Availability of Heavy Metals in Borg Elarab Soil and Their Uptake by Potato Plants (*Solanum tuberosum* L.) Irrigated with Wastewater

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ABSTRACT: To demonstrate availability of heavy metals in soil uptake by potato plants irrigated with wastewater. The wastewater near Sayed Darwish village, Borg Elarab City, Alexandria, Egypt was collected. The measured heavy metals in the wastewater were compared with the permissible levels stated in environmental regulations, Law No. 48 of 1982 concerning the protection of the Nile River and waterways from pollution**.** Heavy metals accumulation in potato irrigated with wastewater as following: Fe (140 mg/kg), Mn (33.2 mg/kg), Zn (31.1 mg/ kg), Cu (6.3 mg/kg), Co (1.1 mg/ kg), Ni (3.2 mg/kg), Pb (2.4 mg/kg), all item are more than allowable limits, concentrations of these available heavy metals in the surface layer (0-5 cm) of irrigated soil of waste water Fe (22.9 mg/kg), Mn (18.6 mg/kg), Zn (18.2 mg/ kg), Cu (4.3 mg/kg), Co (1.7 mg/ kg), Ni (4.1 mg/kg), Pb (4.1 mg/kg), compared with irrigated soil from artesian water Fe (11.2 mg/kg), Mn(9.5 mg/kg), Zn (19.1 mg/ kg), Cu (6.2 mg/kg), Co (1.2 mg/ kg),Ni (0.2 mg/kg), Pb (1.5 mg/kg) respectively. Potato plants irrigated with such wastewater specially wastewater not safe for human and animal consumption accordingly, the study suggests and recommends remediation of wastewater using physical, chemical and/or biological methods.

Keywords: Heavy metals, Borg El arab, waste water, potato plant

INTRODUCTION

Day *et al.* (1979) found that the extractable phosphorous was higher in soils irrigated with the pump water – wastewater mixture than in soils irrigated with pump water. Also, Hinasly *et al.* (1979) indicated that there exists a tremendous increase in the concentrations of Zn, Cu, Fe, and Mn in sandy soils irrigated with sewage water and similar results were obtained by (El – Nennah *et al.*,1982).

Elsokkary (1980) found that contents of Zn, Pb, Cd, and Co in some plants (wheat grain, radish, pepper, cabbage, barley and Jews mallow) depend on its concentration in industrially polluted soil. El- Nennah *et al.* (1982) found that continuous usage of sewage effluents in irrigation, increased markedly available p, soluble B and DTPA- extractable Cd, Co, Cr, Cu and Pb in soil.

Abdel-Tawab (1985) reported that using polluted water in irrigation increased the concentration of Mn, Zn, and Pb in soils located beside the factories at Helwan. Khalil (1990) reported that the prolonged period of irrigation with sewage water has markedly increased the amount of Fe, Zn, Mn, Cu, Pb and Ni in plants grown on Abu Rawash area, but the trace element levels in the leaves and juice fruits citrus and field crops (faba been, lupine) are below the standard level values

Water pollution remains a serious global problem, with impacts on the health of fresh water ecosystems and the human communities. The traditional pollution sources like sewage, industrial wastes and pollutants like pesticides and inorganic fertilizers have combined to degrade water quality, particularly near urban industrial centers and intensive agriculture areas (UNEP/ GEMS, 1995).

Abdel- Sabour *et al.* (2000) showed that the prolonged irrigation with heavy metals contaminated wastewater increased significantly heavy metals contents of the tested soil Moreover, data showed that heavy metals contents in either rice or sorghum plants grown in polluted soils are higher in most cases compared with the control. Abdelrazek (2014) found that the accumulation of heavy metals was pronounced in soil. Moreover, data showed that heavy metals contents in either rice or sorghum plants grown in polluted soils are higher most cases compared with the control.

