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Risk Assessment of Trace Elements Toxicity Through Contaminated Edible Plants from Polluted Irrigation Canal at Giza Governorate, Egypt

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ABSTRACT

To assess the leakage of sanitation service in urban areas on the contamination of water streams and soil besides, a risk assessment study was conducted through the intake of edible plants from polluted irrigated suburban area of El-Zomor area, Egypt. The results revealed that concentrations of trace elements were several folds higher in the studied site compared to the background level in the earth crust indicating that the soil of the studied area is contaminated with heavy metals. Therefore, contamination factor (CF) values of this area indicate that soils were considerably contaminated with Cd, moderately contaminated with Co, Cu, Pb and Mn, but showed signs of low contamination with other metals. Enrichment factor (EF) indicating that moderate enrichment of Cu and very significant enrichment for Cd were contributed to anthropogenic source. To assess the health risk, estimated exposure and risk index were calculated. For the non-carcinogenic risk, the studied elements were not found to cause any risks to the local population, since the hazard index (HI) for studied trace elements were lower than the safe level. The level of cancer risk associated with exposure to these elements falls within the range of safe limits (10^{-4}–10^{-6}) so we consider the risk is unacceptable.

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INTRODUCTION

Egyptian urban coverage with improved sanitation gradually increased from 45% in 1993 to 56% in 2004, reached 100% in urban and 40 % in rural areas by the end of 2012 [1]. The low coverage in rural sanitation, in combination with a sub-optimal treatment results in serious problems of water pollution and degradation of health conditions. That is due to the majority of villages and rural areas discharge their raw wastewater directly into the waterways which is used as an irrigation source.

Long term waste water irrigation may lead to accumulation of trace elements in agricultural soils and plants. Food safety issues and potential health risks make this as one of the most serious environmental concerns [2]. Vegetables accumulate heavy metals in their edible and non edible parts. Although some of the heavy metals such as Zn, Mn, Ni and Cu act as micro-nutrients at lower concentrations; they become toxic at higher concentrations. Health risk due to heavy metal contamination of soil has been widely reported [3-5]. Intake of vegetables is an important pathway of heavy metal toxicity to human being [6]. El-Zomor district considered one of the most rural areas discharge their raw wastewater directly into the waterways which is used as an irrigation source.

The present work deals with the quantification of trace elements concentrations in soil at a suburban area of El-Zomor; a medium sized city of Egypt. The mentioned city having long term uses of treated and untreated sewage water which is used for irrigation. Furthermore, distribution of these elements within the different parts of the plants grown therein was also investigated. Since soil contamination with trace elements can influence human health through different mechanisms, i.e., ingestion (either deliberate or involuntary), inhalation and dermal absorption. Therefore, human health aspects of the investigated trace elements therein will be under study.

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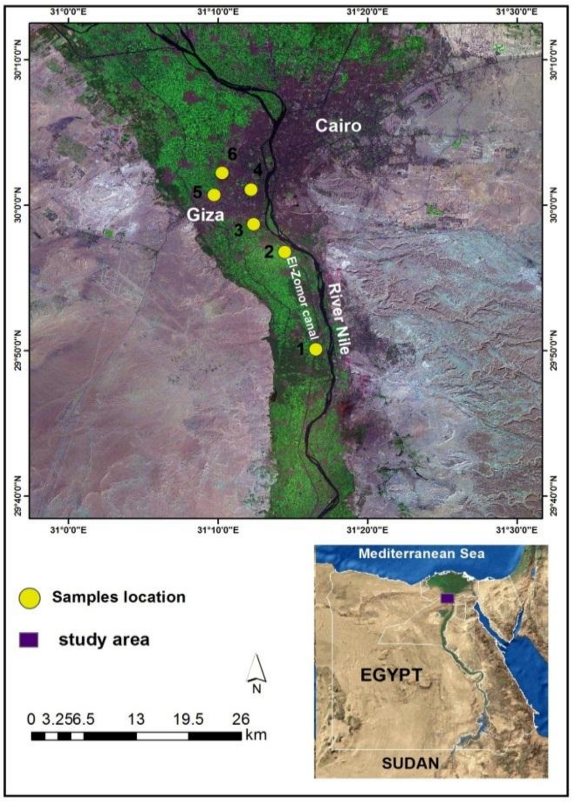

Figure 1. Map of the studied area showing samples location.

