1

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Indirect Impacts of Irrigation with Low Quality Water on The Environmental Safety

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Using low quality water for irrigation is probably one of the main reasons for contaminating the arable lands with potentially toxic elements (PTEs), especially within the arid and semiarid regions. On the other hand, most farmers depend thereon on natural inefficient drainage systems to get rid of excess water flows. It was thought that the hydraulic continuities exist, totally or partially, among (a) the underground waters of the arable lands that receive low quality water for irrigation, (b) the underground waters of the nearby lands that use fresh Nile water for irrigation and (c) the sources of fresh water themselves. Therefore, the following assumptions were considered because of their potentially high ecological implications: H1: soil leakage of low quality irrigation water might have negative consequences on the quality of fresh water itself that is used for irrigating the nearby arable lands. H2: concentrations of potentially toxic elements (PTEs) in irrigation water are probably the main factors controlling their corresponding available and total concentrations in soil. H3: concentrations of PTEs within the edible parts of plants grown on the nearby areas irrigated with fresh water are relatively high and may be considered not suitable for consumption. To investigate the above-mentioned hypotheses, irrigation water (fresh Nile, underground and wastewaters), soil and plant samples were collected from three different governorates, *i.e.* New Salhia (El -Sharqia), ElSaff (Giza) and Meet Kenana (Qualubia). One site from each governorate was selected to represent the arable lands that use fresh Nile water for irrigation while the other sites were irrigated with either the underground water or wastewater solely. Quality of the fresh (Nile) irrigation water used in the studied locations was estimated as class II on the basis of its salinity hazards. The other water samples were estimated to be,according to the same basis, as of potentially high or very high salinity hazards. In case of water sodicity, SAR values did not exceed "13" in nearly most water samples. The BOD and COD values exceeded the acceptable levels (even in the Nile fresh water). Moreover, the measured values in fresh water seemed to be comparable, to some extent, with the corresponding ones estimated for either the underground or wastewaters; accordingly,we accept H1. Concentrations of the PTEs, *i.e.* Pb, Co and Cd in all the collected water samples, generally, did not exceed the maximum permissible levels (MPLs) recommended by FAO (1994). However, Ni was the only one among the studied PTEs whose concentration exceeded the MPL only in the underground water of New Salhiaduring the summer season. It is worthy to mention that AB-DTPA extractable PTEs were correlated significantly with PTEs concentrations in irrigation water. Also, AB-DTPA extractable PTEs were correlated significantly with their total contents in soil; hence, we partially accept the second hypothesis *i.e.* H2 Furthermore; concentrations of PTEs in the edible parts of plants irrigated with fresh Nile water exceeded their permissible levels and therefore, we partially admit H3 since using low quality water for irrigation showed potential hazards on the food quality obtained from the nearby arable lands irrigated with fresh water.

Keywords: Potentially toxic elements, Low quality water, Irrigation, Underground water, Wastewater, Environmental safety.

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Introduction

Soil salinization is one of the main factors affecting soil deterioration in arid and semiarid regions (Peng et al., 2019). Such a problem arises mainly due to the usage of low quality water in irrigation without considering appropriate leaching requirements (Minhas et al., 2019). This consequently threatens food security and sustainability (Saqib et al., 2019). On the other hand, many countries around the world are enforced towards using low quality water as alternative resources for irrigation to overcome the inadequate water supply (Macedonio et al., 2012) *e.g.,* Egypt (Abdel-Kader and Abdel-Rassoul, 2010, Farid et al., 2014, Ali et al., 2016 and Ibrahim et al., 2016). These wastewaters are produced annually in large amounts (Thatai et al., 2019). Although, they are rich in nutrients (Hanjra et al., 2012), however, their high contents of BOD can posses a serious environmental problem (Singh et al., 2019). Moreover, these waters bring high concentrations of potentially toxic elements (PTEs) to soils (Abuzaid et al., 2019 and Abbas and Bassouny, 2018) which are considered non-biodegradable and therefore threatens the ecological system (Ghosh and Manchanda, 2019 and Yin et al., 2019). According to Landrigan et al. (2019), environmental pollution is responsible for 940,000 deaths within the children worldwide in 2016 (two thirds aged under 5 yr). Thus, monitoring the levels of PTEs should be considered periodically while evaluating the suitability of water for irrigation to insure its safe use in crop production.

In Egypt, rapid extension of agricultural lands as well as the reclamation of desert lands placed more pressure on the available water resources (El-Sadek, 2010 and Abu-hashim & Negm, 2018). Under such circumstances, many farmers suffer for lack of fresh water and, therefore, they are forced towards using low quality water (wastewater) for flood irrigation (Farid et al., 2014, Abuzaid and Fadl, 2018 and Okubo et al., 2019) without receiving advanced treatments to decontaminate such wastewaters (Gupta and Yadav, 2019). On the other hand, almost all farmers depend on the natural drainage to get rid of excess water flows (Bakr and Bahnassy, 2019). These wastewaters can contaminate the groundwater (Abdalla and Khalil, 2018) and their effluents may be a reason for the degradation of fresh water bodies (Holt, 2000, Pal et al., 2010 and Edokpayi et al., 2017) especially with the loss of ability of these canals to "self-purify waters due to the disturbances of fresh water continuity" (Spyra et al., 2015).

If hydraulic continuities exist totally or partially among (1) the underground waters of the arable lands that receive low quality water for irrigation, (2) the underground waters of nearby lands that use fresh Nile water for irrigation and (3) the sources of fresh water themselves that are used for irrigation; then, soil leakage of low quality irrigation water might have negative consequences on the quality of fresh water itself that is used for irrigating the nearby arable lands (First hypothesis). In this concern, emerging contaminants are taken as markers of wastewater contamination (de Sousa et al., 2014). Although, there exists dynamic equilibrium between the available and total contents of PTEs in the light textured soils (Abbas and Bassouny, 2018); nevertheless, we postulate that the soluble contents of PTEs in the irrigation water (the more dynamic fraction) are probably the main factors affecting the analogous available and total contents in soils (Second hypothesis). Finally, we assume that the concentrations of PTEs within the different parts of plants grown on areas irrigated with fresh Nile water might be relatively high and therefore, the edible parts of these plants are probably not suitable for consumption (third hypothesis).