Elgala *et al.* (2003) mentioned that the total Fe, Zn, Cu, Co, Ni and Pb concentrations in the upper 10 cm layer increased by about 1.4, 4.5, 1.1, 2.7, 2.8 and 5.5 times in Musturud soil, which irrigated with industrial wastewater; while in Elgabal-Elasfar soil, which irrigated with sewage water, it reached to 9.0, 3.3, 10.6, 9.6, 6.9 and 3.2 times that of soil irrigated with Nile water. In many countries of the world, treated wastewater is considered as an important element in water resources planning (Abd-El-Naim *et al.*,1989). Chang *et al.* (1984) reported that heavy metals tend to accumulate in the surface soil layers and that strong binding force with clay minerals and organic matter limit their movement. These results were in good agreement with those reported by Al-Lahham *et al.* (2003), Abbas *et al.* (2007) and Madrid *et al.* (2007).

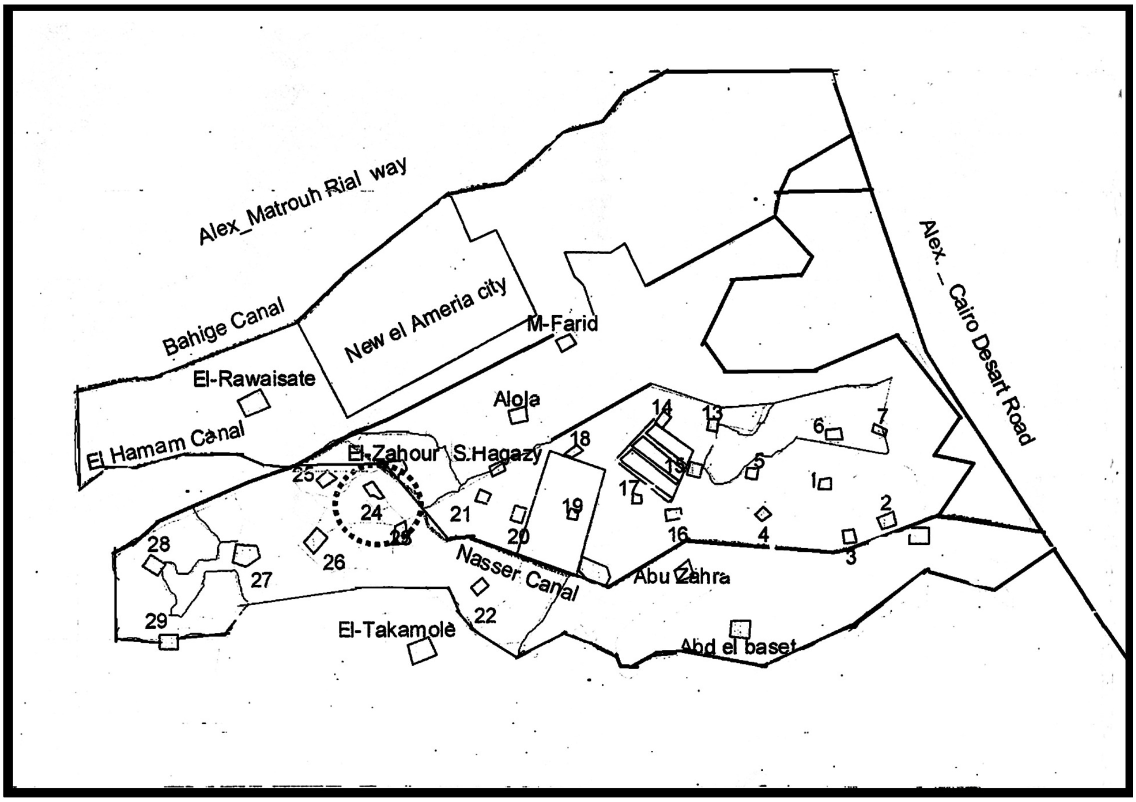
As soil health emphasizes the holistic approach to soil management, it must include water indicators, as the use of wastewater where it was sometimes the only source of irrigating crops, preferable by farmers (Abdelrazek, 2007 and Idowu *et al.* 2007). Industrial liquid wastes are more varied and more concentrated and contain certain various acids, alkalis chemical contaminants, oil, coarse solids, and other constituents. Dissolved materials include inorganic nutrients (Phosphate, ammonium, nitrate, sodium, etc). Toxic wastes (heavy metals mostly from industry Cu, Zn, Hg, Pb, Cd, Cr, Co, As etc.) and non-biodegradable organic chemicals (Mohamed and Abdelrazek, 2014).

