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REGULAR ARTICLE

Soil quality and health risk assessment of heavy metals in agricultural areas irrigated with wastewater from Kitchener Drain, Nile Delta, Egypt

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Abstract

Kitchener drain is one of the largest drains in Nile Delta. It discharges water directly into Mediterranean Sea water affecting on the marine environment. Local population uses its water in irrigation and agriculture field along this drain. So it's important to determine heavy metal content of agricultural soils used this water in irrigation process and assess the hazard and cancer risk on human health living in these areas. Six metals (Fe, Cd, Pb, Ni, Cr and Co) in total and available form were determined in eight geo-referenced soil samples. The order of these metals in soil was as follow; Ni > Cr > Fe > Pb > Cd > Co. The order of these metals in the available form take the sequence of; Fe > Ni > Pb > Cr > Cd > Co. All mean concentrations of metals were exceeding the standard limits of EU, CSQG and AUEC except for cobalt. Mean values of enrichment factors of metals give an indication that the sources of these metals in the environment were from anthropogenic activities. PLI and DC showed considerable degree of contamination in sites 4 & 5. While it showed high degree of contamination in other sites. Hazard quotient from different exposure pathways namely; chemical daily intake (CDI), Dermal contact (DAD) and inhalation (ECinh) and hazard index calculations from metals within different sites were more than one, indicated that there is a chance of non-carcinogenic effects to occur. Also from these pathways, cancer risk (CR) was calculated, which exceed from dermal contact, followed by ingestion and finally from inhalation. Only CR of cobalt showed no risk in the study area when compared with other metals

Key words: Heavy metals, Kitchener, hazard, risk, population

Introduction

In Egypt, the Middle Nile Delta drainage system comprises ten major drains namely Nashart drain; El-Gharbia drain; Drain No. l; Tala drain: Sabal drain, Drain No. l1; Lower No. 8 drain; Drain no.7; Bahr Tira drain; and Coastal areas (EL Gammal, 2016). El-Gharbia main drain or (Kitchener) flows from south to north till Mediterranean Sea with average discharge of 1.9 billion m^3/year. The agricultural drainage, domestic, industrial water represent 75, 23, 2 percent, respectively of its discharge (Abdel Rashid, 2002). In addition to, the lack of farmer's awareness about the use of low quality water for irrigation has led to hygiene problems for farmers and farm animals as result of pollutants and parasites (Taha et al.,

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2012). In the absence of exact treatment plans, the reusing of drainage water will create serious bad effects on soil, crop, animal, and human health (El-Bady, 2014).

One among that serious problems will be the accumulation of heavy metals in the soil (Singh et al., 2009). And, the heavy metals may be carcinogenic and the health effects include neurological impairment and nerve disorders and disfunctions (Markus and McBratney, 2001; Nadal et al., 2004).

There are reports showing food and vegetables are usually the main ways to enter the metals in agricultural soils to the human body, due to increased rate of absorption from the soil (Huang et al., 2008; Zhao et al., 2012). The objectives of this work are estimating the concentrations of Fe, Cd, Pb, Ni, Cr and Co in soil, investigating the degree of pollution and health risk assessment for heavy metals through different exposure pathways for people living in these areas.

Materials and methods

Study area

Kitchener drain is one of the largest drainage systems in the Nile Delta which is located in the central part of Middle Nile Delta as shown in Fig. 1. It originates in El-Gharbia governorate north of Tanta City and extends through Kafr El-Sheikh Governorate in the north direction till the Mediterranean Sea at Baltim city. It has a total catchments area of about 472,500 acres (El-Gammal, 2016). As Kitchener drain collects El-Gharbia governorate agricultural, industrial drainage water and sewage wastewater and sewage drainage water of Kafr El-Sheikh city and industrial drainage of spinning factories of Kafr El-Sheikh. So drainage water is therefore contaminated with salts, agricultural chemicals (pesticides and heavy metals) and other pollutants as pathogens from domestic (Gad and Fadi, 2015). Eight sites were taken using GPS for identifying latitude and longitude with description of site and type of crop (Table 1).

Table 1. Site descriptions and locations.

Sites no	Name	Crop type	Latitude	Longitude
1	Coastal area	Maize	31° 34.658'	31° 11.042'
2	El-Kashaa	Wheat	31° 29.526'	31° 08.934'
3	El-Hamoul	Wheat	31° 17.887'	31° 08.398'
4	El-Karakat	Grass	31° 10.020'	31° 04.613'
5	Kafr Dokhmis	Wheat	31° 07.135'	31° 03.537'
6	After Nemera El-Basal	Maize	31° 02.384'	31° 04.577'
7	Ezbet Gobran	Wheat	30° 59.857'	31° 03.995'
8	Saks	Clover	30° 59.039'	31° 03.172'