To examine the above-mentioned hypotheses, irrigation water (fresh Nile, underground and wastewaters) as well as soil and plant samples were collected from three different locations i.e.New Salhia (El-Sharqia Governorate), ElSaff (Giza Governorate) and Meet Kenana (Qualubia Governorate). One site was selected from each locationto represent the arable lands that are irrigated with the Fresh Nile water while the other sites were selected from those that receive either underground water or wastewater as sole sources for irrigation. The waters were then evaluated for their suitability considering the following parameters, *e.g.* salinity (EC), sodium adsorption ration (SAR), residual sodium carbonate (RSC), Mg-ratio, their PTEs concentrations, chemical oxygen demand (COD) and biological oxygen demand (BOD) contents. Total and available contents of PTEs were also estimated in soils of the sitesunder study. Moreover, PTEs were determined within the areal parts (shoot and seeds/grains) of plants grown on the investigated areas.

Materials and Methods

Soil sampling and preparation

Surface soil samples (0-30 cm) were collected from 8 sites at three different governorates for two successive seasons (winter, January 2017 and summer, August, 2017): (1) New Salhia, El-Sharqia Governorate (one site is irrigated with fresh water canal (S1, 30° 65' 87" N and 31° 96' 44" E) and the other two sites are irrigated with underground water (S2, 30° 65' 99" N and 31° 96' 46" E and S3, 30° 40' 32" N and 31° 58' 13" E)), (2) ElSaff, Giza Governorate (one site is irrigated with fresh water canal (S4, 29° 35' 8.4" N and 31° 16' 11.8" E) and the other site is irrigated with ElKashab canal (S5,29° 70' 58" N and 31° 35' 63" E) which is a mixture of agricultural and industrial discharges and (3) Meet Kenana, Qualubia Governorate (one site is irrigated with Meet Kenana cannel which is a source of Fresh Nile water (S6, 30° 38' 44" N and 31° 24' 54" E), the second site is irrigated with the underground water (S7, 30° 38' 46" N and 31° 24' 90" E) and the third site is irrigated with agricultural wastewater (S8, 30° 20' 8.0" N and 31° 16' 55.7" E)). The soil samples were air dried ground and sieved to pass through a 2 mm-sieve. Afterwards, these samples were analyzed for their physical and chemical characteristics according to Klute (1986) and Sparks et al. (1996), respectively and these results are presented in Table 1.

Locations of study: New Salhia:irrigated with fresh water (S1), irrigated with underground waters (S2 and S3), ElSaff: irrigated with fresh water canals (S4), irrigated with wastewater (ElKhashab canal, S5); Meet Kenana: irrigated with fresh water (S6), irrigated with underground waters (S7,), irrigated with wastewater (S8) Water samples were also collected from the abovementioned sites and then evaluated for their chemical characteristics as outlined by Page et al. (1982) and the obtained results are presented in Table 2.

TABLE 1. Physical and chemical properties of the investigated soil locations

	New Salhia			**ElSaff**		**Meet Kenana**		
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Soil physical characteristics								
Coarse sand, %	87.6	85.4	76.5	11	12	38	47	23
Fine Sand, %	11.1	13.0	21.6	22	16	14	23	27
Silt, %	0.7	0.8	0.9	49	22	22	16	26
Clay, %	0.6	0.8	1.0	18	50	26	14	24
Textural class	S	S	S	L	C	SCL	SL	SCL
Bulk density, Mg m^{-3}	1.52	1.65	1.48	1.24	1.21	1.43	1.30	1.32
Hydraulic conductivity, cm h^{-1}	14.11	13.96	15.66	3.43	0.46	6.87	6.95	4.25
Soil chemical characteristics								
$CaCO_3$, g kg^{-1}	8.0	8.0	14.0	146	330	48	48	34
SOM, g kg-1	7.61	5.43	5.23	20.01	22.92	18.91	15.62	5.13
CEC, $cmol_c$ kg^{-1}	6.16	5.13	7.01	40.54	4263	29.45	23.26	9.69
Winter season								
pH	7.00	7.35	7.58	7.70	7.70	8.46	8.62	8.45
EC	5.00	6.55	11.8	1.88	7.29	0.50	2.61	0.39
Summer season								
pH	7.40	7.90	7.60	7.65	7.58	8.37	7.90	8.37
EC	0.53	3.42	11.27	2.29	12.93	2.60	3.61	2.50

Note:Soil textural class: S: sand, L: loam, C: clay, SCL:sandy clay loam, SL: sandy loam,
Locations of study: New Salhia:irrigated with fresh water (S1), irrigated with underground waters (S2 and S3), ElSaff: irrigated with fresh water canals (S4), irrigated with wastewater (ElKhashab canal, S5); Meet Kenana: irrigated with fresh water (S6), irrigated with underground waters (S7,), irrigated with wastewater (S8)

TABLE 2. Chemical characteristics, boron content and SAR of the irrigation water samples collected from the investigated locations

Parameter	New Salhia			ElSaff		Meet Kenana		
	S1	S2	S3	S4	S5	S6	S7	S8
Winter season								
pH	7.30	7.65	7.59	7.53	7.28	8.46	8.45	8.46
EC	0.37	3.2	3.22	1.00	1.1	0.50	1.18	0.39
SAR	0.38	19.80	20.31	3.52	4.94	1.27	1.76	1.47
Soluble cations, mmolc L^{-1}								
Ca^{2+}	1.10	2.10	1.60	2.70	2.98	2.10	2.70	1.60
Mg^{2+}	2.40	2.90	2.82	3.30	1.42	1.10	4.80	1.40
Na^{+}	0.50	31.30	30.2	6.10	7.33	1.60	3.40	1.80
K^{+}	0.10	0.13	0.16	0.12	0.29	0.16	0.20	0.20
Soluble anions, mmolc L^{-1}								
CO_3^{2-}	-	-	-	-	-	-	-	-
HCO_3^{-}	3.28	2.18	4.46	2	2.18	1.09	0.82	0.82
Cl^{-}	0.46	14.6	17.3	2.45	1.91	0.91	4.09	0.91
SO_4^{2-}	0.36	19.65	13.02	10.47	7.98	3.87	8.89	5.06
B, mg kg^{-1}	nd	0.36	0.34	n.d.	0.83	n.d.	n.d.	n.d.
Summer season								
pH	7.2	7.8	7.8	7.03	6.74	7.12	7.42	7.37
EC	0.47	3.58	3.18	0.33	1.28	0.46	0.76	1.21
SAR	1.07	11.76	15.18	1.25	4.40	1.21	1.56	0.76
Soluble cations, mmolc L^{-1}								
Ca^{2+}	1.6	5.3	3.2	1.1	1.6	2.70	5.90	2.10
Mg^{2+}	1.7	4.7	2.8	0.9	3.9	2.80	3.10	1.40
Na^{+}	1.38	26.3	26.3	1.25	7.3	2.00	3.30	1.00
K^{+}	0.11	0.11	0.11	0.04	0.16	0.11	0.20	0.13
Soluble anions, mmolc L^{-1}								
CO_3^{2-}	-	-	-	-	-	-	-	-
HCO_3^{-}	2.28	3.09	3.72	1.82	2.64	3.45	2.7 0	2.27
Cl^{-}	1.4	18.20	15.50	1.00	5.30	0.90	0.5 0	3.60
SO_4^{2-}	1.11	15.12	13.18	0.47	5.02	3.26	1.43	6.63
B	n.d.	0.49	0.54	n.d.	0.17	0.076	0.058	n.d.