Shouman (2015) found that in El-amia drain the accumulated amounts of heavy metals in soil were in the following order: Pb (ranged from 6.3-7.9 mg kg^{-1}) ≥ Ni (6.2-7.9 mg kg^{-1}) > Co (4.7-7.1 mg kg^{-1}) > Cd (3.8-5.3 mg kg^{-1}).

The objectives of this study were to evaluate a wastewater for irrigation and its effect on the distribution of total and chemically available heavy metals in Silt Clay Loam soil to the depth of 150 cm as well as to evaluate the accumulation of such elements in certain grown crop in Borg El arab area.

MATERIALS AND METHODS

Study area: Borg El arab, 48 Kilometer west of Alexandria – Marsa Matruh road. It lays approximately between latitudes 30^{o} 45^{-} and 30^{o} 55^{-} N, and longitudes 29^{o} 30^{-} and 29^{o} 50^{-} E The study area covered about 504 Hectare planted potatoes and located near alex- cairo desert road and alex- Matrouh road way as shown in Fig 1.



Fig(1). Location map of the study area
Wastewater(1,7,6,5,13,14,17,15,22,23,25,28,9,10)
Artesian water(2,3,4,16,18,20,21,24,26,29,27,8,11,21)

Samples: Soil samples from two sites were collected from Borg Elarab area. The first site is irrigated with artesian water and the second site is irrigated with wastewater in the same area (Cast directly on the irrigation canals). In each site, five soil profiles were dug to the depth of 150 cm and soil samples were collected from successive depths (0-5, 5-10, 10-30, 30-60, 60-90, 90-150 cm). These samples represent variations in cropping patterns, and different irrigation water sources. The present cropping patterns include potatoes (*Solanum tuberosum* L.).Twelve water samples from irrigation water, six samples from the Artesian and six samples from the wastewater were collected for chemical analysis.Twelve plant samples were collected from each side, six samples from the plants which irrigated from Artesian water and six samples from the plants which irrigated from wastewater were collected for chemical analysis.

Analysis: The collected plant samples were washed with tap water, 10^{-4} M HCl solution, and ionized water, then oven dried at 65°C for 48 hours. Plant materials were ground and mixed well and kept for Fe, Zn, Cu, Co, Ni and Pb analysis (Rawa, 1973).

Total heavy metals contents of Fe, Zn, Cu, Co, Ni and Pb in soil were determined after digestion with hydrofluoric/ perchloric acids mixture (Jackson, 1958) .

Available heavy metals were evaluated by extracting the soil with DTPA according to Lindsay and Norvell (1978) and the metals in the extract were determined using an atomic absorption spectrophotometer.

The physical and chemical properties of the soil samples were determend according to the method of (Richards, 1954), Table 1

Also, some chemical composition of the two water sources were measured and presented in Table 2.

Table(1). Some physical and chemical characteristics of the selected soils irrigated with artesian and wastewater.

Parameter	Soil irrigated with artesian water	Soil irrigated with wastewater
pH	8.23	7.62
EC dSm^{-1}	5.71	2.51
$CaCO_3$ %	39	28
OM%	0.55	1.24
CEC $cmolc.kg^{-1}$	10	19
Sand%	76	32
Silt%	1	44
Clay%	23	24
Textural class	**Silt Clay Loam**	**Loam**

Table (2). Some chemical composition of the two water sources in Borg Elarab area