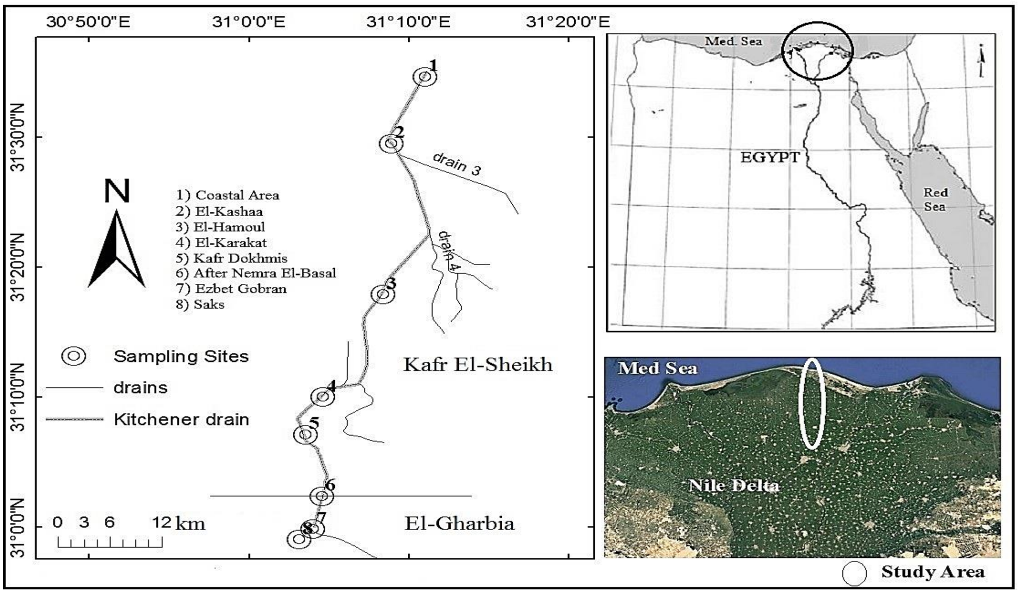

Fig. 1. Map showing studied agricultural sites.

Soil analyses

Soil samples were collected from the sites of the agricultural lands along Kitchener drain. All samples were then carried to the laboratory in plastic bags shortly after collection. The samples were spread over sheets of paper; air dried, thoroughly mixed, passed through a 2 mm sieve to remove gravel and debris, and then packed in plastic bags ready for physical and chemical analyses. The texture of soil samples and organic carbon was determined according to Piper (1947). Electric pH-meter was used to determine the soil reaction. Electrical conductivity was measured by YSI Incorporated Model 33 conductivity meter as described by Jackson (1962).

Total metal content analysis in soil samples

The metal content analysis in soil were done by the method of Oregioni and Aston (1984) and as described previously (El-Amier et al., 2015)

Available heavy metals analysis in soil

Available metals were estimated according to the method of Lindsay and Norvell (1978) using DTPA solution.

Heavy Metals Indices in Hydrosoil Samples

In Hydrosoil samples the heavy metals were estimated by following Zahran, et al. (2015). The enrichment Factor (EF) is magnitude of contaminants and iron (Fe) was chosen as the controlling element (Seshan et al., 2010). The EF values interpretation was done by following Liaghati et al. (2003).

Contamination Factor (CF) by Tomilson et al. (1980) method and Pollution Load Index (PLI) was estimated by following the method of EPA (2002).

Degree of Contamination (DC) and Geo-Accumulation Index (Igeo) as defined by Müller (1969) were identified. The geo-accumulation index (Igeo) was distinguished into seven classes by Buccolieri et al. (2006).

Human health risk assessment

Human health risk assessment was done as described by Abdelhafez & Li (2015). The metals in soil samples in agricultural areas surrounded the Kitchener drain was utilized in calculation of health risk index (HRI), which depends on the daily intake of metals (DMI) and oral reference dose (estimated per day exposure of metal to human body that has no hazardous effect during life time, RFD).

The exposure assessments methods for each metal were calculated by determination of Chemical Daily Intake (CDI), Dermal Absorbed Dose (DAD) and Exposure Concentration (EC) using the following equations according to USEPA (2011a):

$$CDI = \left(\frac{C*IngR}{BW}\right) * \left(\frac{EF*ED}{AT}\right) * Cf \text{.................. (6)}$$

$$DAD = \frac{\frac{C*SA*SL*ABS}{BW}}{\frac{EF*ED}{AT}} * Cf \text{.......................... (7)}$$

$$EC\ inhalation = \left(\frac{C*EF*ED}{ATn}\right) * Cf(inh) \text{............ (8)}$$

Where:

C: metal concentration in soil (µg/g)
IR: ingestion rate per unit time (mg/day)
ED: exposure duration (years)
EF: exposure frequency (days/year)
BW: humans body weight (Kg)
AT: averaging time (days)
SA: surface area of contact (cm^2)
SL: skin adherence factor (mg/cm^2h)
ABS: absorption factor (unitless)
Cf: conversion factor (10^{-6}Kg/mg)
ATn: average time (hours)
Cf(inh): conversion factor of $3.5 * 10^{-4}$

Cf (inh): conversion factor was used to estimate the average concentrations of heavy metals per unit volume of the air based on the air quality guideline (National Ambient Air Quality Standards, 2014).