Note: See footnotes of Table 1
B: boron

Soil and water chemical analyses

Available concentrations of Pb, Ni, Co and Cd were extracted by AB-DTPA according to Soltanpour (1985). Total contents of these PTEs were measured in soils after being digested using a tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$, 10:4:1) according to Sahrawat et al. (2002). COB and BOD contents in waters were determined according to Young (1973). Concentrations of B in the water samples were determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, Ultima 2 JY Plasma, USA). Concentrations of Pb, Ni,Co and Cd were determined in the water samples, soil digests and the AB-DTPA soil extracts by Atomic Absorption Spectrophotometer(AAS),Perkin-Elmer Model-2380.

Results and Discussion

Evaluating the suitability of water for irrigation

Table 3 presents the criteria used to evaluate the suitability of the investigated water samples for irrigation. According to The USDA Salinity Laboratory System (1954), the Nile irrigation water collected from both New Salhia and Meet Kenanalocations could be evaluated as class II on basis of water salinity and this probably indicates medium salinity hazards. Accordingly, moderate leaching is recommended while using this water for irrigation. The other water samples were evaluated as highly (C3) and very highly (C4) saline water. Regarding water sodicity, their SAR values did not exceed the value "13" in most of the water samples except for those of site 2 (in winter season only) and site 3 (in bothwinter and summer seasons) which are underground waters used for irrigation of New Salhia location. The other parameters of the water evaluation, *i.e.* Mg-ratio and RSC, both of them did not exceed the permissible levels recommended by FAO (FAO, 1994) during the winter season. However, significant increases occurred in both parameters during the summer season. In this concern, Mg-hazard was detected in the water samples collected from the three locations, *i.e.* Nile water of both New Salhia and Meet Kenana as well as the water of ElKhashab canal. Likewise, RSC values exceeded the "zero" value for the same locations in addition to the wastewater samples collected from Meet Kenana. It is worthy to mention that the boron level in all the collected water samples did not exceed the permissible level of 0.7 mg L^{-1} according to the FAO regulations (FAO, 1994) and; therefore, these waters have no restrictions on their use for irrigation on basis of B toxicity.

COD and BOD contents in irrigation water

Fig. 1 reveals that the values of each of chemical oxygen demand (COD) and biological oxygen demand (BOD) in fresh Nile water seemed to be comparable; however, to a lower extent, with the corresponding values estimated for either the underground water or the wastewaters that were used for land irrigation. On the other hand, COD and BOD values were higher in winter season than in summer one. It is worthy to mention that BOD is the amount of oxygen needed by microbes to decay the carbon based materials within five days period (Jørgensen et al., 2005; Cardete et al., 2019). The acceptable levels of BOD in irrigation water should not exceed 30 mg L^{-1} (Salameh et al., 2018; Singh et al., 2019); yet, the results obtained herein exceeded this permissible level. Such high BOD values imply rapid depletion of oxygen in water (Thatai et al., 2019). The COD is another important aspect to be considered while evaluating the degree of water pollution. It is the amount of oxygen needed to oxidize the organic matter completely (Scholz, 2006) and its acceptable value should not exceed 200 mg L^{-1}(Bhuyan et al., 2018). Unfortunately, the obtained values exceeded this acceptable level of COD in irrigation water. It is then thought that such high values of COD probably indicate direct discharging of the untreated wastewater in the water bodies (Wats et al., 2019). Probably, long term irrigation with wastewater mighty leach silt and clay particles from the top soil and consequently develop macro-pore network connection (Leuther et al., 2019). Thus, there is no wonder to find out the values of soil hydraulic conductivity (the measure of a soil ability to transmit water) seemed to be relatively high when compared with the values estimated by Davie (2008) for the sandy loam (2.59 cm h^{-1}), clay loam (0.23 cm h^{-1}) and clay (0.06 cm h^{-1}) soils. These results probably bring to light the presence of indirect discharges through hydraulic conductivity between the wastewaters used for irrigation and nearby lands that were irrigated using Fresh Nile water. Accordingly, we partially accept the first hypothesis.

TABLE 3. The parameters used to estimate the suitability of water for irrigation

	New Salhia				ElSaff	Meet Kenana		
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Winter season								
EC	C2	C4	C4	C3	C3	C2	C3	C2
SAR	S1	S3	S3	S1	S1	S1	S1	S1
Mg ratio	34.29	46.62	47.32	27.5	16.14	17.19	32	23.33
RSC	2.68	-29.25	-25.9	-4.22	-5.44	-0.67	-2.78	-1.18
B-hazards	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
Summer season								
EC	C2	C4	C4	C2	C3	C2	C3	C3
SAR	S1	S2	S2	S1	S1	S1	S1	S1
Mg ratio	51.52	47.00	46.67	45.00	70.91	50.91	34.40	40
RSC	0.79	-23.32	-22.69	0.53	-4.82	1.34	-0.80	1.14
B-hazards	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Note: See footnotes of Table 1.