Parameter	units	FAO * guidelines	Law No. 48 of1982	Artesian water	Wastewater*
pH		6.5-8.4	7-8.5	8.8	7.3
EC	$dS.m^{-1}$	< 3		2.53	3.80
TDS	ppm	< 450	500	1619.2	2432
COD	$mg\ L^{-1}$	=====	>10	n.d	250
BOD5	$mg\ L^{-1}$	=====	>5	6.5	563.7
Ca^{2+}	$mg\ L^{-1}$	=====	------	5.12	7.81
Mg^{2+}	$mg\ L^{-1}$	=====	------	1.9	7.3
Na+	$mg\ L^{-1}$	< 70	-----	7.1	13.10
Total N	$mg\ L^{-1}$	< 30.0	>1	5.11	75.2
$NO3^{-}$	$mg\ L^{-1}$	10	>45	1.13	16.82
$PO^{=}4$	$mg\ L^{-1}$	8.6	1	0.07	4.34
B	$mg\ L^{-1}$	< 1.0	-----	0.12	0.28
Cl^{-}	$mg\ L^{-1}$	<140	-----	5.91	14.9
HCO^{-}_3	$mg\ L^{-1}$	< 90	-----	5.94	4.32
Fe	$mg\ L^{-1}$	5.0	>1	2.81	3.69
Mn	$mg\ L^{-1}$	0.2	>0.5	0.95	1.32
Zn	$mg\ L^{-1}$	2.0	>1	0.90	1.15
Cu	$mg\ L^{-1}$	0.2	>1	0.31	0.64
Ni	$mg\ L^{-1}$	0.2	-----	0.21	0.82
Co	$mg\ L^{-1}$	0.05	-----	0.11	0.3
Cd	$mg\ L^{-1}$	0.01	>0.01	0.13	0.46
Pb	$mg\ L^{-1}$	5.0	>0.05	0.41	0.62
SAR		< 9.0	-----	3.80	4.76

n.d = not detected   * Fair *et al*. 1971), FAO (1976), WHO (1993)
*Source of wastewater (artificial water from Industrial City Borg Elarab and sewage water from Mary Mina a church)

RESULTS AND DISCUSSIONS

I-Total Heavy metals content in soils:

Data in Table 3 show the total amounts of Fe, Mn, Zn, Cu, Co, Ni and Pb in different layers of the investigated soils profiles. Data reveal that the total content of these elements differed according to water source used for irrigation. These results are in agreement with the findings of Pescod (1992) who found that after 6 years of continually applying sludge at a cropland disposal site over 90 % of the applied heavy metals were found in the 0 to 15 cm soil depth. This depth is practically within the plow layer. If the soil still irrigated with this water for the long time, the root zone could be polluted with Zn, Cu, Ni and Pb.

Table (3). Total and DTPA-extractable heavy metals, mgkg^{-1} in the studied soils as affected by source of irrigation and soil depth

Depth (cm).	Fe		Mn		Zn		Cu		Co		Ni		Pb	
	Total	DTPA	Total	DTPA	Total	DTPA	Total	DTPA	Total	DTPA	Total	DTPA	Total	DTPA
Soil irrigated with wastewater														
0-5	62 5	22.9	37.27	18.6	31.54	18.2	8.95	4.3	1.93	1.7	5.89	4.1	6.88	4.1
5-10	70.4	23.2	32.80	14.2	31.74	17.2	7.36	3.1	1.84	1.5	5.67	4.3	6.47	2.7
10-30	62.2	20.1	34.98	10.4	19.68	11.3	7.75	3.8	1.15	0.6	3.36	2.9	6.26	2.8
30-60	48.5	9.2	23.12	7.5	19.64	9.3	6.95	2.4	0.68	0.2	4.96	3.6	3.69	2.1
60-90	39.8	10.2	36.38	6.2	6.51	5.96	5.65	2.6	0.97	0.5	3.51	2.1	2.88	1.6
90-150	46.4	5.5	23.10	4.2	15.20	7.2	4.86	1.2	0.88	0.7	2.63	1.6	4.49	1.1
Soil irrigated with artesian water														
0-5	40.9	11.2	15.58	9.5	23.23	19.1	13.59	6.2	1.65	1.2	0.98	0.2	2.39	1.5
5-10	50.8	9.3	10.37	9 .6	14.13	8.3	2.84	1.9	1.98	1.4	0.87	0.5	2.42	1.6
10-30	40.7	9.2	15.66	7.2	15.14	5.6	1.69	1.4	1.64	0.8	0.98	0.5	2.57	1.1
30-60	33.7	7.2	15.36	7.6	15.13	5.3	1.48	0.6	1.38	0.6	0.94	0.1	2.62	1.0
60-90	49.7	4.6	14.24	5.3	6.12	4.4	1.75	0.9	1.37	0.2	0.70	0.1	1.75	0.8
90-150	49.7	2.3	13.25	3.4	5.13	1.2	1.75	0.3	0.65	0.1	0.63	0.2	1.33	0.7

