat grains and radish leaves planted in silty loam or loamy sand soils irrigated with SW followed by GW > ADW > NW is related to the high Cl^- and low Ca^{++} of SW (Table 1), which could lead to Cd uptake as indicated by Wenzel *et al.*, 1996. The increas of Ni concentration in radish leaves or wheat grains over Pb or Co, is related to its higher concentration in soil (Wild, 1988), or because Ni is one of the most soluble and mobile among heavy metals in the soil solution (EPA, 1995), and Pb is more strongly adsorbed by soils and forms insoluble crystalline compounds (Santillian and Jurinak, 1975). In addition, SW increases the pollutants accumulation in plants. This may be attributed to the low pH values of SW which increase the availability and movement of heavy metal cations from the bulk soil to the root surface (Marzouk, 2003 and Alloway, 1995). The high organic matters in SW, facilitate the movement of heavy metals in the soil, (Badran, 1999). The high content of organic wastes give rise to intense microbiological and biochemical activity in the rhizosphere, which enable roots to mobilize some of the metals (Alloway, 1995, Scotti and Silva, 1988, and Kiranjit *et al.,* 1998).

The CF values of Cd, Pb, and Co were higer in loamy sand soil over silty loam soil. This may be attributed to that the decrease of soil particle size of silty loam soil, which increase total adsorbed surface areas compared with loamy sand soil, (Hamon *et al.*, 1995 and Yujun *et al.,* 1996), and pollutants were therefore more available to plant grown in loamy sand soil.

Table 8 . The effect of irrigation water sources on heavy metal accumulation in wheat grains compared to soil content (2003 -2004 growing season).

Soil type	Irrigation water sources[1]	Mean heavy metal concentration (ug/g dw)													Mean of total CF
		Soil (average cont.)[2]				Wheat grains				Mean	CF[3]				
		Cd	Pb	Ni	Co	Cd	Pb	Ni	Co		Cd	Pb	Ni	CO	
Silty loam soil	NW	1.109	148.747	41.869	23.957	1.334 g	4.643 f	12.476 d	0.845 f	4.825	1.203	0.031	0.298	0.035	0.392
	GW	1.110	148.971	41.957	23.977	1.082 i	4.224 h	14.502 a	0.724 h	5.133	0.975	0.028	0.346	0.030	0.345
	ADW	1.113	149.192	41.834	24.014	2.033 d	3.058 j	9.258 j	1.071 d	3.855	1.827	0.020	0.221	0.045	0.528
	SW	1.113	150.990	41.884	24.028	3.077 a	7.743 b	13.247 c	1.554 a	6.405	2.765	0.051	0.316	0.065	0.799
	TSW	1.113	150.297	41.773	23.971	2.470 b	6.455 c	10.347 g	1.083 c	5.089	2.219	0.043	0.248	0.045	0.639
	Mean	1.112	149.639	41.863	23.989	1.999	5.225	11.966	1.055	5.061	1.798	0.035	0.286	0.044	0.541
Loamy sand soil	NW	0.583	78.790	37.183	13.776	1.150 h	5.343 e	10.890 f	0.565 i	4.480	1.973	0.067	0.293	0.041	0.594
	GW	0.583	78.849	37.222	13.783	0.818 j	4.518 j	13.882 b	0.531 j	4.937	1.403	0.057	0.373	0.039	0.468
	ADW	0.585	78.927	37.136	13.797	1.558 f	3.948 i	9.489 h	0.823 g	3.955	2.663	0.050	0.256	0.060	0.757
	SW	0.586	79.785	37.218	13.809	2.376 c	7.844 a	12.112 e	1.208 b	5.885	4.055	0.098	0.325	0.087	1.141
	TSW	0.585	79.299	37.118	13.780	1.968 e	6.053 d	9.399 i	0.878 e	4.575	3.364	0.076	0.253	0.064	0.939
	Mean	0.584	79.130	37.175	13.789	1.574	5.535	11.154	0.801	4.766	2.692	0.070	0.300	0.058	0.788
Toxic limits[5]		5.00	100.00	100.00	50.00	>100	>60	>80	>115	CF[4]	1.0:10.0	0.01:0.1	0.1:1.0	0.01-0.1	

1 = NW = Nile water GW = Ground water ADW = Agricultural drainage water SW = sewage water and TSW = treated sewage water

2 = average concentration = (metal concentration at the bigninng in soil + metal concentration at the end in soil)/2

3 = Concentration factor= metal concentration in plant/ total metal concentration in soil (Kloke *et al.,* 1994)

4 = reference value of CF (according to Kloke *et al.* , 1994).