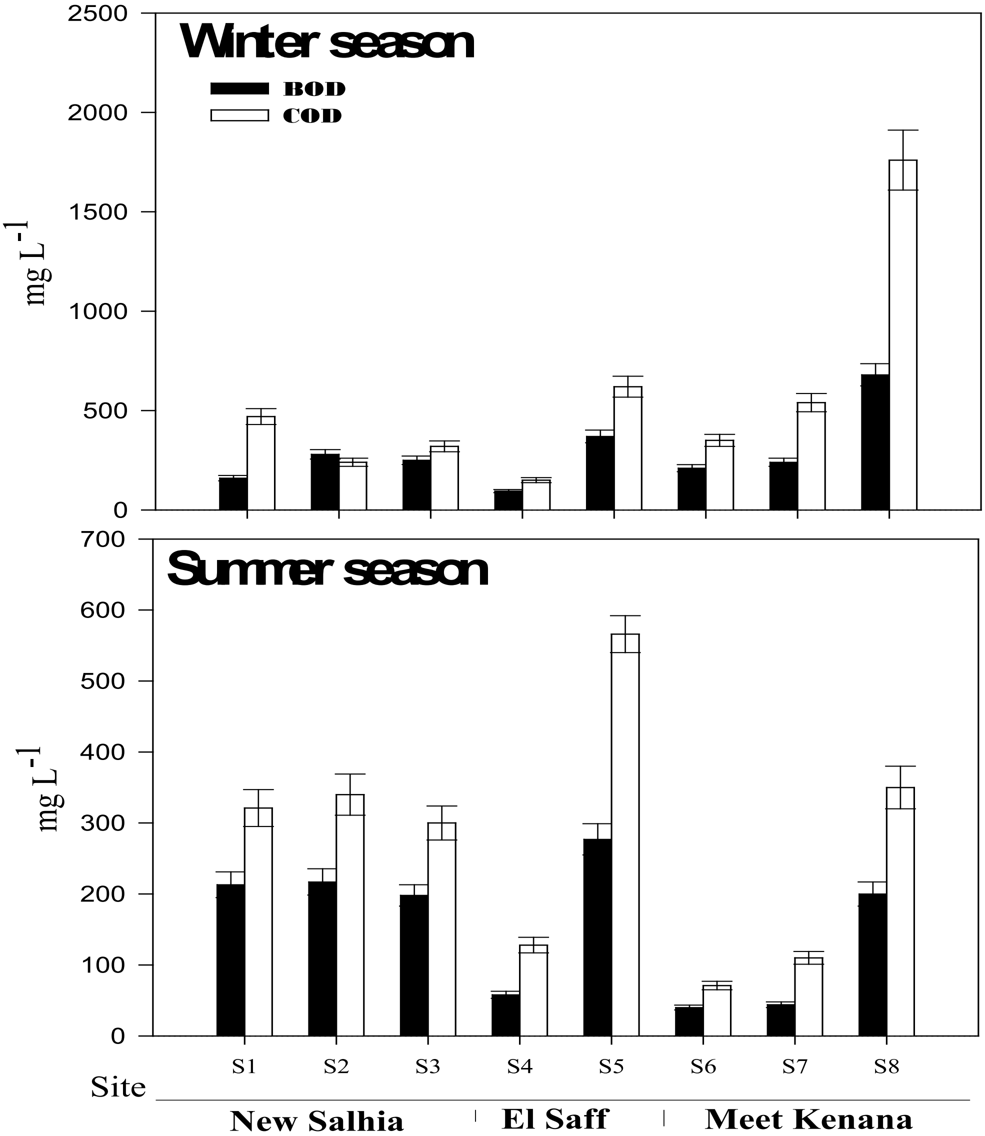

Fig 1. COD and BOD contents (means ± SD) ofthe investigated water samples (Reference level of BOD was shown by the dot-line)

PTEs in the irrigation water

Lead (Pb) content in all the collected water samples did not exceed the maximum permissible level (MPL= 5 mg L^{-1} adopted by FAO (1994) during the two seasons of study. Likewise, Co and Cd contents did not exceed the permissible levels (0.05 and 10 mg L^{-1}, respectively) in all the studied locations (Fig. 2). Generally, the concentrations of the investigated PTEs during the summer season were relatively higher than the corresponding ones detected in winter. This might be related to the increases that occurred in the evaporation rate from the water bodies during the summer season compared with that occurred during the winter season. It is worthy to mention that the concentration of Ni did not exceed MPLin water (MPL=0.2 mg L^{-1}) during the winter season; yet pronounced increases occurred in concentrations of Ni during the summer season. Such increases exceeded the MPL in only the location of New Salhia which is irrigated with underground water.

PTEs in the investigated soils

AB-DTPA extractable contents in soil

Figure 3 reveals that the concentrations of AB-DTPA extractable Pb and Co in the soil of New Salhia,which was irrigated with the fresh Nile water, were the highest among the investigated locations during the winter and summer seasons. Likewise, AB-DTPA extractable concentrations of Ni and Cd in such a soil were relatively high during the summer season only. Probably, many agricultural practices, *i.e.* chemical fertilizers enriched the soil with PTEs (Abdelhafez et al., 2012). Moreover, the retention capacity of PTEs in such a soil seemed to be relatively low probably because the summation of silt and clay contents in this soil did not exceed 2% (see Table 1). On the other hand, the organic content in irrigation water (as displayed by BOD and COD), in both sites of New Salhia soil which were irrigated with either the groundwater or wastewater, might increase the retention capacity of PTEs in soil forming less available fractions of PTEs in soil (Abbas and Bassouny, 2018). Generally the concentrations of AB-DTPA extractable Pb, Ni and Cd were higher in summer than in winter. This might occur because PTE contents in irrigation water were higher in summer than in winter. It is worthy to mention that the variations in AB-DTPA extractable PTEs seemed to be appreciable among the studied locations during the two successive (winter and summer) seasons. Accordingly, this fraction could not be used solely to express the phytotoxicity of PTEs in soil, and the total content of these metal ions should be included to indicate their potential hazards. In this concern, many factors e.g. soil organic matter may be incorporated in building up less labile fractions of PTEs in soil (Abbas and Bassouny, 2018; Mohamed et al., 2018).