MATERIALS AND METHODS

Site description

The experimental site covers the area of El-Zomor area, a medium sized city at Giza governorate (29˚ N latitude, 31˚ E longitude), Egypt (Figure. 1). The city having long term uses of polluted water with untreated sewage water which is used for irrigation from El-Zomor canal. Due to lack of sanitation service in this area, so much urban areas discharge their effluents along with El-Zomor canal. Also, effluents from various small scale industries situated in the city are also discharged along with El-Zomor canal. Large-scale vegetable production is conducted in this area, largely to supply markets in the city.

Soil, water and plant sampling

Soil samples from agricultural farms were collected by an auger using a plastic scooper. Non soil particles (e.g. stones, wooden pieces, rocks, gravels, organic debris) were removed from soil. Soil was air dried, oven dried and this dried soil was sieved through a <0.2 mm sieve and stored in the labeled polythene sampling bags [7].

Water samples that were used for irrigation practices were collected from each site (Fig. 1) in pre cleaned high-density polyethylene bottles. These bottles were rinsed earlier with a metal-free soap and then soaked in 10% HNO_3 overnight. Finally, washed with deionized water [8]. Samples were brought to the lab in ice tank and stored at 4 °C until analysis. Surface sediment samples were collected using a grab sampler for the bottom sediments.

A diversity of vegetables and cereal crops grown in the study area; maize (Zea Maize) and wheat (*Triticumaestivum* L.) as cereal crops, cabbage (*Brassica oleracea var. capitata*), cauliflower(*Brassica oleracea. Botrytis* L.), lettuce (*Lactuca sativa*), watercress (*Nasturtium officinalle*), malva (*Malvaporviflora* L.) and onion (*Allium cepa*) as a vegetable crops were collected from different sites of the sampling zone in 3–5 replicates and stored in labeled polythene sampling bags and brought to the lab, where they were harvested in edible and non-edible parts. Finally the vegetable samples were washed with tap water to remove any kind of deposition like soil particles. Edible parts of vegetables were then oven dried and ground into powdered form for making the plant digests [9].

Trace elements analysis

For trace elements extraction, 1 g dried sample of soils, sediment or plant were digested in 15 mL of HNO_3, $H_2SO_4$and $HClO_4$ mixture (5:1:1) at 80 ºC until a transparent solution was obtained [10]. Water samples (50 mL) were digested with10 mL of concentrated HNO_3 at 80 ºC until the solution became transparent [11]. The setransparent solutions were then diluted to 50mL with distilled water and filtered through filter paper, Whatman number 42. The concentrations of Cd, Co, Cu, Cr, Pb, Mn, Ni and Zn in the filtrate were determined by using inductively coupled plasma (ICP-JY ULTIMA). Low concentration elements were determined using atomic absorption spectrometry (Perkin Elmer 3300) with hydride generator equipped with graphite ferns. The recovery percentages for the studied elements ranged from 94 to 107% which ensured high precision for chemical analysis. Most of the chemicals used in this study were analytical grade, and mostly obtained from the Merck Company (Darmstadt, Germany).

Data analyses

Contamination Factors, Degree of Contamination, Modified Degree of Contamination and pollution load index were evaluated for risk assessment. In the present study, the contamination factor (CF) and the degree of contamination (Cd) are used to determine the contamination status of soil [12]. The contamination factor is calculated according to the Equation 1.

$$CF = \frac{\text{Measured concentration}}{\text{Background concentration}} \quad (1)$$

Modified degree of contamination (mCd) was defined as the sum of all contamination factors [13] and calculated as below:

$$mCd = \sum_{i=1}^{i=n} CF \quad (2)$$

Calculated contamination factor (CF) and degree of contamination (mCd) for this study is defined. The pollution load index (PLI), proposed in literature [14] was calculated based on following equation.

$$PLI = (CF1 \times CF2 \times CF3 \times ..... \times CFn)^{1/n} \quad (3)$$

The PLI is able to give an estimate of the metal contamination status and the necessary action that should be taken.