II- DTPA-extractable heavy metals in soils:

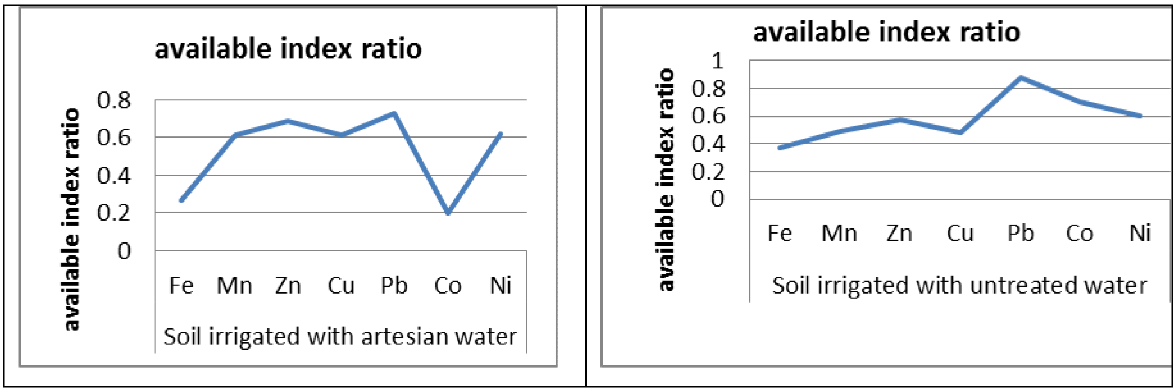
Results given in Table 4 show the DTPA-extractable Fe, Mn, Zn, Cu, Co, Ni and Pb in the successive layers of Borg ELarab soil as affected by irrigation with artesian water and wastewater. Chemically available values for different heavy metals vary according to water source and decreased with increasing soil depth. The increasing extractability of the concerned heavy metals in the soil irrigated with wastewater could be attributed to increasing the total contents. Beside the relatively low pH values (increase of acidity in wastewater in this soil also in Table (4) the chemically available Mn, Zn and Cu showed the highest values in the upper layer for soil irrigated with wastewater compared to other elements Fig 2.

Table (4). available index ratio* for different heavy metals in the studied soils as affected by source of irrigation and soil depth

	Soil irrigated with wastewater water							Soil irrigated with artesian water						
Depth (cm).	Fe	Mn	Zn	Cu	Co	Ni	Pb	Fe	Mn	Zn	Cu	Co	Ni	Pb
0-5	0.37	0.49	0.57	0.48	0.88	0.70	0.60	0.27	0.61	0.82	0.45	0.73	0.20	0.62
5-10	0.33	0.43	0.54	0.42	0.82	0.76	0.42	0.18	0.93	0.59	0.67	0.71	0.57	0.66
10-30	0.32	0.30	0.57	0.50	0.52	0.85	0.43	0.23	0.46	0.37	0.83	0.94	0.51	0.43
30-60	0.19	0.32	0.47	0.35	0.29	0.73	0.57	0.21	0.49	0.35	0.41	0.43	0.11	0.38
60-90	0.26	0.18	0.92	0.46	0.52	0.59	0.57	0.09	0.37	0.72	0.51	0.15	0.14	0.46
90-150	0.12	0.13	0.47	0.25	0.80	0.60	0.24	0.04	0.24	0.23	0.17	0.15	0.32	0.53

*Available index ratio AIR= Available heavy metals/Total heavy metals)

These results coincide with those of (Dumontet *et al*. 1990 and El-Gendi *et al*. 1997) who found that irrigating sandy soil in the Abou- Rawash area with drainage water increased total Cu, Zn and Fe, which reached 125, 170 and 5 times that of the virgin soil in the same area. It seems that the high permeability of the calcareous soil in Borg Elarab area, besides the colloids state of the suspended matter, facilitates the downward movement of heavy metals (ionic, complexed with organic molecules and /or finely dispersed colloidal).