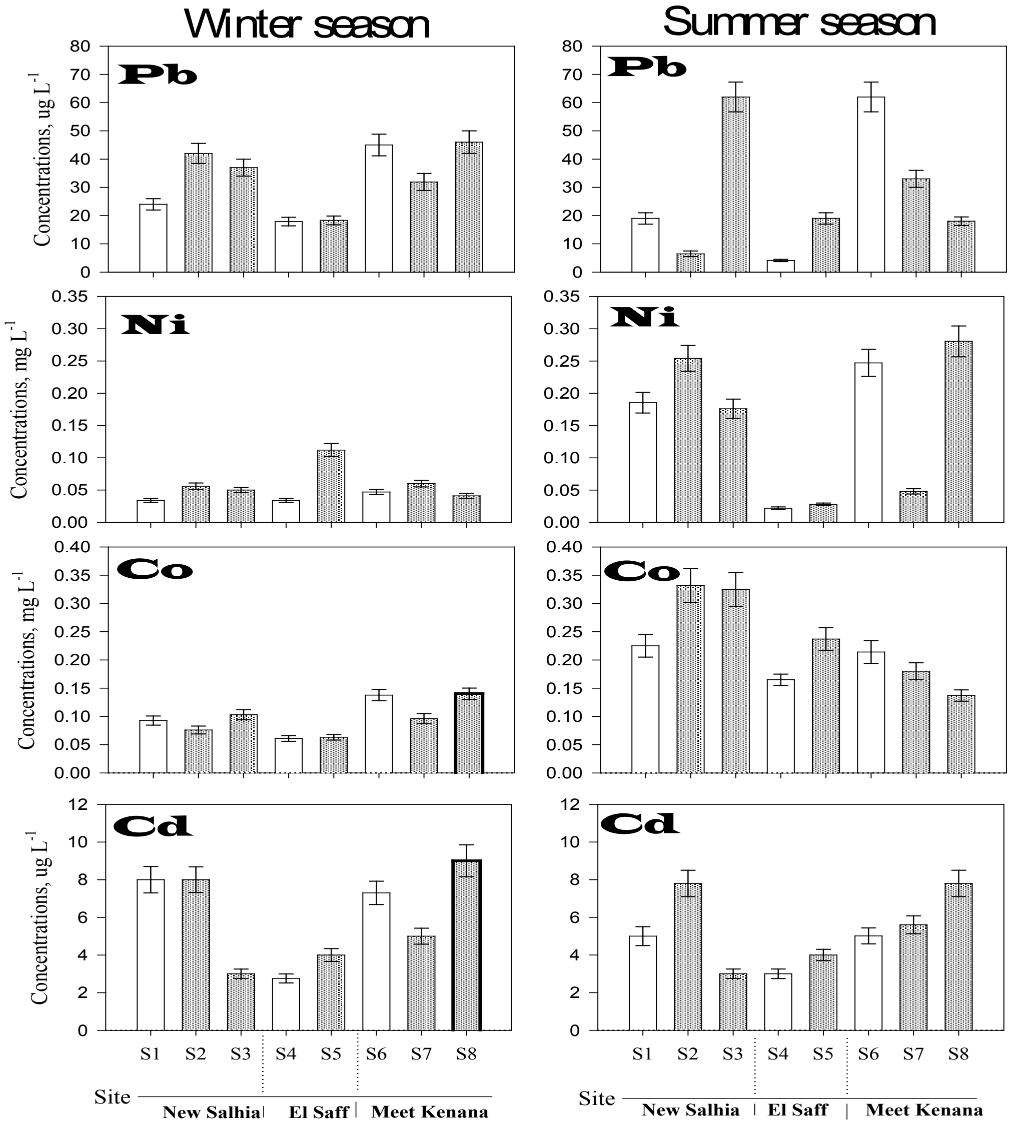

Fig. 2. Concentrations of PTEs (means ± SD) in the investigated water samples (Reference maximum acceptable level (MAL) was shown by the dot-line) .

See footnote Table 1.