5 = Toxic limits = toxic limits to the cultivated plant, according to Anderson *et al.* , (1973), Tietjen, (1975) and Cottenie *et al.*, (1976).

The Figuers followed by the same letters are insignificant.

Table 9 . The effect of irrigation water sources on heavy metal accumulation in wheat grains compared to soil content (2004 -2005 growing season).

Soil type	Irrigation water sources[1]	Mean heavy metal concentration (ug/g dw)														Mean of total CF
		Soil (average cont.)[2]				Wheat grains				Mean	CF[3]					
		Cd	Pb	Ni	Co	Cd	Pb	Ni	Co		Cd	Pb	Ni	CO		
Silty loam soil	NW	1.126	154.790	42.830	24.419	1.401 g	4.875 f	13.100 d	0.087 f	5.066	1.244	0.031	0.306	0.036		0.404
	GW	1.131	156.557	43.325	24.377	1.137 i	4.435 h	15.228 a	0.760 h	5.390	1.005	0.028	0.351	0.031		0.354
	ADW	1.141	155.270	43.189	24.669	2.134 d	3.211 j	9.720 j	1.125 d	4.048	1.870	0.021	0.225	0.046		0.541
	SW	1.133	165.615	42.949	24.639	3.231 a	8.130 b	13.910 c	1.631 a	6.726	2.852	0.049	0.324	0.066		0.823
	TSW	1.124	162.357	42.505	24.405	2.593 b	6.778 c	10.864 g	1.137 c	5.343	2.307	0.042	0.256	0.047		0.663
	Mean	1.131	158.918	42.960	24.502	2.099	5.486	12.564	1.108	5.315	1.856	0.034	0.292	0.045		0.557
Loamy sand soil	NW	0.588	81.113	37.789	13.964	1.207 h	5.579 e	11.434 f	0.593 i	4.703	2.053	0.069	0.303	0.042		0.617
	GW	0.589	81.480	38.058	13.930	0.859 j	4.744 j	14.576 b	0.558 j	5.184	1.458	0.058	0.383	0.040		0.485
	ADW	0.592	81.095	38.046	14.044	1.635 f	4.145 i	9.963 h	0.864 g	4.152	2.762	0.051	0.262	0.062		0.784
	SW	0.592	86.310	37.961	14.064	2.495 c	8.236 a	12.718 e	1.128 b	6.179	4.215	0.095	0.335	0.090		1.184
	TSW	0.588	84.028	37.559	13.937	2.066 e	6.356 d	9.869 i	0.922 e	4.803	3.514	0.076	0.263	0.066		0.980
	Mean	0.590	82.885	37.883	13.988	1.652	5.812	11.712	0.841	5.004	2.800	0.078	0.309	0.060		0.810
Toxic limits[5]		5.00	100.00	100.00	50.00	>100	>60	>80	>115	CF[4]	1.0:10.0	0.01:0.1	0.1:1.0	0.01-0.1		

1= NW = Nile water GW = Ground water ADW = Agricultural drainage water SW = sewage water and TSW = treated sewage water

2 = average concentration = (metal concentration at the bigninng in soil + metal concentration at the end in soil)/2

3 = Concentration factor= metal concentration in plant/ total metal concentration in soil (Kloke *et al.*, 1994)

4 = reference value of CF (according to Kloke *at al.*, 1994).

5 = Toxic limits = toxic limits to the cultivated plant, according to Anderson *et al.*, (1973), Tictjen, (1975) and Cottenie *et al.*, (1976).

The Figuers followed by the same letters are insignificant.

Table 10 . The effect of irrigation water sources on heavy metal accumulation in radish leaves compared to soil content (2003 -2004 growing season).