Enrichment factor (EF)

The enrichment factor was calculated using the formula was originally introduced by Buat-Menard and Chesselet [15] as shown in Equation 4.

$$EF = \frac{C_m / C_{Background}}{Fe_m / Fe_{Background}} \quad (4)$$

where C_m (sample) is concentration of the examined chemical element in the examined environment, $C_{Background}$ (sample) is the worldwide background concentration of the examined chemical element, Fe_m is the concentration of the reference chemical element in the examined environment and $Fe_{Background}$ is the worldwide background concentration of the reference element. Iron (Fe) was used as a reference metal because of its high abundance in soil and the fact that it mainly originates in soil from the earth crust [16]. The significance of EFs values are outlined according to literature [17] as follows:

EF≤2 indicates that the predominant source of element is the earth crust, 2<EF>5 moderate enrichment from another source rather than the earth crust such as human

Activities, 5>EF≤20 very significant enrichment, 20>EF ≤40 very high enrichment and EF>40 refers to severe enrichment factor.

Human health risk assessment

To assess the human health risk of heavy metals, it is necessary to calculate the level of human exposure to that metal by tracing the route of exposure of pollutant to human body. There subsist many exposures routes for heavy metals that depend upon a contaminated media of soil and vegetables on the recipients. Receptor population use the vegetables enriched with higher concentration of heavy metals which enters the human body leading to health risks [18]. In the present research work vegetables grown at the wastewater irrigated area were collected and their metal concentration was used to calculate the health risk index (HRI). Value of HRI depends upon the daily intake of metals (DMI) and oral reference dose (RFD). RFD is an estimated per day exposure of metal to the human body that has no hazardous effect during life time[2].

Exposure assessments

The daily metal intake (DMI), dermal absorbed dose (DAD), and exposure concentration (EC) were estimated to assess the risks posed by the studied trace elements in soil and plants collected from the studied area via ingestion, dermal contact, and inhalation pathways according to the human health evaluation manual (Part A) and supplemental guidance for dermal and inhalation risk assessments (Part E and F)[3]. The equations were as follows:

DMI soil and plants ingestions = ((C× IngR)/BW) × ((EF × ED)/ AT) × Cf (5)

DAD dermal= ((C×SA×SL×ABS)/BW) / ((EF×ED)/AT) × Cf (6)

EC inhalation = ((C× EF × ED)/ ATn) × Cf_{inh} (7)

where C is the metal concentration of media (soil or plants) (mg/kg), IngR is the ingestion rate per unit time (mg/day), ED is the exposure duration (years), EF is the exposure frequency (days/year), BW is the humans bodyweight (kg), AT is the averaging time(days), SA is the surface area of contact (cm^2), SL is the skin adherence factor ($mg/cm^2/h$), ABS is the absorption factor (unit less) and Cf is the conversation factor (10^{-6} kg/mg). ATn is the average time (hours) and Cf_{inh} is the conversation factor of 3.5×10^{-4}, which was used to estimate the average concentrations of trace elements per unit volume of the air based on the air quality guideline [25]. The inputs used in this study are representative of the Egyptian population from the previous studies and the USEPA.

All parameters used in the calculation of DMI, DAD, and EC were obtained from the USEPA [24] reports published during different periods.