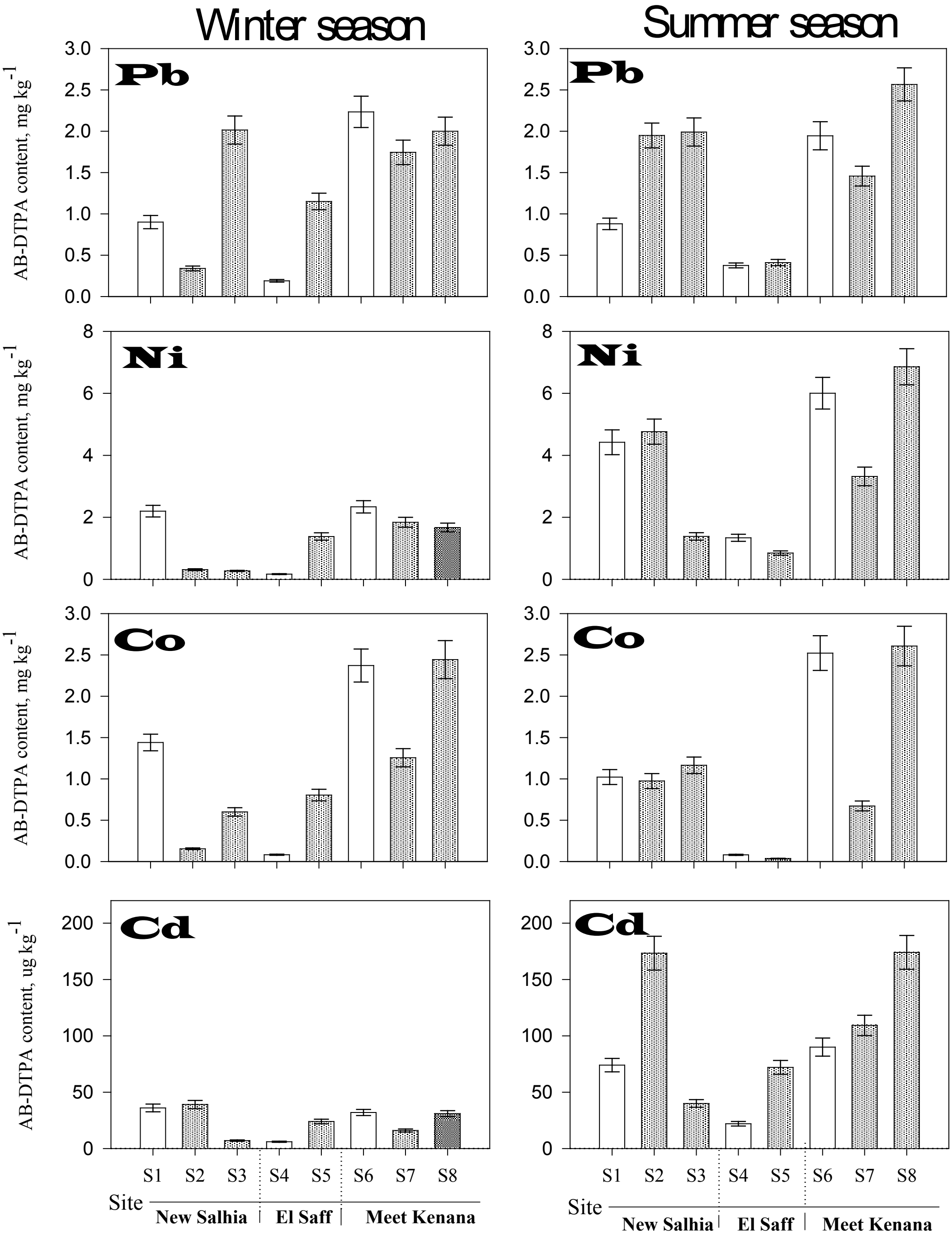

Fig. 3. AB- DTPA-extractable PTEs (means ± SD) in the investigated soil (see footnote Table 1).

Total contents of PTEs in soil

Concentrations of PTEs in the investigated soils did not vary notably between the two studied seasons (variations between the winter and summer values seemed to be low). Thus, the average concentrations of PTEs in soils (during the two seasons of study) were calculated and then presented graphically (Fig. 4). Generally, the total concentrations of PTEs in soil stood below the permissible levels as recommended by Kabata-Pendias (1995), *i.e.* Pb= 100 mg kg^{-1}. Ni= 100 mg kg^{-1}, Co=50 mg kg^{-1}, Cd, 3 mg kg^{-1}. Accordingly, total PTEs in soil might not posses any potential hazards for the growing plants.

Correlation studies were then conducted to investigate the relationships between PTEs contents in irrigation water and the corresponding concentrations in soil (total and AB-DTPA extractable concentrations) and the calculated "r[2]" values are presented in Table 4. Generally, the concentrations of PTEs in water were significantly correlated with the AB-DTPA extractable-fractions in soil (except for Ni and Co during the first season only). Likewise, AB-DTPA extractable-PTEs were significantly correlated with their total contents in water (except Ni during the winter season only). Such results probably indicate that the irrigation water enriched soils with PTEs and, at the same time, controlled their availability in soil. With time, these available concentrations of PTEs changed into less labile forms; hence, increases the total contents of PTEs in soil. Therefore, we accept the second hypothesis.

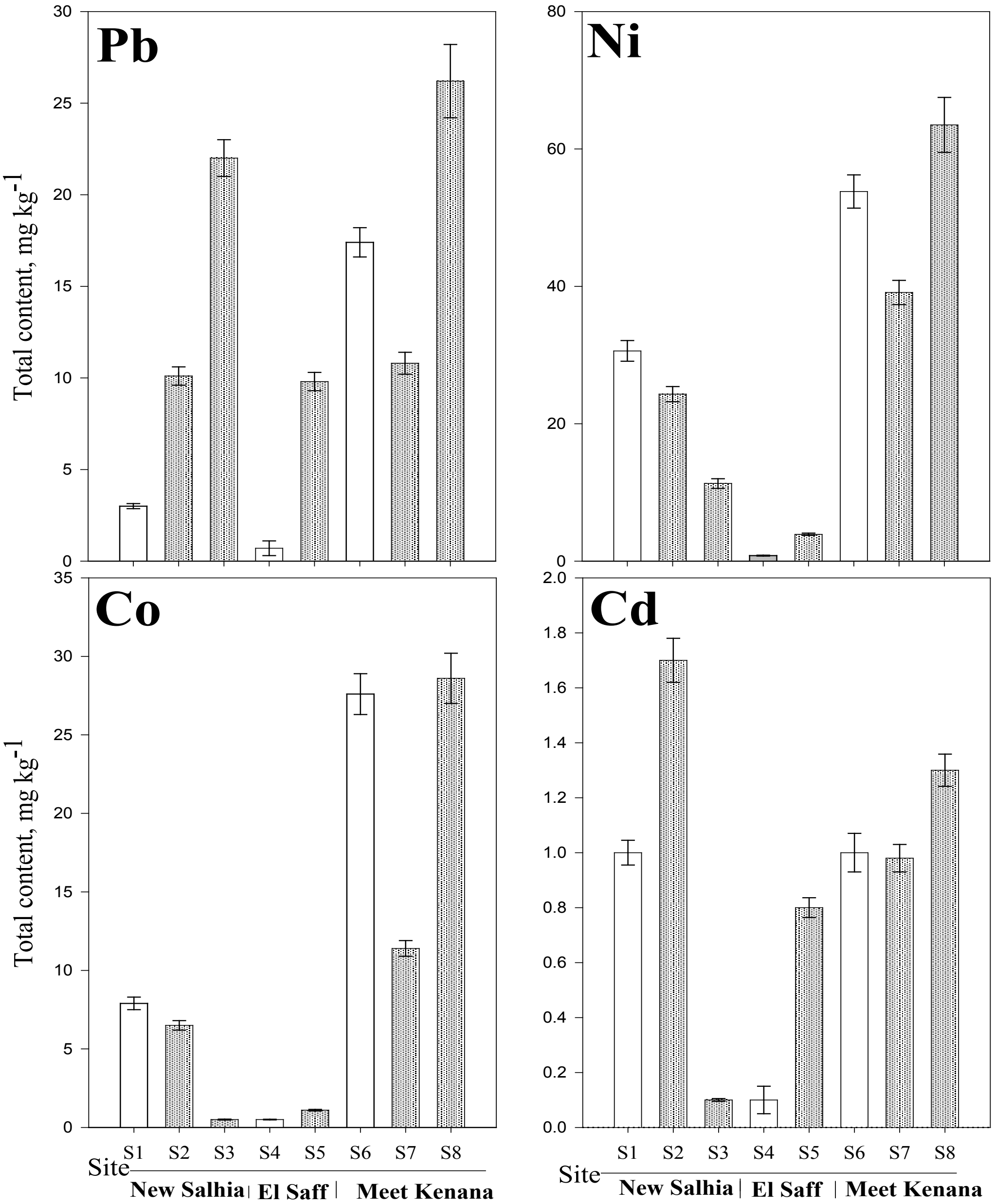

Fig. 4.Total concentrations of PTEs in the investigated soil (the average of two seasons±SD)
See footnotes of Table 1.