CDI, DAD and EC values was used to quantify hazard quotient (HQ) separately for each metal; consequently, the hazard index (HI) was calculated. According to USEPA, (2011a), HI is categorized as < 1 = no significant hazard of non-carcinogenic effects and >1 = chance of non-carcinogenic effects occurring. So the carcinogenic risks (CR) were calculated for appropriated media and pathways. HQ and CR in Kitchener surrounded soils via Ingestion, Dermal Contact and Inhalation Exposure.

$$HQ = \left(\frac{CDI}{RfD0}\right) = \left(\frac{DAD}{RfD0*GIABS}\right) = EC/(RfCi * 1000\ \mu g/mg) \text{.............. (9)}$$

$$HI = \sum HQ \text{.. (10)}$$

$$CR = CDI * SF0 = DAD * \left(\frac{SF0}{GIABS}\right) = IUR * EC \text{... (11)}$$

RFD_o: oral reference dose (mg kg^{-1} day^{-1})
RfCi: inhalation reference concentration (mg m^{-3})
SF_o: oral slope factor
IUR: inhalation unit risk ((µg $m^{-3})^{-1}$)
The values of RFD_o, RfCi, SF_o, GIABS and IUR were obtained from the USEPA (2011 b, c).

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 the USEPA (1991). The input parameters to characterize the HI values are obtained from USEPA (1991), Lee et al. (2006), Zheng et al. (2010) and Ferreira-Baptista & De Miguel (2005) as shown in Tables (2 & 3).

Results and Discussion

There are few sources of heavy metals contamination in agricultural soil. These include the parent material from which the soil is derived and in addition anthropogenic exercises (Chen et al., 2002).

The percentage of soil texture was varied from one location to another (Table 4). As location 1 was sandy; loamy sand at sites 2, 3; loamy at 4 & 5 and clayey loam at sites 6 & 7 & 8. The percentage of OC was 0.32 % at location 1 (sandy soil at the coast nearby sea). While the highest value of OC was recorded at site 6, followed by site 4. It may be attributed to the positive significant correlation between organic carbon with clay and silt and negative correlation with sand (0.8 and -0.8, respectively), as Table (5). Sandy soils are very poor with organic matter when compared with those fine particulates. Organic carbon is strongly correlated with clayey sediments than other soil types (Palma et al., 2012; El-Amier et al., 2016).

Table 2. Input parameters to characterize the 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}
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 Average time- cancer risk	ED*365 70*365		days
SL	Skin adherence factor	0.2	0.2	mg cm^{-2} h^{-1}
SA	Exposure skin area	3300	2800	cm^2
ABS	Dermal absorption factor	0.001 for Cd 0.01 for other elements		unitless
AT_n	Average time-non cancer risk Average time- cancer risk	ED*365*24 70*365*24		hours

Table 3. Toxicity parameters used to investigate non-cancer and carcinogenic risks.

Metals	SFo $mgkg^{-1}day^{-1}$	IUR $(\mu gm^3)^{-1}$	RfDo $mgkg^{-1}day^{-1}$	RfCi mg m^3	GIABS	ABS
Cd	0.28	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
Pb		8.0E-05	*3.5E-03	-	1	0.1
Ni		2.4E-04	1.1E-02	1.4E-05	0.04	0.01

Data obtained from USEPA (2011a, 2011b, 2011c); *data obtained from Ferreira-Baptista & De Miguel (2005).

Table 4. Values of soil texture, organic carbon (OC), EC and pH of soil samples.

Sites no.	Soil Texture %			Texture Class	O.C %	EC $d.sm^{-1}$	pH
	Sand	Silt	Clay				
1	70.6	17.6	11.8	Sandy	0.32	1.64	8.35
2	43.4	32.4	24.2	Loamy Sand	0.98	1.97	8.38
3	37.6	36.8	25.6	Loamy Sand	0.85	2.19	8.29
4	31.2	39.9	28.9	Loamy	1.08	2.53	8.22
5	33.9	38.6	27.5	Loamy	0.93	2.26	8.25
6	20.8	43.8	35.4	Clay Loam	1.75	3.12	7.92
7	27.4	40.7	31.9	Clay Loam	0.88	2.77	8.11
8	24.5	42.3	33.2	Clay Loam	0.97	2.95	8.07
Mean	36.18	36.51	27.31	--	0.97	2.43	8.20

Table 5. Correlation matrix between different variables and metals.

Variable	Fe	Cd	Pb	Ni	Cr	Co	Sand	Silt	Clay	OC	EC	pH
Fe	1											
Cd	-0.18	1										
Pb	-0.26	-0.09	1									
Ni	-0.51	-0.01	0.53	1								
Cr	-0.61	0.72*	0.02	0.06	1							
Co	0.04	0.39	0.23	-0.16	0.61	1						
Sand	-0.78*	-0.01	0.39	0.18	0.53	0.20	1					
Silt	0.79*	-0.01	-0.43	-0.25	-0.53	-0.19	-0.99**	1				
Clay	0.76*	0.03	-0.34	-0.09	-0.52	-0.19	-0.99**	0.98**	1			
OC	0.78*	0.02	0.05	-0.06	-0.35	0.23	-0.80*	0.	0.81*	1		
EC	0.70	-0.15	-0.28	0.11	-0.62	-0.27	-0.91**	0.88**	0.94**	0.77*	1	
pH	-0.63	0.32	0.01	-.30	0.7	0.28	0.76*	-0.72*	-0.81*	-0.75*	-0.95**	1