Non-cancer and cancer risk assessments

The obtained DMI, DAD, and EC values were used to quantify the hazard quotient (HQ) separately for each metal; consequently, the health risk index (HRI) was calculated. In addition, the carcinogenic risks (CR) were calculated for appropriate media and pathways. HQ and carcinogenic risks (CR) in soil and plants via ingestion,

[2] <http://www.epa.gov/iris/substS>.
[3] http://www.epa.gov/oswer/riskassessment/human_health_exposure.htm.

dermal contact, and inhalation were calculated as follows:

$$HQ = (DMI/ RfDo) = (DAD/ (RfDo \times GIABS) = EC/ (DfCi \times 1000\ \mu g mg^{-1}) \quad (8)$$

$$HRI = \sum HQ \quad (9)$$

$$CR = DMI \times SFo = DAD \times (SFo/GIABS) = IUR \times EC \quad (10)$$

where RFDo is the oral reference dose (mg/kg/day), RFCi is the inhalation reference concentration (mg/m), SFo is the oral slope factor and IUR is the inhalation unit risk (μg/m). The values of SFo, RFDo, RFCi, GIABS, and IUR were obtained from the USEPA website [25, 26]. A HRI below one indicates that there is no significant hazard of non-carcinogenic effects. Conversely, an HRI above one indicates that there is a chance of non-carcinogenic effects occurring [24]. The total cancer risk for each metal was calculated for each exposure pathway, and compared with the maximum acceptable risk of 1E-06 to 1E-04 as suggested by USEPA [27]. The values of the parameters used for the above mentioned calculations representative of Egyptian population from the previous studies and USEPA, and are given in Tables 1 and 2.

TABLE 1. Input parameters to characterize the ADD and HI values.

Parameter	Description	Value		Unit
		Adults	Children	
C	Contamination concentration in media			
IR	Ingestion rate per unit time			
	Soil	100	200	mg day-1
	*Zea Maize	184.4	92.2	g day-1
	*Wheat	369.9	185	g day-1
	*Onion	46.3	23.15	g day-1
	*Vegetables	76.4	38.2	g day-1
EF	Exposure frequency	180		day year-1
ED	Exposure duration	30	6	years
BW	Body weight	70	15	kg
AT	Average time – non cancer risk	ED*365		Days
	Average time – cancer risk	70*365		
SL	Skin adherence factor	0.2	0.2	mg cm-2 h-1
SA	Exposure skin area	3300	2800	cm2
ABS	Dermal absorption factor	0.001 for Cd 0.01 for other elements		Unit less
ET	Exposure time	24		hours day-1
ATn	Average time – non cancer risk	ED*365*24		Hours
	Average time – cancer risk	70*365*24		

Data obtained from USEPA[4], Lee, et al. [19]and Zheng, et al. [20], * EAS,

TABLE 2. Toxicity parameters used to investigate the non-cancer and carcinogenic risks.

Element	SF0 mg $kg^{-1}day^{-1}$	IUR, $(ugm^3)^{-1}$	RFDo, $mgkg^{-1}day^{-1}$	RFCi, mg m^3	GIABS	ABS
Cd		1.8E-03	1.0E-03	1.0E-05	0.025	0.001
Co		-	3.0E-04	6.0E-06	1	0.01
Cr		9.0E-03	*3.0E-03	*2.9E-05	0.013	0.01
Cu		-	4.0E-02	-	1	0.01
Pb	0.28	8.0E-05	*3.5E-03	-	1	0.1
Mn		-	1.4E-01	5.0E-05	1	0.01
Ni		2.4E-04	1.1E-02	1.4E-05	0.04	0.01
Zn		-	3.0E-01	-	1	0.01

Data obtained from USEPA[5]; *Data obtained from Ferreira-Baptista and De Miguel [21]

[4] http://www.epa.gov/ncea/pdfs/efh/front.pdf>

[5] http://www.epa.gov/oswer/riskassessment/human_health_exposure.htm
http://www.epa.gov/air/criteria.html
http://www.epa.gov/region9/superfund/prg/index.html
http://www.epa.gov/reg3hwmd/risk/human/rb-concentrationtable/usersguide.htm.

RESULTS AND DISCUSSION

Concentration of trace elements in soil of the studied area

Total content of the trace metals in surface soil of the studied area are illustrated in Table 3. Although, the total concentration of trace elements in soil of the studied area were lower than the permissible limits according to European Union standards (http://ec.europa.eu/environment/waste/studies/pdf/heavymetalsreport.pdf), while comparing these concentrations of trace elements with the background level in the earth crust indicating that the soil of the studied area are contaminated with these metals. Cd, Co,Cu, Pb and Mn recorded higher concentration values than the background levels of earth crust indicating considerable inputs of these metal ions in the surface soil. This might be attributed to accumulation of these metals during long period using this kind of water. Also, excessive mineral fertilization addition which commonly contains considerable quantities of these elements had led to accumulation of these metals in soil [22].

