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Pollution Risk Assessment of Heavy Metals along Kitchener Drain Sediment, Nile Delta

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Table S1. Pollution quantification (single and total complex indices) used in this study.

Ecological indicators	Formula	Value	Environmental risk grade	References
Single indices of pollution:				
Potential Contamination Index (PCI)	$\mathbf{PCI_i} = \frac{\mathbf{C_x max}}{\mathbf{C_{bkg}}}$	PCI < 1	Unpolluted, low level of pollution	Davaulter and Rognerud, 2001) Wu et al. (2015)
		1 ≤ PCI ≤ 3	Moderate polluted	
		PCI ≥ 3	Strong polluted	
Geoaccumulation Index (I*geo*)	$\mathbf{I}geo = \mathbf{Log2}\left(\frac{C_x}{\mathbf{1.5Bn}}\right)$	Igeo ≤ 0	Uncontaminated	Muller (1969), ` Lu and Bai (2010)
		0 < Igeo < 1	Uncontaminated to moderately contaminated	
		1 < Igeo < 2	Moderately to heavily contaminated	
		2 < Igeo < 3	Moderately to strongly contaminated	
		3 < Igeo < 4	Strongly contaminated	
		4 < Igeo < 5	Strongly to extremely contaminated	
		Igeo > 5	Extremely high contaminated	
Total complex indices of pollution (integrated indices):				
Pollution Load Index (PLI)	$PLI = (Cf_1 \times Cf_2 \times \ldots\ldots \times Cf_n)^{1/n}$	PLI > 1	Polluted	Tomlinson et al., 1980 Seshan et al., 2010
		PLI ≤ 1	No pollution	
Degree of Contamination (D*c*)	$Dc = \sum_{i=1}^{n} Cf_i$ $Cf = C_x/C_{Background}$	Dc < 8	Low DC	Hakanson (1980); Caeiro et al. (2005)
		N ≤ Dc < 16	Moderate DC	
		16 ≤ Dc < 32	Considerable DC	
		Dc > 32	Very high DC	

C_x: metal concentration in soil analyzed sample; $C_{background}$: metal concentration in the reference environment; Bn: the geochemical background value in average shale of element n; 1.5: the background matrix correction due to terrigenous effects; C*f*: the contamination factor.

Table S2. Eco-toxicity indices used in the present study.

Eco-toxicity indices	Formula	Value	Environmental risk grade	References
The mean Probable Effects Level quotient ($mPEL_Q$)	$mPEL_Q = \frac{\sum_{i=1}^{n} \frac{C_x}{PEL_i}}{n}$	$mPEL_Q \leq 0.1$	Low degree of contamination	Carr et al., 1996 Long et al., 2006
		$0.1 < mPEL_Q \leq 1.5$	Medium-low degree of contamination	
		$1.51 < mPEL_Q \leq 2.3$	High-medium degree of contamination	
		$mPEL_Q > 2.3$	High degree of contamination	
The mean Effect Range Median quotient ($mERM_Q$)	$mERM_Q = \frac{\sum_{i=1}^{n} \frac{C_x}{ERM_i}}{n}$	$mERM_Q \leq 0.1$	Low priority site	Long et al., 2000
		$0.1 < mERM_Q \leq 0.5$	Medium-low priority site	
		$0.5 < mERM_Q \leq 1.5$	High-medium priority site	
		$mERM_Q > 1.5$	High priority site	
Contamination Severity Index (CSI)	$W_t = \frac{L_{f_i} x E_v}{\sum_{i=1}^{n} (L_{f_i} x E_v)}$ $CSI = \sum_{i=1}^{w} W_t [(\frac{C_x}{ERL_i})^{1/2} + (\frac{C_x}{ERM_i})^2]$	Uncontaminated		Burton, 2002; MacDonald et al., 2000
		$CSI < 0.5$	Very low severity of contamination	
		$0.5 \leq CSI < 1$	Low severity of contamination	
		$1 \leq CSI < 1.5$	Low to moderate severity of contamination	
		$1.5 \leq CSI < 2$		
		$2 \leq CSI < 2.5$	Moderate severity of contamination	
		$2.5 \leq CSI < 3$	Moderate to high severity of contamination	
		$3 \leq CSI < 4$		
		$4 \leq CSI < 5$	High severity of contamination	
		$CSI \geq 5$	Very high severity of contamination	
			Ultra-high severity of contamination	
Hazard Quotients (HQ)	$HQ = \frac{C_x}{SQG}$	$HQ < 0.1$	No adverse effects	Feng et al., 2011 MacDonald et al., 2000
		$0.1 \leq HQ \leq 1$	Potential hazards	
		$1 < HQ \leq 10$	Moderate hazards	
		$HQ > 10$	High hazards.	
Modified Hazard Quotient (mHQ)	$mHQ = [C_x (\frac{1}{TEL_i} + \frac{1}{PEL_i} + \frac{1}{SEL_i})]^{1/2}$	$mHQ < 0.5$	Nil to very low severity of contamination	Benson et al., 2018
		$0.5 \leq mHQ < 1.0$	Very low severity of contamination	
		$1.0 < mHQ < 1.5$	Low severity of contamination	
		$1.5 < mHQ < 2.0$	Moderate severity of contamination	
		$2.0 < mHQ < 2.5$	Considerable severity of contamination	
		$2.5 < mHQ < 3.0$	High severity of contamination	
		$3.0 < mHQ \leq 3.5$	Very high severity of contamination	
		$mHQ > 3.5$	Extreme severity of contamination	

C_x: metal concentration in soil analyzed sample; PEL: probable effect level; ERM: effects range median; L_f: Loading factor; E*v*: Eigenvalue; ERL: effects range low; SQG: sediment quality guidelines: TEL: threshold effect level; SEL: severe effect level.