Soil type	Irrigation water sources[1]	Mean heavy metal concentration (ug/g dw) Soil (average cont.)[2] Cd	Pb	Ni	Co	Wheat grains Cd	Pb	Ni	Co	Mean	CF[3] Cd	Pb	Ni	CO	Mean of total CF
Silty loam soil	NW	1.118	152.379	42.418	24.203	2.878 c	7.656 d	15.520 g	1.282 d	6.834	2.574	0.050	0.366	0.053	0.761
	GW	1.121	153.442	42.714	24.190	3.360 a	8.510 c	19.509 a	0.797 i	8.044	2.997	0.055	0.457	0.033	0.886
	ADW	1.129	153.005	42.574	24.369	3.091 b	6.160 g	18.787 c	1.589 b	7.407	2.738	0.040	0.441	0.065	0.821
	SW	1.127	159.817	42.476	24.365	2.225 d	12.106 a	17.467 e	2.057 a	8.464	1.974	0.076	0.411	0.084	0.636
	TSW	1.120	157.558	42.180	24.202	1.831 g	9.773 b	13.924 i	1.364 c	6.723	1.635	0.062	0.330	0.056	0.521
	Mean	1.123	155.240	42.472	24.266	2.677	8.841	17.041	1.418	7.494	2.384	0.057	0.401	0.058	0.725
Loamy sand soil	NW	0.586	80.132	37.530	13.870	1.725 h	5.072 i	14.974 h	0.892 h	5.666	2.944	0.063	0.399	0.064	0.868
	GW	0.586	80.370	37.675	13.854	2.157 e	5.796 h	17.804 d	0.621 j	6.595	3.681	0.072	0.473	0.045	1.068
	ADW	0.589	80.250	37.617	13.923	1.959 f	4.432 j	17.706 b	1.087 f	6.296	3.326	0.055	0.471	0.078	0.983
	SW	0.590	83.614	37.630	13.942	1.518 i	7.549 e	17.330 f	1.204 e	6.900	2.573	0.090	0.461	0.086	0.803
	TSW	0.587	82.044	37.362	13.857	1.258 j	7.236 f	13.084 j	0.988 g	5.642	2.143	0.088	0.350	0.071	0.663
	Mean	0.588	81.282	37.563	13.889	1.723	6.017	16.180	0.958	6.220	2.933	0.074	0.431	0.069	0.877
Toxic limits[5]		5.00	100.00	100.00	50.00	>100	>60	>80	>115	CF[4]	1.0:10.0	0.01:0.1	0.1:1.0	0.01-0.1	

1= NW = Nile water GW = Ground water ADW = Agricultural drainage water SW = sewage water and TSW = treated sewage water

2 = average concentration = (metal concentration at the bigninng in soil + metal concentration at the end in soil)/2

3 = Concentration factor= metal concentration in plant/ total metal concentration in soil (Kloke *et al.*, 1994)

4 = reference value of CF (according to Kloke *et al.*, 1994).

5 = Toxic limits = toxic limits to the cultivated plant, according to Anderson *et al.*, (1973), Tictjen, (1975) and Cottenie *et al.*, (1976).

The Figuers followed by the same letters are insignificant.

Table 11 . The effect of irrigation water sources on heavy metal accumulation in radish leaves compared to soil content (2004 -2005 growing season).

Soil type	Irrigation water sources[1]	Mean heavy metal concentration (ug/g dw) Soil (average cont.)[2] Cd	Pb	Ni	Co	Wheat grains Cd	Pb	Ni	Co	Mean	CF[3] Cd	Pb	Ni	CO	Mean of total CF
Silty loam soil	NW	1.135	155.564	43.186	24.572	2.935 c	7.733 d	15.675 g	1.307 d	6.913	2.586	0.050	0.363	0.053	0.763
	GW	1.142	157.439	43.861	24.521	3.427 a	8.552 c	19.704 a	0.813 i	8.124	3.001	0.054	0.449	0.033	0.884
	ADW	1.155	156.031	43.697	24.882	3.153 b	6.222 g	18.975 c	1.621 b	7.493	2.730	0.040	0.434	0.065	0.817
	SW	1.140	167.556	43.360	24.842	2.269 d	12.227 a	17.642 e	2.099 a	8.559	1.990	0.073	0.407	0.084	0.639
	TSW	1.130	163.844	42.796	24.558	1.868 g	9.871 b	14.063 i	1.392 c	6.799	1.653	0.060	0.329	0.057	0.525
	Mean	1.140	160.087	43.380	24.675	2.730	8.921	17.212	1.446	7.578	2.392	0.055	0.396	0.058	0.726
Loamy sand soil	NW	0.594	81.446	37.930	14.018	1.760 h	5.123 i	15.124 h	0.910 h	5.729	2.963	0.063	0.399	0.065	0.873
	GW	0.595	81.863	38.282	13.985	2.200 e	5.825 h	17.982 d	0.634 j	6.660	3.697	0.071	0.470	0.045	1.071
	ADW	0.600	81.420	38.223	14.121	1.998 f	4.476 j	17.883 b	1.109 f	6.367	3.330	0.055	0.468	0.079	0.983
	SW	0.596	87.334	38.157	14.147	1.548 i	7.624 e	17.504 f	1.228 e	6.976	2.597	0.087	0.459	0.087	0.808
	TSW	0.591	84.714	37.672	13.994	1.283 j	7.308 f	13.215 j	1.008 g	5.704	2.171	0.086	0.351	0.072	0.670
	Mean	0.595	83.355	38.053	14.053	1.758	6.071	16.342	0.978	6.287	2.952	0.072	0.429	0.070	0.881
Toxic limits[5]		5.00	100.00	100.00	50.00	>100	>60	>80	>115	CF[4]	1.0:10.0	0.01:0.1	0.1:1.0	0.01-0.1	