Concentration of trace elements in plants of the studied area

Trace elements concentrations varied among different plants (Table 4), which might be attributed to differential absorption capacity of test vegetables and crops for different elements [23]. The average of total concentration of different vegetables (lettuce, watercress, cauliflower, malva and cabbage) was higher than the concentration of other crops with the exception of wheat. The variations in trace elements concentrations in vegetables/cereals may be ascribed to the differences in their morphology and physiology for elemental uptake, exclusion, accumulation and retention [25]. Sinha *et al.* [26] have also found lower concentrations of the heavy metals in cereal crops as compared to leafy and non leafy vegetables grown in wastewater irrigated areas. Among metal concentrations in vegetables and maize grown at the studied area, the trend appeared as Zn>Mn>Cu>Pb>Ni > Cr>Co>Cd while in wheat crops grown at the same area the trend appeared as Zn>Pb>Mn> Ni>Cr>Cu> Co> Cd. The concentrations of metals were compared to permissible limits of EU commission regulation [27]; it was found that Cd, Cr, Pb and Zn concentrations were higher than in all the vegetables and cereal crops; whereas Cu concentration was higher than the safe limits in vegetables. The present concentrations of Cd and Pb were higher than in all the vegetables and wheat crops when compared with safe limits given by EU commission regulation [27], while Mn and Co showed lower concentrations than the permissible ones.

Cadmium and Pb are non-essential metals causing adverse health effects even at very low concentrations [27]. Zhuang *et al.* [28] have also found higher concentrations of Cd and Pb than the permissible limits in vegetables.

Concentration of trace elements in irrigated water of the studied area

The concentrations of heavy metals in the irrigation water at study sites ranged between 0.0002–0.0005 for Cd, 0.00015-0.0009 for Co, 0.0005–0.0011 for Cr, 0.012–0.016 for Cu, 0.003–0.004 for Pb, 0.004-0.16 for Mn, 0.00–0.00065 for Ni and 0.008–0.09 mg/L for Zn during one year samples collection, whereas the studied sites, trace elements concentrations in irrigation water were very low or below the detectable limits set by FAO [29] (Table 5). Although, trace elements in water samples recorded low concentrations values as compared with critical levels, high concentration values of these elements were found in sediment samples for the same locations. This was attributed to the clay texture of the sediment which can accumulate excessive amounts of elements on the surface.

TABLE 3. Total content of trace elements in soil of the studied area (mg/kg).

Site	Cd	Co	Cr	Cu	Pb	Ni	Mn	Zn
Site 1								
Mean	2.55	49.34	42.86	58.3	25.23	47.61	606.31	110.8
(Min – Max)	(1.9 – 3.5)	(25.75 – 85.2)	(45.7 -51. 5)	(7.1 – 55.85)	(27.5 – 94.9)	(35.4 – 51.6)	(567 – 651.9)	(90.6 -128.8)
S.D	0.6	22.06	6.33	46.25	19.46	2.33	31.19	14.08
Site 2								
Mean	2.29	35.99	41.38	60.83	26.58	50.19	723.43	125.76
(Min – Max)	(2.1 – 2.5)	(23.7 – 55.64)	(45.5 – 58.34)	(16.53 – 39.4)	(55.5 – 71.33)	(33.2 – 52.3)	(640 – 821.7)	(102.1 -151.2)
S.D	0.92	18.2	18.02	44.18	13.19	20.57	295.1	52.68
Site 3								
Mean	1.73	21.34	34.86	73.9	46.93	43.54	721.85	119.83
(Min – Max)	(1.4 -2.00)	(19.9 – 23.15)	(40.3 -48.35)	(30.1 - 58.8)	(61.53 – 86.9)	(31.9 - 39.25)	(692.3 – 799)	(107.8 -135.0)
S.D	0.72	8.6	14.16	36.25	21.48	17.62	291.49	48.72
Site 4								
Mean	1.98	23.49	40.5	77.78	48.9	50.09	824.14	129.44
(Min – Max)	(0.9 – 2.8)	(20.65 – 26.3)	(43.45 – 52.7)	(31.7 -61.9)	(58.93 – 93.1)	(35.6 - 45.2)	(792.4 – 874.0)	(111.35 – 154.5)
S.D	0.7	2.09	3.43	25.2	11.34	3.84	35.40	17.92
*Background level	0.36	14.9	122	28.7	23.9	57	646	149
EU Standard	3.0	-	150	140	300	75	-	300