Fig(2). Available index ratio in soils irrigated with artesian and wastewater

III- Effect of wastewater on heavy metals concentrations in potato growing in the Borg ELarab area

Contents of Fe, Zn, Cu, Co, Ni and Pb in leaves potato plants grown on the studied areas are found in Fig. 3. Results show that, the highest values of heavy metals content were found in plants grown on soil irrigated with waste water. This coincides with the previous findings that soil contained the highest values of chemically available heavy metals (Table 3). Variation in accumulation percent of different heavy metals in potato plant arranged in the following order: Cu > Ni > Pb > Co , Fe > Mn ≥ Zn (Table 4).Heavy metals are non-biodegradable and persistent environmental contaminants, which may be uptake and then absorbed by tissues of vegetables plants (Khairiah *et al*. 2004; Al Jassir *et al*., 2005; Singh and Kumar, 2006; Sharma *et al*., 2008).

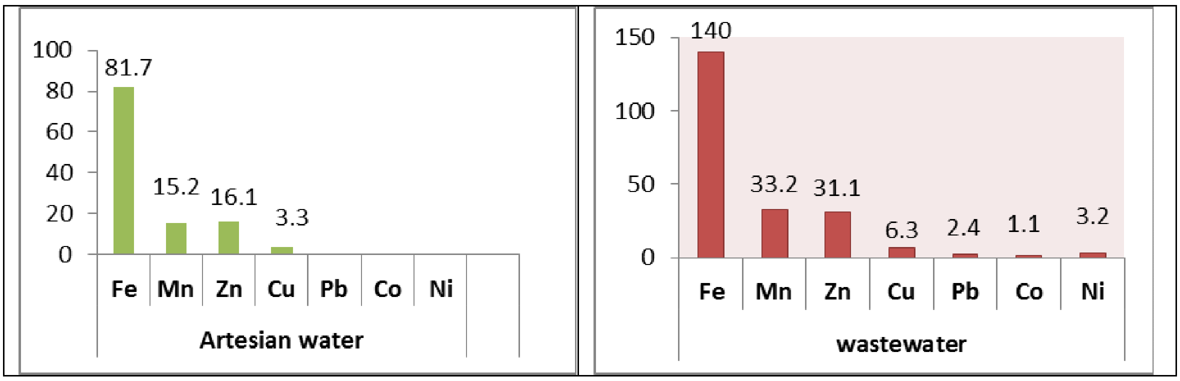


Fig (3). Heavy metals concentrations mgkg^{-1}in leaves of potato affected by source of water irrigation.

Radwan and Salama (2006) studied the mean concentrations and range of heavy metals found in fresh fruits and vegetables samples from several local markets in Alexandria city, Egypt during 2005. Among vegetables, the leafy vegetables lettuce and spinach have content of Pb, Cd, Cu and Zn ranged between 0.28 -0.65, 0.05-0.09, 1.82-2.22, 7.80 – 12.0; 0.23-0.43, 0.09-0.15, 3.50-5.90 and 18.0 -22.8 mg/kg dry weight, respectively. The means of Pb, Cd, Cu and Zn for lettuce and spinach were 0.58, 0.07, 1.97, 9.76; 0.34, 0.11, 4.48 and 20.9 mg/ kg dry weight, respectively. In addition, Arora *et al.* (2008) reported that wastewater irrigated spinach has shown significantly higher concentrations of Fe (309 mg/kg), Mn (69.4mg/kg), Cu (16.5 mg /kg) and Zn (33.1 mg/ kg), compared to the freshwater – irrigated spinach, indicating the highest metal absorption for this vegetable.

Correlation matrix between available heavy metals in soil and concentrated heavy metals in potato plant irrigated with wastewater as the same result with Correlation matrix between available index ratio in soil and concentrated heavy metals in potato plant irrigated with wastewater:

There is a significant strong correlation between the concentration of heavy metals in the soil and its concentration on the potato plants Fig 4,5.
Available index ratio in soils irrigated with wastewater relatively higher than soil irrigated with artesian these rever that the important available index ratio in these study Fig 2. Available index ratio in soils has high correlation with heavy metals concentrations in potato plants