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

Table 6. Concentrations of heavy metals (mg/kg) of soil samples

Site no.	Metals					
	Fe	Cd	Pb	Ni	Cr	Co
1	4.00	3.00	673.60	2911.00	1139.20	5.67
2	377.50	1217.10	524.50	1264.40	2156.00	11.21
3	699.90	74.50	412.80	1.90	576.90	8.92
4	685.70	210.40	15.40	4.60	1128.60	7.61
5	714.30	48.40	438.40	6.90	6.60	0.68
6	1004.30	37.50	722.70	2546.80	16.40	8.17
7	241.20	337.50	368.20	3569.90	667.20	1.23
8	895.90	409.60	152.20	921.40	124.50	2.45
Mean	577.85	292.25	413.48	1403.36	726.93	5.74
SD	340.37	402.37	240.54	1434.11	735.46	3.90
Average shale	47200	0.3	20	68	90	19
EU, 2002	-	3	300	75	150	-
CSQG (Agricultural soil)	-	1.4	70	50	64	40
AUEC	30890	0.1	17	18.6	35	11.6

-SD: Standard deviation -Average shale, after Turekian and Wedepohl (1961) -Average upper earth crust, after wedepohl (1995) -CSQG of Agricultural soil: Canadian soil quality guidelines, 2007. -EU, 2002: European Union Standards

There is numerous mineral matter, water, air, organic matter and living organisms in soil. So heavy metals contamination in agricultural soil is a potential environmental threat (Chopra et al., 2009; Simon et al., 2016). From Table (6), Total content of heavy metals concentrations in agricultural soils of the studied locations were as the following sequence: Ni > Cr > Fe > Pb > Cd > Co.

Iron varied from 4 to 1004.3 with mean value of 577.85 mg/kg. The highest mean value was recorded at site 6 which characterized by high organic carbon content. The sandy sediments showed low concentrations of heavy metals than clayey sediments as observed by Abdel-Azeem (2015) and El-Alfy (2015). The concentrations of iron are within limits.

Cadmium is an element that occurs naturally at low levels in the environment (Stankovic et al., 2011). The range of Cd in studied locations was (3.00 mg/kg) in site 1. While the highest value was (1217.10 mg/kg) in site 2. This could be attributed to using of pesticides in agriculture. The mean value of Cd exceeded than the standard limits. Chromium content of soil is known to enhance pollution from many types of industrial wastes and sludge (Rahman et al., 2012). The lowest value of Cr was observed in site 5, were its highest value was recorded at site 2. The mean value of Cr in the study area is more than the EU standard limit and CSQG.

Lead is the most immobile element and its content in soil is closely associated with clay minerals (Yaylali-Abanuz, 2011). Pb ranged between 15.4 to 722.7 with mean value of 413.48 mg/kg. The highest value of lead was recorded at site 6 may attributed to incorporation of lead to agricultural soil through various types of pollutions (Alloway, 1990). The mean value of lead is more than obtained by the standard limits.

Nickel can enter the environment as a result of the natural weathering and leaching of rocks (Chau and Kulikovsky-Cordeiro, 1995). It varied from 1.9 in site 3 to 3569.90 µg/g with mean value of 1403.36 µg/g. the mean value of nickel is higher than the limits as Table (6). Many fertilizers contribute nickel in soil and also industries (McGrath, 1995; Cempel and Nikel, 2006). The increase of Ni concentration of soil around Kitchener drain is as a result of usage of wastewater in irrigation, this is agreed with El-Bady (2014) who found same impacts.

Mining and processing of cobalt-bearing ores leads to increased levels of cobalt in soil, also agricultural ferilizers contribute cobalt in soil (Smith and Carson, 1981). It varied from 0.68 to 11.21 mg/kg. The highest mean value was recorded in site 2. While this site characterized by many agricultural activities. This agreed with Toth et al. (2016) who obtained high concentrations of cobalt in agricultural lands. Also the highest values of Co may be attributed to irrigation with industrial wastewater and the variability of concentrations of it between sites may attribute to accumulation of organic matter and solid wastes (Zohny, 2002). Co in the studied sites is within the standard limits of EU, CSQG and AUEC.

The quantity of soil impacted (naturally or anthropogenically) with heavy metal is an important step in the study of environmental contamination (Huu et al., 2010). The Enrichment factor of metals in soil samples in different sites are; Cd (5874.7-507259.3), Pb (53-397424), Ni (1.9-505144.1), Cr (4.8-149361.8) and Co (9.1- 4695.2) (Table 7). It's obvious that EF values > 2 in all sites proved that the sources are more likely to be anthropogenic except for nickel in site 3 may from natural process like run off from soils (McGrath, 1995). The high Enrichment factors of metals are an indication to different processes either sewage, agricultural or industrial pollutants along the studied areas.

The contamination factors of Fe showed low CF in sites 1, 2, 7 and 8; moderate CF in sites 4, 5 and 6. But it sowed very high CF in site 3 at El-Kashaa area as a result of agricultural wastes. For Cd, it showed very high CF level in all sites, except for sites 4 & 5 & 6 (low CF). PLI ranged between 0.4 and 7.79. It showed low pollution level in sites 4 & 5 and high pollution level in other sites. DC showed considerable degree of contamination in sites 4 & 5. While it showed high degree of contamination in other sites (Table 8).