*Bradford et al. [24]

TABLE 4. Total concentration of trace elements in plants of the studied area.

Plant	Cd	Co	Cr	Cu	Pb	Ni	Mn	Zn
	mg kg^{-1}							
				Maize				
(n=1)	Nd	0.05	0.45	17.6	2.65	2.3	35.3	82.85
				Wheat				
Average	0.465	1.2	8.475	7.425	55.5	8.85	24.85	151.00
S.D	0.403	1.131	10.218	4.49	77.782	1.909	25.951	175.362
				Onion				
n=1	0.10	0.10	2.1	7.2	1.01	3.5	26.6	14.8
				Vegetables				
Average	0.333	1.103	3.077	20.763	13.343	5.878	47.373	1233.465
S.D	0.185	0.864	3.152	12.931	24.935	2.697	20.55	1800.451
EU [33]	0.2	50	1	20	0.43	-	500	50

Nd: not detected

TABLE 5. Concentration of trace elements in irrigation water of El-Zomor canal.

Site	Concentration mg/kg							
	Cd	Co	Cr	Cu	Pb	Ni	Mn	Zn
				Site 1				
water	0.0002	0.00015	0.0005	0.012	0.003	Nd	0.004	0.008
Sediment	1.84	19.31	33.04	38.17	12.66	37.65	620.36	77.98
				Site 2				
water	0.0003	0.0005	0.0011	0.014	0.004	0.00007	0.008	0.013
Sediment	0.2	32.37	25.2	24.7	8.03	20.8	178.8	74.37
				Site 3				
water	0.0005	0.0009	0.0009	0.016	0.004	0.00065	0.16	0.09
Sediment	2.11	23.5	39.25	72.28	43.26	39.81	604.59	128.89
				Site 4				
water	0.0004	0.0006	0.0006	0.012	0.003	0.00036	0.06	0.046
Sediment	1.2	14.73	26.61	71.22	25.98	38.69	457.69	119.08
*Background level		13	30	20	20	38	790	70
**Standard level	0.01	0.05	0.1	0.2	5.0	0.2	0.2	2.0

*Background level of sediment [30]; **Standard level of pollution for irrigation water [29].

Contamination factor, modified degree of contamination and pollution load index of the studied soil.

The assessment of soil contamination was carried out using the contamination factor and the degree of contamination, based on four classification categories recognized by Liu *et al.* [31] whereas the modified degree of contamination (mC_d) classification and description were proposed by Abrahim and Parker [32].

The overall contamination of soils at the site, based on the CF values indicate that soils were considerably contaminated with Cd, moderately contaminated with Co, Cu, Pb and Mn, but showed signs of low contamination with Cr, Ni and Zn. In the case of modified degree of contamination, the first site of the studied soils fall under moderate contamination, while the other sites were low degree of contamination. This might be attributed for the dilution effect of pollutants along with the canal.

Pollution severity and its variation along the sites was determined with the use of pollution load index. This indexes a quick tool in order to compare the pollution status of different places [14]. The values of pollution load index (Table 6) were found to be generally high (>1). These confirmed that long term uses of polluted water might be excess the accumulation amounts of heavy metals in the soil irrigated.