Table S3. Threshold, midrange and extreme effects sediment guidelines for selected metals (mg/kg)

Sediment Quality Guidelines		**Pb**	**Cd**	**Ni**	**Cr**	**Cu**	**Zn**	**Co**	**Reference**
ERL		35	5	30	80	70	120	-	Macdonald et al., 2000 Graney and Eriksen 2004
% of lower ERL		16.67	16.67	16.67	16.67	83.33	16.67		
TEL		35	0.6	18	37.3	16	120	-	
% of lower TEL		16.67	16.67	16.67	16.67	16.67	16.67		
ERM		110	9	50	145	390	270	-	
% of lower ERM		66.67	83.33	66.67	16.67	100	83.33		
PEL		91.3	3.53	36	90	197	315	-	
% of lower PEL		66.67	16.67	16.67	16.67	100	83.33		
SEL		250	10	75	110	110	270	-	
% of lower SEL		66.67	100	100	16.67	83.33	83.33		
GBC	Shale standard	20	0.3	68	90	45	95	19	Turekin and Wedephol, 1961 Taylor, 1946
	% of lower GBC	16.67	16.67	100	16.67	50	16.67		
	Earth Crust	12.5	0.15	75	100	39	67	17	

ERL: effects range low; TEL: threshold effect level; ERM: effects range median; PEL: probable effect level; SEL: severe effect level; GBG = geochemical background.

Table S4. Health risk assessment indices were used in this study.

Human health risk indices	Formula	Value	Cancer risks levels	References
Chemical Daily Intake (CDI)	$CDI = (C \times IngR \times EF \times ED \times CF)/(BW \times AT)$			USEPA, 2011a Abdelhafez and Li, 2015
Dermal Absorbed Dose (DAD)	$DAD = (C \times SA \times SL \times ABS/BW)/(EF \times ED)/AT)$			
Exposure Concentration (EC)	$EC_{inhalation} = (C \times EF \times ED \times CF_{inh})/(AT_n)$			
Non-cancer hazard assessment				
Hazard quotient (HQ)	$HQ = (CDI/RFD_0)$ $HQ = DAD/(RFD_0 \times GIABS)$ $HQ = (EC/RFC_i \times 1000\ \mu g/mg)$			USEPA, 2011a, b & c
Hazard index (HI)	$HI = \sum HQ$	HI ≤ 1 HI > 1	No significant hazard of non-carcinogenic effects Chance of non-carcinogenic effects	
Carcinogenic risk				
Cancer risks (CR)	$CR = CDI \times SF_0$ $CR = DAD \times (SF_0/GIABS)$ $CR = IUR \times EC$	$CR<10^{-6}$ $10^{-6} \le CR < 10^{-5}$ $10^{-5} \le CR < 10^{-4}$ $10^{-4} \le CR < 10^{-3}$ $CR > 10^{-3}$	Very low Low Medium High Very high	USEPA, 2011 b & c Li et al. (2015)

Abbreviation: C: metal concentration in sediment or 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^2 h) , ABS: absorption factor (unitless), Cf_{inh}: conversion factor (10^{-6} Kg/mg) (National Ambient Air Quality Standards, 2014)., ATn: average time (hours), Cf(inh): conversion factor of 3.5 *10^{-4}, RFD_0: oral reference dose (mg kg-1 day^{-1}), RfC_i: inhalation reference concentration (mg m^{-3}), SF_0: oral slope factor, IUR: inhalation unit risk ((μg m^{-3})$^{-1}$), The values of RFD_0, RFC_i, SF_0, GIABS and IUR were obtained from the USEPA (2011 b, c).

Table S5. Input parameters to characterize the HI values.

Parameter	Description	Value		Unit
		Adult	Child	
C	Contamination concentration			
IR	Ingestion rate per unit time (soil)	100	200	mg day^{-1}
EF	Exposure frequency	180	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^2h
SA	Exposure skin area	3300	2800	cm^2
ABS	Dermal absorption factor	0.001 for Cd		Unitless
		0.01 for other elements		
ATn	Average time-non cancer risk	ED*365*24		Hours
	Average time- cancer risk	70*365*24		

Table S6. Toxicity parameters used to investigate non-cancer and carcinogenic risks according to USEPA (2011a, b & c) and Ferreira-Baptista and De Miguel (2005).

Metals	SF_0 mg $kg^{-1}day^{-1}$	IUR $(\mu g\ m^3)^{-1}$	RFD_0 mg $kg^{-1}day^{-1}$	RFC_i 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
Cu		-	4.0E-02	-	1	0.01
Mn		-	1.4E-01	5.0E-05	1	0.01
Zn		-	3.0E-01	-	1	0.01