Geo-accumulation index of Fe, showed non polluted category at all sites. For Cd, moderately polluted at sites 1 & 6; strongly polluted at site 2 and moderately to strongly pollute in other sites. For Ni, non-polluted category at sites 3, 4, 5; unpolluted to moderate pollution at site 8 and moderately polluted in other sites. For Pb, it showed non polluted category at sites 4 & 8. While it showed moderate pollute in other sites. For Cr, it showed unpolluted category in sites 5, 6, 8; unpolluted to moderate pollution category in other sites. For Co, it showed unpolluted category in all sites (Figure 2).

As shown in Table (9), the range of available metals are as follow: Fe (2.6-4.09), Cd (0.818-1.64), Pb (1.244-2.812), Ni (1.952-2.853), Cr (1.024-2.365) and Co (0.367-1.098). The mean values of metals in the study area are more than those recorded by Abd El-Fattah (2015) in the soil of Mostorod area except for lead. This may have attributed to the high use of drainage water in the agricultural field. The sequence of available metals in soil of studied area were Fe > Ni > Pb > Cr > Cd > Co. All mean concentrations of available metals were within the acceptable limits except for Cd and Co. This could be related to untreated wastewater which used in irrigation and attributed to the phosphate and superphosphate which be used in agricultural activities as fertilizers (Abd El-Fattah, 2015 and El-Amier et al., 2017).

Table 7. Enrichment factor of metals.

Site no.	Metals					
	Fe	Cd	Pb	Ni	Cr	Co
1	1	118000.0	397424.0	505144.1	149361.8	4695.2
2	1	507259.3	3279.0	2324.9	2995.2	22.9
3	1	16747.2	1391.9	1.9	432.3	297.4
4	1	48276.1	53.0	4.7	863.2	89.9
5	1	10660.7	1448.4	6.7	4.8	34.6
6	1	5874.7	1698.3	1760.2	8.6	541.2
7	1	220149.3	3602.6	10273.3	1450.7	9.1
8	1	71931.8	400.9	713.9	72.9	14.9
Mean	1	124862.4	51162.3	65028.7	19398.7	713.1

Table 8. Contamination factors, PLI and contamination degree of metals.

Site no.	CF						PLI	DC
	Fe	Cd	Pb	Ni	Cr	Co		
1	0.00	10.00	33.68	42.81	12.66	0.30	1.28	99.45
2	0.01	4057	26.23	18.59	23.96	0.59	7.79	4126.37
3	174.98	24.83	20.64	0.03	6.41	0.47	4.43	227.36
4	1.82	0.17	0.77	0.07	12.54	0.40	0.66	15.77
5	1.02	0.65	21.92	0.10	0.07	0.04	0.40	23.80
6	1.46	0.18	36.14	37.45	0.18	0.43	1.74	75.84
7	0.34	6.97	18.41	52.50	7.41	0.06	3.21	85.70
8	0.89	10.92	7.61	13.55	1.38	0.13	2.37	34.49
Mean	22.57	513.84	20.68	20.64	8.08	0.30	2.74	586.10

Table 9. Concentrations of available heavy metals.

Sites no.	Metals					
	Fe	Cd	Pb	Ni	Cr	Co
1	2.633	1.043	2.243	2.521	1.958	1.005
2	3.341	1.172	2.812	2.457	2.125	1.098
3	3.115	0.818	2.618	2.814	1.802	0.985
4	3.914	1.519	1.995	2.014	2.365	0.854
5	2.829	0.935	2.375	1.952	1.251	0.654
6	4.097	1.641	2.116	2.853	1.025	0.547
7	3.562	1.293	1.244	1.894	1.136	0.367
8	3.79	1.405	1.882	2.158	1.024	0.425
Mean	3.410	1.228	2.161	2.333	1.586	0.742
SD	0.52	0.29	0.48	0.38	0.54	0.28
Limit	-	0.31[a]	13[a]	8.1[a]	8[a]	0.25[b]

a) Maclean et al., 1987; b) Stewart, 1953

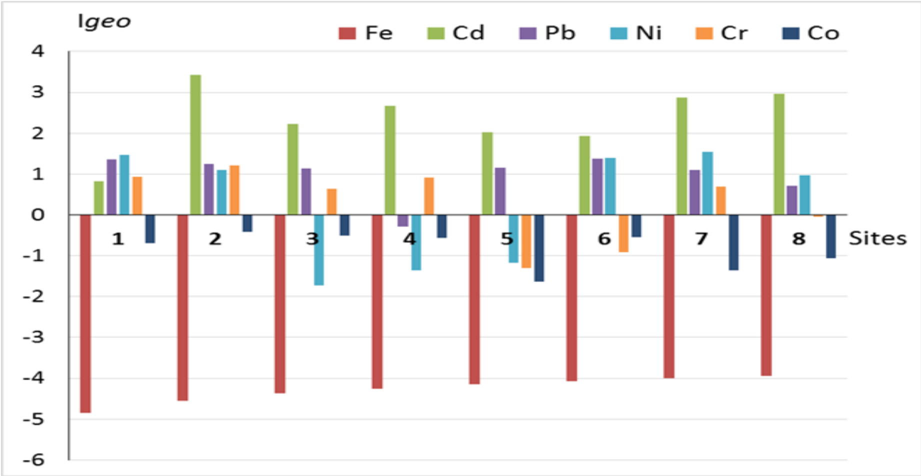

Fig. 2. Geo-accumulation index of metals in agricultural areas around Kitchener drain.