1= NW = Nile water GW = Ground water ADW = Agricultural drainage water SW = sewage water and TSW = treated sewage water

2 = average concentration = (metal concentration at the bigninng in soil + metal concentration at the end in soil)/2

3 = Concentration factor= metal concentration in plant/ total metal concentration in soil (Kloke *et al.,* 1994)

4 = reference value of CF (according to Kloke *et al.,* 1994).

5 = Toxic limits = toxic limits to the cultivated plant, according to Anderson *et al.,* (1973), Tictjen, (1975) and Cottenie *et al.,* (1976).

The Figuers followed by the same letters are insignificant.

This was in agreement with Chaney and Giordano, 1977 and Wild, 1988, who reported that the amount of metal absorbed by a plant is affected by concentration and speciation of the metal in the soil solution, and the movement of the metal from the bulk soil to the root surface. Vassilev *et al.,* 1999, indicated that the uptake of Cd by winter barley was higher in plants grown in sandy loam soil than clay loam soil. Contrarly, Ni availability in loamy sand soil was lower than in silty loam soil that may be due to that Ni is one of the most soluble and mobile of heavy metal in the soil. From these results it could be concluded that heavy metal availability and accumulation in the plant is affected by soil heavy metal or OM contents, soil chemical and physical properties (especially clay %), leachability of element (depending on chemical and physical properties of the element), and microbial activities. In addition , heavy metal content of

irrigation waters, pH, salinity and organic wastes content were also changed with the time affected, (Marzouk, 2003).

It should be mentioned that, the detected pollutant levels in wheat grains or radish leaves were the phytotoxicity limits according to the standred limits (Anderson *et al.,* 1973, and Cottenie *et al.,* 1976).

Though this study confirms that the treated sewage water can effectively increase water resource for irrigation especially in light soil, but there is a need for continuous monitoring of the concentration of potentially toxic elements in soil, plants and ground water.

REFERENCES

Abbdein, A. E.E. 1986. Pedological status of heavy metals in the vicinity of some industrial and high way areas in soil of Nile-delta. M.Sc.Thesis, Faculty of Agriculture, Alex. Univ., pp. 146-152.

Abou-Zeid, M. 1992. Water Resources Assessment for Egypt. Canadian Journal of Development Studies, Special Issue, 1-8.

Ahmed, Safiea. A. 1986. Assessment of compliance of industry and sewage work with Anti-pollution LAW 48/1982 for the protection of River Nile and waterways in Egypt. M.Sc., Thesis, Faculty of Midicine, Ain Shams Univ., pp. 70-75.

Allen, L.B., P.H. Sitonen and H.C. Thomposon. 1997. Methods for the determination of arsenic, cadmium, copper, lead and tin in sources, corn syrups and high fructose corn syrups by inductively coupled plasma atomic emission spectrometry. J. Agric. Food Chem., 45 (1): 162-165.