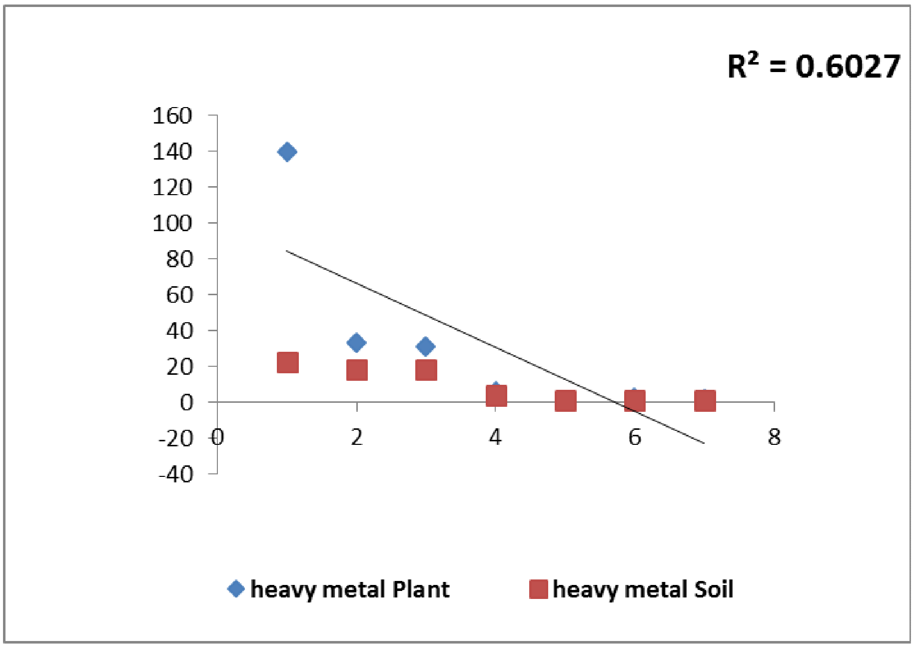


Fig (4). Available heavy metals in soil irrigated with wastewater and concentrated heavy metals potato plan

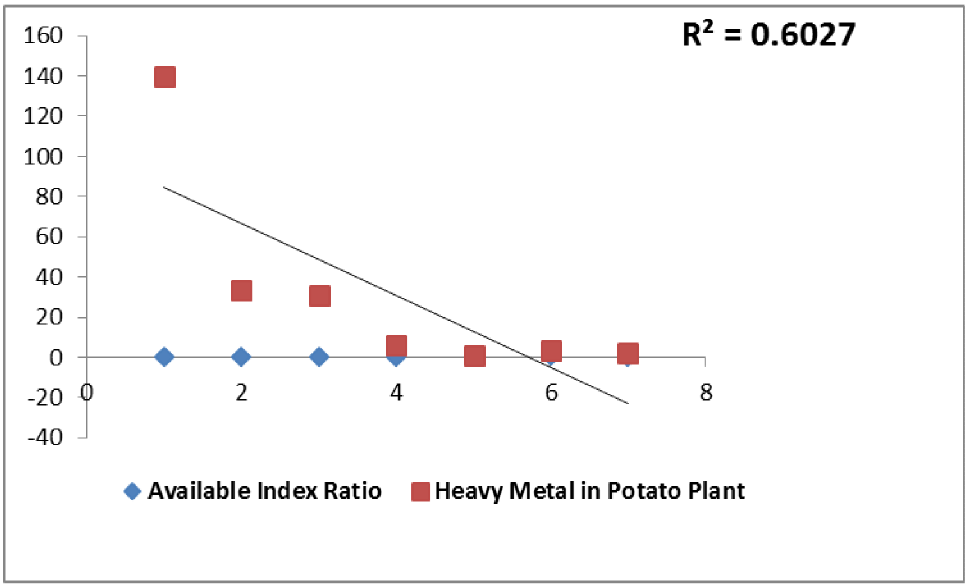


Fig (5). Available Index Ratio and concentrated heavy metals in potato plant (Available Index Ratio (AIR= Available heavy metals/Total heavy metals)

Table 4. Effect of different sources water irrigation on yield components of potato grown in Borg Elarab area

Irrigation Water sources	Tuber yield (Ton ha^{-1})	Straw yield (kg ha^{-1})
Artesian water	9.425	8.905
Wastewater	7.820	6.642

The shoots in potato plants grown in soils irrigated with artesian water were higher than soil irrigated with Wastewater respectively. Indicating that the tuber yield was more than the straw yield in soil irrigated with Wastewater Table 4

Conclusions

This depth is practically within the blow layer. If the soil still irrigated with this water for the long time, the root zone could be polluted with Zn, Cu, Ni and Pb. The increasing extractability of the concerned heavy metals in the soil irrigated with wastewater could be attributed to increasing the total contents of profiles. The highest values of heavy metals content were found in potato plants grown on soil irrigated with wastewater.