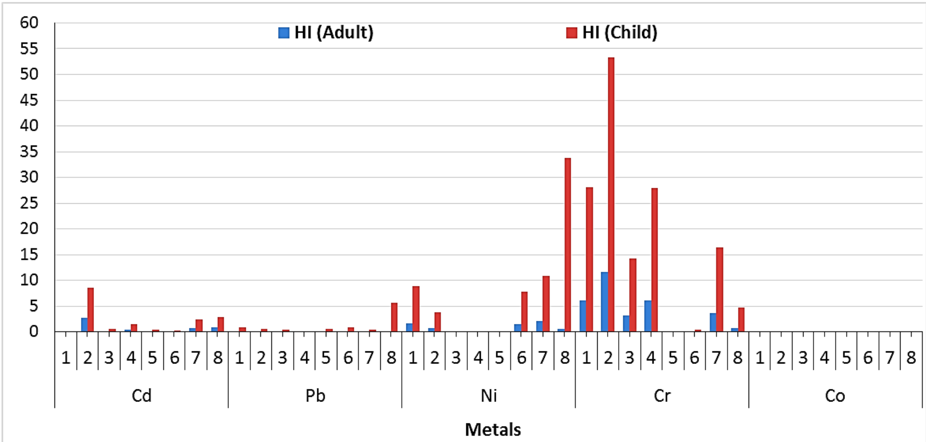

Fig. 3. Distribution of mean values of HI of heavy metals for adult and child within different sites.

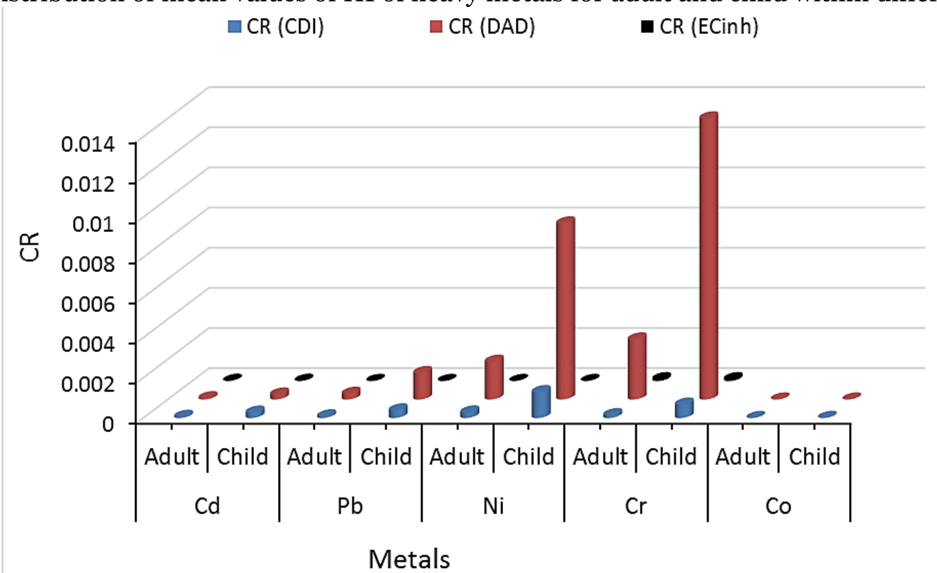

Fig. 4. Distribution of mean cancer risk values of different pathways for heavy metals for adult and child.

Human health risk assessment

Non-cancer hazard assessment

From the calculation of HQ for each type of exposure including ingestion, dermal contact and inhalation; hazard index for Cd exceed one in site 2 for adults, the same site, site 7 and 8 for children. For Pb, it doesn't represent hazard for adults, only in site 8 for children. Lauwerys et al. (1984) stated that Persons who have lived in polluted area with cadmium have accumulated significantly more cadmium in the renal cortex and in the liver than those who have resided in other regions (Table 10).

Hazard index values of Ni indicate non-cancer hazard in sites 1, 6, 7 for adults and 1, 2, 6, 7 and 8 for children (RAIS, 2007). For Cr, hazard index values exceed the range in all sites except 5, 6 and 8 for adult and 5, 6 for children. Abd-El-Fatah (2015) recorded high value of HI for Cr for children. But the HI value of Co don't exceed the limit for both in all sites. It is clear that different activities play role in distribution of hazard within different locations (Pagilla and Canter, 1999; Mondol et al., 2011). Cobalt is an essential element to human health (e.g. it is part of vitamin B12), but when in excess can cause serious effects to lungs and heart (ATSDR, 2004). Distribution of mean values of HI is as shown in Figure (3).