Alloway, B.J. (Ed.). 1995. Heavy Metal in Soils. 1-37. Blackie Academic & Professional,

Anderson, A.J., D.R. Meyer and F.K. Mayer. 1973. Heavy metal toxicities: Levels of nickel, cobalt and cadmium in the soil and plants associated with visual symptoms and variation in growth of an oat crop. Aust. J. Agric. Res., 24: 557-571.

Badran, N.M. 1999. Impact of organic materials on the mobility of Pb and Ni in polluted soil. Egyptian J. of Soil Science, 39(4): 561-577.

Chaney, R.L. and P.M. Giordano. 1977. Soils for the management of organic wastes and waste water eds. Elliot, L.F. and Stevenson, F.J., Soil Sci. Soc Am., Soc. Agron & Crop Sci. Soc. Am., Madison, 235-279.

Cottenie, A., A. Dhaese and R. Camerlynck. 1976. Plant quality response to uptake of polluting elements. Quality Plantarum, 26 : 293-319.

Darrall, N.M. 1989. The effect of air pollutants on physiological processes in plants. Plant, Cell and Environment, 12: 1-30.

Denny, H.J. and D.A. Wilkins. 1987. Zinc tolerance in *Betula* spp. IV. The mechanism of ecomycorrhizal amelioration of zinc toxicity. New Phytologist, 106 : 545-553.

EPA. 1995. National primary drinking water regulations. Contaminate specific fact sheets inorganic chemicals- Consumer Version. EPA 811-F-95-002-C, pp: 1-4.

Eugenia, G. G., A. Vicente and B. Rafael . 1996. Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. Environmental pollution, 92 (1): 19-25.

FAO. 1996. Irrigation in the near east region, 87-90.

Gadallah, M.A.A. 1996. Phytotoxic effects of industrial and sewage waste waters on growth, chlorophyll content, transpiration rate and relative water content of potted sunflower plants. Water, Air, and Soil Pollution, 89: 33-47.

Hamon, R.E., S.E. Lorenz, P.E. Holm, T.H. Christensen and S.P. McGrath. 1995. Changes in trace metal species and other components of the rhizosphere during growth of radish. Plant, Cell and Environ., 18: 749-756.

Hart, J.J., R.M. Welch, W.A. Norvell, L.A. Sullivan and L.A. Kochian. 1998. Characterization of cadmium binding, uptake, and translocation in intact seedlings of bread and durum wheat cultivars. Plant Physiol., 116(4): 1413-1420.

King, L.D. 1988. Retention of metals by several soils of the southeastern United States. Journal of Environmental Quality, 17: 239-246.

Kiranjit, S., B.L. Kawatra, S.K. Hira Mann and K. Setia. 1998. Toxic heavy metal contents of food materials consumed by the population in tube well and sewage water irrigated areas. J. Foods Science and Technology-Mysore. 35(6): 543-546.

Kloke A.D.R. Sauerbeck and H. Vetter. 1994. In Changing metal cycles and human health, Nriagu, J. ed., Springer-Veriag, Berlin, 113-114.

Lehoczky, E., P. Marth, I. Szabados, M. Palkovics and P. Lukacs. 2000. Influence of soil factors on the accumulation of cadmium by lettuce. Communications in Soil Science and Plant Analysis, 31 : 11-14.

Marzouk, A.S. 2003. Monitoring and fate of certain chemical pollutants in some environmental copartment. Ph.D. Thesis, Faculty of Agriculture, Ain Shams Univ., pp. 54 – 90.

Mowafy, M.M., Z.H. Zidan, A.K. Sobiha and A.S. Marzouk. 2005. Monitoring of certain heavy metals in different irrigation water sources. Annals Agric. Sci. Ain Shams Univ. Cairo, 50 (2) : 665 – 674.

National, Academy of Science-National Academy of Engineering. 1972. Water quality Criteria, US-EPA, Washington D.C,1-10.

Said, H.H.E. 1980. Studies on soil and plant pollution with lead. M.Sc. Thesis, Faculty of Agriculture, Ain Shams Univ., pp. 91-96.

Santillian, Medrano J. and J.J. Jurinak. 1975. The chemistry of lead and cadmium in soil: Solid phase formation. Soil Sci. Soc Amer Proc, 39: 85-356.

Scotti, I.S. and S. Silva. 1988. Effect of some soil properties on uptake of Co-57 by lettuce and

Radish. Annali-della-Facolta di Agraria, Universita Cattolica del Sacro Cuore Milano,28(1):75-85.