Enrichment factor

A common approach to estimating anthropogenic impact on water and sediments is to calculate a normalized enrichment factor (EF) for metal concentrations above uncontaminated background levels. EF values ranging between 0.1 and 2 can be considered in the range of natural variability, whereas ratios greater than 2 indicate some enrichment corresponding mainly to anthropogenic inputs. The significance of EFs values which outlined according to Faiz *et al.* [17] indicating that moderate enrichment of Cu and very significant enrichment for Cd was from another source rather than the Earth crust such as human activities (Table 7). While the EFs obtained for other metals reveals that these elements are depleted in some of the phases relative to crustal abundance in the study area.

TABLE 6. Contamination factors, degree of contamination, modified degree of contamination and pollution load index of the studied area.

Site	Contamination factor (CF)								Contamination degree	Modified degree of contamination	Pollution load index
	Cd	Cr	Co	Cu	Pb	Ni	Mn	Zn	C_d	mC_d	PLI
Site 1	7.08	0.35	3.311	2.03	1.055	0.835	0.939	0.744	16.35	2.044	1.29
Site 2	6.35	0.34	2.42	2.12	1.112	0.88	1.12	0.844	15.18	1.897	1.28
Site 3	4.79	0.29	1.43	2.58	1.96	0.76	1.117	0.804	13.73	1.72	0.85
Site 4	5.48	0.33	1.58	2.71	2.046	0.88	1.28	0.869	15.17	1.897	1.94

TABLE 7. Enrichment factors of heavy metals in the studied soil.

Site	Enrichment factor (EF)							
	Cd	**Co**	**Cr**	**Cu**	**Pb**	**Ni**	**Mn**	**Zn**
Site 1	6.506	1.58	1.17	2.02	0.671	1.05	0.83	1.18
Site 2	0.89	3.34	1.13	1.66	0.539	0.73	0.304	1.43
Site 3	6.24	1.60	1.17	3.21	1.92	0.93	0.68	1.63
Site 4	4.02	1.14	0.89	3.58	1.31	0.102	0.58	1.71

TABLE 8. Hazard index values of heavy metals for adult and children in the studied area.

HI	CD	CO	CR	CU	PB	MN	NI	ZN
				Adult				
Maize	0.003	0.118	0.215	0.002	0.010	0.108	0.049	0.037
wheat	0.005	0.128	0.222	0.002	0.051	0.108	0.051	0.038
Onion	0.003	0.119	0.215	0.002	0.010	0.108	0.049	0.036
Vegetables	0.003	0.118	0.215	0.002	0.010	0.108	0.049	0.036
				Children				
Maize	0.021	0.761	0.872	0.014	0.080	0.142	0.136	0.298
wheat	0.023	0.785	0.889	0.014	0.174	0.142	0.140	0.300
Onion	0.021	0.761	0.872	0.013	0.078	0.141	0.136	0.297
Vegetables	0.021	0.765	0.873	0.013	0.082	0.141	0.136	0.302

TABLE 9. Carcinogenic risks for Cd, Co, Ni and Pb in the studied area for adult.

CR	CD	CO	NI	PB	TOTAL CR
Adult	2.10598E-06	2.76218E-08	8.26001E-08	5.64277E-05	5.86439E-05
Child	2.10598E-06	2.76218E-08	8.26001E-08	0.00017747	0.000179686

Human health risk assessment

To assess the health risk associated with trace elements contamination of plants grown at the studied area, estimated exposure and risk index were calculated. The model used in this study to calculate the exposure of human to the elemental toxicants is based on those developed by the US Environmental Protection Agency [33]. Exposure is expressed in terms of a daily dose and is calculated separately for each element and for each exposure pathway. Specifically, the doses contacted through ingestion of plants and inhalation of particles, and the dose absorbed through the skin have been calculated as shown in Equations 7 to 9 [24, 26]. The doses thus calculated for each element and exposure pathway are subsequently divided by the corresponding reference dose to yield a hazard quotient (HQ) (or non-cancer risk), whereas for carcinogens the dose is multiplied by the corresponding slope factor to produce a level of cancer risk as shown in Equations 10 and 11. The toxicity values used in the analysis were taken from the USEPA [24, 26, and 28], Ferreira-Baptista and De-Miguel [21], Abdelhafez and Li [22].