Cancer risk assessment

From Table (11) and Figure (4), CR values of Cd range between (5.92E-07 and 2.40E-04) with mean value of 5.76E-05. It exceeds limit for child as mean value equal to 2.69E-04. Mean value of CR for Pb is within limit for adult and exceed limit for child 3.81E-04. CR values for Ni and Cr were exceed the limit, but within limit for Co. For mean CR values of dermal contact in the study area, they are exceeding the limit for all metals except for Cd for adult and Co for both species. For mean carcinogenic values of inhalation exposure, it doesn't exceed the limit for both species. The carcinogenic risks of these elements were within the acceptable level (1×10^{-4}), indicating that the carcinogenic risk posed by those toxic elements to children and adults in the surrounding of drain via ingestion or dermal is accessible when compared with inhalation.

Table 10. Hazard quotient and hazard index values for adult and children within different sites.

Metals	Sites no.	HQ (Adult)			HI	HQ (Child)			HI
		CDI	DAD	EC		CDI	DAD	EC	
Cd	1	2.11E-03	2.29E-03	2.16E-03	6.57E-03	0.01	0.01	0.00	0.02
	2	8.57E-01	9.31E-01	8.75E-01	2.66E+00	4.00	3.69	0.88	8.56
	3	5.25E-02	5.70E-02	5.36E-02	1.63E-01	0.24	0.23	0.05	0.52
	4	1.48E-01	1.61E-01	1.51E-01	4.60E-01	0.69	0.64	0.15	1.48
	5	3.41E-02	3.70E-02	3.48E-02	1.06E-01	0.16	0.15	0.03	0.34
	6	2.64E-02	2.87E-02	2.70E-02	8.21E-02	0.12	0.11	0.03	0.26
	7	2.38E-01	2.58E-01	2.43E-01	7.39E-01	1.11	1.02	0.24	2.37
	8	2.89E-01	3.13E-01	2.95E-01	8.96E-01	1.35	1.24	0.29	2.88
Pb	1	0.14	0.04	-	0.17	0.63	0.17	-	0.80
	2	0.11	0.03	-	0.13	0.49	0.13	-	0.63
	3	0.08	0.02	-	0.11	0.39	0.11	-	0.49
	4	0.00	0.00	-	0.00	0.01	0.00	-	0.02
	5	0.09	0.02	-	0.11	0.41	0.11	-	0.52
	6	0.15	0.04	-	0.18	0.68	0.18	-	0.86
	7	0.07	0.02	-	0.09	0.35	0.09	-	0.44
	8	0.03	0.01	-	0.04	0.14	5.43	-	5.57
Ni	1	0.1864	0.0001531	1.495	1.682	0.8700	5.903	2.094	8.866
	2	0.0810	0.0000665	0.650	0.731	0.3779	2.564	0.909	3.851
	3	0.0001	0.0000001	0.001	0.001	0.0006	0.004	0.001	0.006
	4	0.0003	0.0000002	0.002	0.003	0.0014	0.009	0.003	0.014
	5	0.0004	0.0000004	0.004	0.004	0.0021	0.014	0.005	0.021

Table 10. Contd…

	6	0.1631	0.0001339	1.308	1.472	0.7612	5.164	1.832	7.757
	7	0.2286	0.0001877	1.834	2.063	1.0670	7.239	2.567	10.873
	8	0.0590	0.0000484	0.473	0.532	0.2754	32.884	0.663	33.822
Cr	1	0.268	5.5847	0.2825	6.13	0.8193	1.2484	26.062	28.130
	2	0.506	10.5694	0.5347	11.61	1.5505	2.3627	49.324	53.237
	3	0.135	2.8281	0.1431	3.11	0.4149	0.6322	13.198	14.245
	4	0.265	5.5328	0.2799	6.08	0.8117	1.2368	25.820	27.868
	5	0.002	0.0324	0.0016	0.04	0.0047	0.0072	0.151	0.163
	6	0.004	0.0804	0.0041	0.09	0.0118	0.0180	0.375	0.405
	7	0.157	3.2708	0.1655	3.59	0.4798	0.7312	15.264	16.475
	8	0.029	0.6103	0.0309	0.67	0.0895	0.1364	4.443	4.669
Co	1	0.013	0.0036	0.0068	0.02	0.0041	0.0621	0.0017	0.068
	2	0.026	0.0071	0.0134	0.05	0.0081	0.1228	0.0033	0.134
	3	0.021	0.0057	0.0107	0.04	0.0064	0.0978	0.0027	0.107
	4	0.018	0.0048	0.0091	0.03	0.0055	0.0834	0.0023	0.091
	5	0.002	0.0004	0.0008	0.00	0.0005	0.0074	0.0002	0.008
	6	0.019	0.0052	0.0098	0.03	0.0059	0.0895	0.0024	0.098
	7	0.003	0.0008	0.0015	0.01	0.0009	0.0135	0.0004	0.015
	8	0.006	0.0016	0.0029	0.01	0.0018	0.0268	0.0874	0.116

Table 11. Carcinogenic risk values from different exposure pathways within different sites.