Shaole, W., F. Xinbang and A. Wittmeier. 1997. Microwave digestion of plant grain reference materials in nitric acid or mixture of nitric acid and hydrogen peroxide for the determination of multi-elements by inductively coupled plasma mass spectrometry. J. Analat. Atomic-Spectrometry, 12 (3): 797-806.

Sheila, M. Ross (Ed.). 1994. Toxic Metals in Soil-plant Systems. Toxic Metals : Fate and distribution in contaminated ecosystems, 189-243.

Tictjen, C. 1975. Principal problems of the use of city wastes for crop production and soil conservation. In FAO Soil Bulletin, 27: 211-226.

Tsadilas, C.D., M. Theodora, N. Barbayiannis and D. Dimoyiannis. 1995. Influence of sewage sludge application on soil properties and on the distribution and availability of heavy metal fraction. Communications in Soil Science and Plant Analysis, 26 (15 and 16), 2603-2619.

Tyler, G. 1981. Leaching of metals from the A-horizon of a spruce forest soil. Water, Air and Soil Pollution, 15: 353-369.

Vassilev, A., P. Zaprianova, and I. Atanassov. 1999. Removal of Cd by winter barley (*H. vulgare* L.), grown in soils with Cd pollution. Bulgarian J of Agricultural Science, 5 (1): 131-136.

Wenzel, W.W., W.E.H. Blum, A. Brandstetter, F. Jockwer, A. Kochl and M. Oberforster. 1996. Effect of soil properties and cultivar on cadmium accumulation in wheat grain. Zeitschrift–fur-Pflanzenernahrung und Bodenkunde, 159 (6): 609-614.

Wild A. 1988. Russell's Soil Conditions and Plant Growth. 11th ed. Longman, London.

Willaert, G. and M. Verloo. 1992. Effect of various nitrogen fertilizers on the chemical and biological activity of major and trace elements in a cadmium contaminated soil. Pedologie, 42(1): 83-91.

Yujun, Y., E. A. Herbert , L. Yimin, C.P. Huang and P. F. Sanders. 1996. Adsorption of mercury (II) by soil: Effects of pH, chloride, and organic matter. J. Environ. Qual., 25 : 837-844.

تأثير الرى بمياة الصرف الصحى المعالج على امتصاص وتراكم العناصر الثقيلة بالنباتات المزروعة

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يهدف هذا البحث إلى دراسة تأثير الرى بمياه الصرف الصحى المعالج على امتصاص وتراكم بعض العناصر الثقيلة فى النباتات المزروعة بأنواع التربة المختلفة التى كانت تروى بمياة الصرف االصحى لفترة طويلة مقارنة بمياه الرى الأخرى.

أوضحت النتائج أن العناصر الثقيلة محل الدراسة (نيكل، رصاص، كادميوم، كوبلت) كانت أكثر تراكماً بالأراضى الثقيلة عنه فى الأراضى الخفيفة بكل من الأصص المزروعة سواء بالقمح أو الفجل كما كان تركيز وتراكم عنصر الرصاص > النيكل > الكوبلت > كادميوم. كما أظهرت الدراسة أيضاً أن مياه الصرف الصحى ومياة الآبار أدت الى زيادة معدل التلوث بالأراضى المروية بدرجة أكبر من مصادر الرى الأخرى

كما أوضحت متوسطات تركيزات العناصر بكل من حبوب القمح وأوراق الفجل أن تراكم النيكل > الرصاص > الكوبلت > كادميوم. كما أن الرى بمياة الصرف الصحى سبب أعلى تراكم لكل من الكوبلت والرصاص والكادميوم، فى حين أن الرى بمياة الآبار أدى إلى زيادة تراكم عنصر النيكل بالنباتات المروية. وعلى النقيض، فإن الرى بمياة الصرف الزراعى والصرف الصحى المعالج أظهر أقل مستويات التراكم لكل من النيكل والرصاص والكادميوم. وقد أوضحت الدراسة أيضاً أن قدرة النباتات على امتصاص كل من الكادميوم و الرصاص والنيكل والكوبلت تتأثر ليس بمصدر مياة الرى فقط بل أيضاً بطبيعة العنصر وتركيزة فى التربة ونوع النبات المزروع.