TABLE 4. Coefficient of determination “r^2” values calculated for the relations between PTEs content in soil and water

	Winter season			Summer Season		
	PTEs content in water	AB-DTPA-PTEs	Total-PTEs in soil	PTEs content in water	AB-DTPA-PTEs	Total-PTEs in soil
Lead, Pb						
PTEs content in water						
AB-DTPA-PTEs	0.818*			0.972**		
Total-PTEs in soil	0.558	0.811*		0.781*	0849**	
Nickel, Ni						
PTEs content in water						
AB-DTPA-PTEs	0.017			0.823*		
Total-PTEs in soil	0.682	0.353		0.679	0.927**	
Cobalt, Co						
PTEs content in water						
AB-DTPA-PTEs	0.517			0.963**		
Total-PTEs in soil	0.483	0.911**		0.956**	0.956**	
Cadmium, Cd						
PTEs content in water						
AB-DTPA-PTEs	0.907**			0.987**		
Total-PTEs in soil	0.862**	0.892**		0.931**	0.917**	

Note: ** Correlation is significant at the 0.01 level (2-tailed).* Correlation is significant at the 0.05 level (2-tailed).

Concentrations of PTEs within the different parts of the grown plants

Concentrations of the investigated PTEs were estimated in both shoots and grains/fruits of the plants grown at the same locations of water and soil sampling for two successive seasons and the results are presented in Fig. 5. The common crop cultivated in winter was wheat; while the common crop cultivated in summer was maize. Egg plant and leak were also grown at “S2” and “S7” locations (respectively) in summer, while pepper was grown only at S1 location in winter. Generally, the concentrations of PTEs within shoots of the same plants seemed to be comparable among the different locations (varying in the contamination levels); however, these concentrations varied noticeably from one crop to another. This probably indicates that plants have low affinity to absorb PTEs from soil. It is worthy to mention that the normal concentrations of PTEs in plants grown on uncontaminated soils ranged from 0.1 to 10 mg Pb kg^{-1}, 30-40 mg Co kg^{-1}, 10- 100 mg Ni kg^{-1}, 5 to 30 mg Cd kg^{-1} plant (Kabata-Pendias and Pendias, 2001). The results obtained herein exceeded the normal levels of Pb in plant shoot; however, these values remained within the normal range of Ni and Cd. On the other hand, pepper plants grown on the Nile irrigated soil of New Salhia accumulated the highest concentrations of PTEs within their fruits. This indicates high potentiality of the contaminants to enter the food chain through ingestion (Abdelhafez et al., 2015;Hashim et al., 2017;Thatai et al., 2019). According to the JOINT FAO/WHO Food Standards (2011), the maximum acceptable levels for contaminants and toxins in foods should not exceed 0.2 mg Pbkg^{-1} and 0.2 mg Cd kg^{-1}. Our results exceeded these permissible levels and therefore, we partially accept the third hypothesis.