Metals	Species	Sites								Mean
		1	2	3	4	5	6	7	8	
Cancer Risk (Chemical daily Intake)										
Cd	Adult	5.92E-07	2.40E-04	1.47E-05	4.15E-05	9.55E-06	7.40E-06	6.66E-05	8.08E-05	5.76E-05
	Child	2.76E-06	1.12E-03	6.86E-05	1.94E-04	4.46E-05	3.45E-05	3.11E-04	3.77E-04	2.69E-04
Pb	Adult	1.33E-04	1.03E-04	8.14E-05	3.04E-06	8.65E-05	1.43E-04	7.26E-05	3.00E-05	8.16E-05
	Child	6.20E-04	4.83E-04	3.80E-04	1.42E-05	4.04E-04	6.65E-04	3.39E-04	1.40E-04	3.81E-04
Ni	Adult	5.74E-04	2.49E-04	3.75E-07	9.07E-07	1.36E-06	5.02E-04	7.04E-04	1.82E-04	2.77E-04
	Child	2.68E-03	1.16E-03	1.75E-06	4.23E-06	6.35E-06	2.34E-03	3.29E-03	8.48E-04	1.29E-03
Cr	Adult	2.25E-04	4.25E-04	1.14E-04	2.23E-04	1.30E-06	3.24E-06	1.32E-04	2.46E-05	1.43E-04
	Child	1.05E-03	1.98E-03	5.31E-04	1.04E-03	6.08E-06	1.51E-05	6.14E-04	1.15E-04	6.69E-04
Co	Adult	1.12E-06	2.21E-06	1.76E-06	1.50E-06	1.33E-07	1.61E-06	2.43E-07	4.83E-07	1.13E-06
	Child	5.22E-06	1.03E-05	8.21E-06	7.01E-06	6.21E-07	7.52E-06	1.13E-06	2.26E-06	5.29E-06
Cancer Risk (Dermal Absorbed Dose)										
Cd	Adult	6.42E-07	2.61E-04	1.60E-05	4.51E-05	1.04E-05	8.03E-06	7.23E-05	8.77E-05	6.26E-05
	Child	2.54E-06	1.03E-03	6.32E-05	1.78E-04	4.10E-05	3.18E-05	2.86E-04	3.47E-04	2.47E-04
Pb	Adult	4.60E-04	3.58E-04	2.82E-04	1.05E-05	2.99E-04	4.93E-04	2.51E-04	1.04E-04	2.82E-04
	Child	2.15E-03	1.67E-03	1.32E-03	4.91E-05	1.40E-03	2.30E-03	1.17E-03	4.85E-04	1.32E-03
Ni	Adult	3.90E-03	1.69E-03	2.54E-06	6.16E-06	9.23E-06	3.41E-03	4.78E-03	1.23E-03	1.88E-03
	Child	1.82E-02	7.90E-03	1.19E-05	2.87E-05	4.31E-05	1.59E-02	2.23E-02	5.75E-03	8.77E-03
Cr	Adult	4.69E-03	8.88E-03	2.38E-03	4.65E-03	2.72E-05	6.75E-05	2.75E-03	5.13E-04	2.99E-03
	Child	2.19E-02	4.14E-02	1.11E-02	2.17E-02	1.27E-04	3.15E-04	1.28E-02	2.39E-03	1.40E-02
Co	Adult	3.04E-07	6.00E-07	4.78E-07	4.07E-07	3.61E-08	4.37E-07	6.58E-08	1.31E-07	3.07E-07
	Child	1.42E-06	2.80E-06	2.23E-06	1.90E-06	1.69E-07	2.04E-06	3.07E-07	6.12E-07	1.43E-06
Cancer Risk (Inhalation)										
Cd	For Adult & Child	5.18E-08	4.89E-06	9.06E-06	8.88E-06	9.25E-06	1.30E-05	3.12E-06	1.16E-05	7.48E-06
Pb		1.73E-09	7.00E-07	4.29E-08	1.21E-07	2.78E-08	2.16E-08	1.94E-07	2.36E-07	1.68E-07
Ni		1.16E-06	9.05E-07	7.13E-07	2.66E-08	7.57E-07	1.25E-06	6.36E-07	2.63E-07	7.14E-07
Cr		1.88E-04	8.18E-05	1.23E-07	2.98E-07	4.47E-07	1.65E-04	2.31E-04	5.96E-05	9.08E-05

Conclusion

The results give an indication that the use of drainage waters in irrigation not only effect on the soil quality as identified by metal indices but also represent as hazard to health of population. The soil of agricultural lands use wastewater from Kitchener drain enriched with metals exceeding the natural limits.

Pollution load index also identified highly pollution level with metals in the study area. Hazard Index for most metals exceeded the acceptable limit, as it may cause adverse effects on the human health either adults or children. It would be especially important to take measures (e.g. controlling industrial sources) to prevent any further increase of toxic metals as Cr in the soil. Awareness for those populations should be introduced and search for another possible source of irrigation water is a must to keep soil, plants and finally the health of population to prevent accumulation of different contaminants to human.

Authors' contributions

Both Yasser El-Amier and Muhammad El-Alfy contributed equally to the overall design of the study as well as field work, treatment of data and manuscript preparation. Hazem Abd El-Hamid contributed to the samples analysis. Both authors approved the final version of the manuscript for publication.

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