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الملخص العربي

صلاحية المعادن الثقيلة في اراضى برج العرب وامتصاصها بنباتات البطاطس المروية بمياه الصرف

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زادت مخلفات الصرف الناتجة عن الأنشطة البشرية، بشكل ملحوظ مما أدى إلى زيادة مشكلة التخلص منها ، وتسبب ذلك فى تأثير غير مرغوب فيه على الموارد الطبيعة والإنسان. ومع كثرة استخدام المياه العادمة في ري المحاصيل لابد من مراقبة دقيقة بسبب احتمال وجود مكونات غير مرغوب فيها من المعادن الثقيلة والملوثات العضوية. ولمعرفة تأثير الري بمياه الصرف على التربة ، تم دراسة خصائص التربة الزراعية في مدينة برج العرب (٥٠٤ هكتار منزرعة بنبات البطاطس) وتم جمع عينات من التربة والنبات من الاراضى المروية بمياه الصرف (مصدرها المجمع الصناعى ودير مارى مينا ببرج العرب) ومن المروية بمياه الآبار ككنترول. تم اخذ عينات من خمس قطاعات من التربة على ابعاد متعاقبة إلى عمق ١٥٠ سم (٠– ٥ ، ٥–١٠، ١٠–٣٠، ٣٠–٦٠، ٦٠–٩٠،٩٠–١٥٠ سم). تم دراسة تأثير مياه الصرف على تركيز العناصر الثقيلة في التربة وامتصاص النبات لها. وأظهرت النتائج أن المحتوى الكلي لهذه المعادن الثقيلة كانت أعلى في الطبقة السطحية من تلك الطبقات تحت السطحية .وكانت تركيزات هذه المعادن الثقيلة في الطبقة السطحية (٠–٥ سم) من التربة المروية من مياه الصرف كالاتى. (الحديد٢٢.٩ ملجم/كجم)، (المنجنيز١٨.٦ملجم/كجم)، (الزنك ١٨.٢ ملجم/كجم)، (النحاس ٤.٣ ملجم/كجم)، (الكوبلت ١.٧ ملجم/كجم)، (النيكل٤.١ ملجم/كجم)، (الرصاص ٤.١ ملجم/كجم. بالمقارنة مع

التربة المروية بمياه الآبارعلى التوالي وهى (الحديد١.٥ ملجم/كجم)، (المنجنيز٠.٢ ملجم/كجم)، (الزنك ٩.١ ملجم/كجم)، (النحاس١.٥ ملجم/كجم)، (الكوبلت ٩.٥ ملجم/كجم)، (النيكل١١.٢ ملجم/كجم)، (الرصاص ١١.٢ ملجم/كجم. تجاوز مجموع المعادن الثقيلة في الطبقة السطحية الحدود المسموح بها فى التربة المروية بمياه الصرف. وأظهرت الدراسة أن. نباتات البطاطس المزروعة في التربة وفقا لقدرتها على تراكم المعادن الثقيلة كما في الترتيب التالي البطاطس المروية بمياه صرف اكثر فى تراكم العناصر الثقيلة من البطاطس المروية بمياه البئر وإختلاف تركيز المعادن الثقيلة فى البطاطس المرواه بمياه الصرف وفقا للترتيب التالي:النحاس > النيكل > الرصاص > الكوبلت والحديد > المنجنيز ≤ الزنك . بجانب التراكم المفرط للكوبلت، النيكل والرصاص فى نبات البطاطس المروى بمياه الصرف.

الكلمات الدلالية : معادن ثقيلة ، برج العرب ، مياه الصرف غير المعالجة ، نبات البطاطس