For the non-carcinogenic risk, the studied elements were not found to cause any risks to the local population (Table 8), since the HRIs for studied trace elements were lower than safe level (1). Regarding non-cancer effects, Co, Cr and Mn exhibit health risk indexes larger than one. The HRI of Cr (i.e. > 0.8), which if contacted by children in large enough doses can trigger neurological and developmental disorders, is particularly close to the ‘‘safe’’ level of HRI = 1.0. Themost sensitive subpopulation is the young children, because of their hand-to-mouth activity, whereby contaminated dust can be readily ingested [33]. Therefore, the exposure of the street dust to children could exhibit more potential health risk. Also reference dose of these elements were found to be very low due to their high toxic effects [21].

For cancer risk, the only carcinogen risk for inhalation exposure modes was considered in the model, and the aggregate risk is calculated by Equation 11. The level of cancer risk associated with exposure to these elements (Table 9) falls within the range of threshold values (10^{-4}–10^{-6}) above which environmental and regulatory agencies consider the risk unacceptable.

It was conclude that long term uses of polluted water with sewage water might cause accumulation of toxic elements in soil and plants cultivated with this kind of water. Therefore uses of treated waste water should be subjected to strict laws to protect the environment from contamination with toxic metals. Therefore, continuous monitoring of toxic metal status in the agricultural soils is important to insure its safe use.

CONCLUSION

An environmental monitoring on trace elements concentrations in soil at a suburban area of El-Zomor, a medium sized city of Egypt, having long term uses of treated and untreated sewage water for irrigation was conducted. Comparing concentrations of trace elements with the background level in the earth crust indicating that the soil of the studied area is contaminated with these metals. Therefore, CF values of this area indicate that soils were considerably contaminated with Cd, moderately contaminated with Co, Cu, Pb and Mn, but showed signs of low contamination with Cr, Ni and Zn. Pollution load index were found to be generally high (>1). Enrichment factor (EF) values indicating that moderate enrichment of Cu and very significant enrichment for Cd was from another source rather than the earth crust such as human activities. To assess the health risk associated with trace elements contamination, estimated exposure and risk indices were calculated.

For the non-carcinogenic risk, the studied elements were not found to cause any risks to the local population, since the HIs for studied trace elements were lower than the safe level. The level of cancer risk associated with exposure to these elements falls within the range of threshold values (10^{-4}–10^{-6}) above which environmental and regulatory agencies consider the risk unacceptable.

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Persian Abstract

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چکیده

برای ارزیابی نشتی سیستم تخلیه فاضلاب درمناطق شهری درآلودگی جریان های آب وخاک، مطالعه ای روی گیاهان خوراکی موجود درحومه آلوده شده در منطقه El-Zomor اروپاانجام شد. نتایج نشان دادکه غلظت عناصرکم مقداردرمنطقه مورد مطالعه چندبرابربیشترازسطح موردانتظاردرپوسته زمین بوده که مشخص می کند منطقه موردمطالعه بافلزات سنگین آلوده شده است. بنابراین مقادیرفاکتورآلودگی(CF)این مناطق مشخص می کندکه خاک باCdآلوده شده، با Co، Cu، PbوMn نسبتاآلوده شده، اماعلایم آلودگی کمتری بافلزات دیگرنشان داده است. فاکتورغنی سازی(EF) نشان می دهدکه غنی سازی متوسط Cu وغنی سازی خیلی بالابرایCd به منبع انسانی مرتبط بوده است. برای ارزیابی ریسک سلامت، شاخص ریسک و پرتودهی محاسبه شدند. برای ریسک غیرسرطان زا بودن، پارامترهای مطالعه شده هیچ خطری برای جمعیت حومه نداشت، چون شاخص خطر (HI)برای عناصرمطالعه شده کمترازسطح مورداطمینان بود. سطح خطرابتلابه سرطان دراثردرارتباط قرارگرفتن بااین عناصردرمحدوده امن($۱۰^{-۶}$-$۱۰^{-۴}$)قرار می گیرد، بنابراین فهمیده ایم که خطرغیرقابل قبول است.