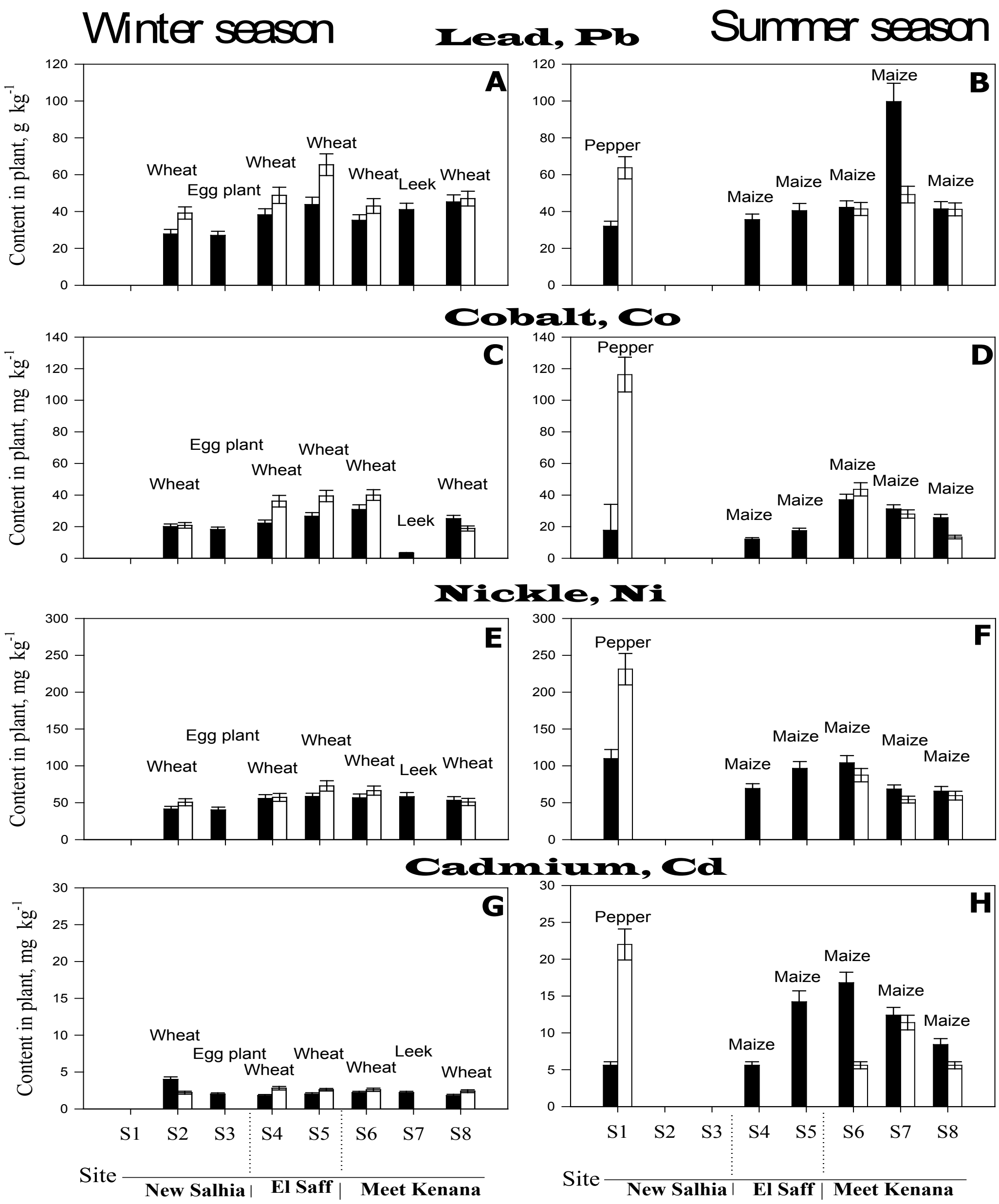

Fig. 5. Concentrations of PTEs in plants (means ± SD) collected from the investigated soils for two successive seasons. See footnotes of Table 1.

Conclusion

Many farmers are forced towards using low quality water for irrigating their lands; however, these waters mayalsobring many contaminants to soils. It is thought that the phytotoxicity of PTEs in soil is mainly attributed to the available concentrations of PTEs in soil rather than the total contents; even so, many agricultural practices change temporarily the available fractions of PTEs in soil e.g. application of the organic amendments. Thus, it is acceptable to consider the total contents of PTEs as well to indicate the phyto-toxicity of PTEs in soil. Results obtained herein also indicate that the irrigation water is the primary factor affecting the available fractions of PTEs in soil. These fractions build up, in turn, the total concentrations of PTEs in soil. Moreover, considerable concentrations of PTEs find their ways to the underground water; hence, contaminate the nearby landsthat are irrigated with the Fresh Nile water. Accordingly, PTEs transferred to the edible parts of the grown plants and possessed potentially ecological hazards. Thus,precautions should be followed while using these low quality waters for irrigation especially with the loss of ability of the fresh water canals to "self-purify waters due to the disturbances of fresh water continuity".

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التداعيات الغير مباشرة للري باستخدام مياه منخفضة الجودة علي سلامة البيئة

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يعتبر الري باستخدام مياه منخفضة الجودة (العادمة) أحد أهم الاسباب التي تؤدي إلي تلوث التربة بالعناصر محتملة السمية، خصوصا في المناطق الجافة وشبه الجافة، والتي تستخدم مثل هذه النوعية من المياه كمصدر وحيد لري أراضيها، وفي المقابل يعتمد اغلب المزارعين علي الصرف الطبيعي غير الكفء للتخلص من المياه الزائدة، وبالتالي تظهر احتمالية وجود اتصال هيدروليكي مستمر أو متقطع بين المياه الجوفية في الارض التي تروي بمياه منخفضة الجودة، والاراضي المجاورة لها، والتي يتم ريها بمياه النيل، وقد يمتد هذا الاتصال الهيدروليكي ليشمل مصدر مياه الري العذبة نفسها، وبالتالي تضح أهمية الدراسة من الناحية البيئية في التحقق من فروض الدراسة التالية، الفرض الاول: يحدث تسريب أرضي للمياه منخفضة الجودة التي تستخدم في الري، ويصل هذا التسريب إلي المياه العذبة التي تروي الاراضي المجاور منها، مما تؤثر سلباً علي خواص المياه العذبة، الفرض الثاني: تركيز العناصر محتملة السمية في المياه هي العامل الاساسي المحدد للمستويات الكلية والميسرة للعناصر محتملة السمية في التربة، والفرض الثالث: تركيز العناصر محتملة السمية في الجزء المأكول من النباتات النامية في الاراضي القريبة من تلك المروية بالمياه العادمة تعتبر مرتفعة نسبيا، وغير صالحة للاستخدام، وللتحقق من صحة هذه الفروض، فإنه تم جمع عينات مياه، وتربة ونبات من ٣ محافظات مختلفة وهي الصالحية الجديدة (الشرقية)، والصف (الجيزة)، وميت كنانه (القليوبية)، بحيث تشمل العينات التي تم جمعها من كل محافظة، عينة مروية بالمياه العذبة والباقي يتم ريه إما بمياه العادمة أو المياه الجوفية (من ابار غير عميقة)، وقد اظهرت النتائج ان المياه العذية تعتبر رتبة ثانية اعتمادا علي مقياس الملوحة بها، بينما باقي مصادر المياه تعتبر عالية أو عالية جدا في ملوحتها، ومن منظور الصودية فلم تتعدي SAR في معظم عينات المياه "١٣"، كما اظهرت نتائج كل من قيم BOD و COD في مياه النيل قيم قريبة من تلك المتحصل عليها في المياه الجوفية أو المياه العادمة المستخدمة في الري، ومما سبق يتضح صحة الفرض الاول جزئيا، كما اظهرت النتائج أن تركيز الرصاص، والكوبلت والكادميوم في عينات المياه موضع الدراسة لم يتعدي الحدود المسموحة، ولكن تعدي تركيز النيكل الحدود المسموحة بها فقط في منطقة سهل الصالحية الجديدة في موسم الصيف، هذا وقد اظهرت النتائج أيضا وجود ارتباطات معنوية بين التركيزات الميسرة للعناصر المحتملة السمية في التربة والتركيزات المقابلة لها في مياه الري، كما ارتبطت هذه التركيزات الميسرة بالتركيزات الكلية في التربة، ومما سبق يتضح صحة الفرض الثاني، وتشير النتائج ايضا إلي أن تركيزات بعض العناصر محتملة السمية في الاجزاء المأكولة من النبات حتي تلك التي تم تروي بمياه النيل تعدت الحدود المسموح بها، وبالتالي يتم قبول الفرض الثالث جزئيا وبالتالي نستنتج أن استخدام مياه منخفضة الجودة في الري ذات مخاطر محتملة علي نوعية الغذاء المتحصل عليه في المناطق القريبة حتي إذا تم ريها بالمياه العذبة.