Assessment of the Heavy Metals Pollution and Ecological Risk in Sediments of Mediterranean Sea Drain Estuaries in Egypt and Phytoremediation Potential of Two Emergent Plants

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Supplementary Materials

Table S1. Coordinates and characterization of sampling sites along the four drains and Mediterranean Sea coast.

Sites	Location name	Longitude (E)	Latitude (N)	Different activities nearby sampling locations from LU/LC analysis
Drains stream				
1	El- Bustan drain	31.4536	31.7201	• Wastewater from Kafr Al-Battikh City • Wastewater from the industrial zone in New Damietta city. • Agricultural drainage water (agriculture lands and Orchids
2	El- Bustan drain	31.4422	31.7197	
3	Gamasa drain	31.4389	31.5534	• Wastewater from agricultural lands and villages along the drain
4	Gamasa drain	31.4157	31.5610	
5	Gamasa drain	31.4034	31.5119	
6	Belqas drain	31.4839	31.4011	• Agricultural drainage water
7	Kitchener drain	31.5489	31.1694	• Wastewater from agricultural lands and villages along the drain. • Collect industrial drainage of spinning factories of Kafr El-Sheikh and El-Gharbia Governorates.
8	Kitchener drain	31.4903	31.1502	
Drains estuary and Mediterranean Sea coast				
9	Med. coast	31.4775	31.7331	• Urban activities
10	Drain estuary	31.4748	31.7250	• Near the border of Damietta Port and New Damietta city.
11	Med. coast	31.4706	31.7106	• Residential area and El-Bustan drain estuary.
12	Med. coast	31.4426	31.5760	• Industrial activity is very intense in Gamasa cities and industrial effluents are discharged to Gamasa drain.
13	Drain estuary	31.4454	31.5637	
14	Med. coast	31.4499	31.5329	• Residential area and Gamasa drain estuary • Near the international coastal road
15	Med. coast	31.4913	31.4285	• The process of establishing the New Mansoura City. • Near the international coastal road. • Belqas drain estuary
16	Drain estuary	31.4992	31.4126	
17	Med. coast	31.5057	31.4020	
18	Med. coast	31.5755	31.2115	• Residential area and Kitchener drain estuary. • Near the international coastal road. • Near tourist villages. • Near the international coastal road.
19	Drain estuary	31.5822	31.1856	
20	Med. coast	31.6006	31.1047	

Table 2. Various pollution indices formulas used in the present study.

Index	Formula	References
Single indices of pollution		
Enrichment factor (Ef)	$\mathbf{EF} = \left(\frac{\boldsymbol{C_{sample}}}{\boldsymbol{Fe_{sample}}}\right) / \left(\frac{\boldsymbol{C_{ref}}}{\boldsymbol{Fe_{ref}}}\right)$	Franco-Uria et al. (2009)
Contamination factor (Cf)	$\mathbf{CF} = \boldsymbol{C_{sample}} \,/\, \boldsymbol{C_{ref}}$	Hakanson (1980)
Geoaccumulation index (Igeo)	$\mathbf{Igeo} = \mathbf{Log2}\left(\frac{\boldsymbol{C_{sample}}}{\mathbf{1.5Bn}}\right)$	Muller (1969); Lu and Bai (2010)
Ecological risk factor (Er)	$\mathbf{Er} = \mathbf{Ti} * \mathbf{Cf}$	Hakanson (1980)
Total complex indices (include integrated indices and indices of ecological risk)		
Degree of contamination (Dc)	$\mathbf{Dc} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \mathbf{CF}\boldsymbol{i}$	Hakanson (1980); Caeiro et al. (2005)
Potential ecological risk index (PERI)	$\mathbf{PERI} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \mathbf{ER}$	Kowalska et al. (2016)

Abbreviation: C*sample*: metal concentration in soil analyzed sample; Fe *sample*: concentration of the reference metal in soil analyzed sample; C*ref*: (background) metal concentration in the reference environment; Fe*ref* (background), reference 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; Ti: the toxic-response factor for a given substance; Cf: the contamination factor.

Table S3. Classes of used indices for metals in the present study.

Index	Value	Soil quality	Index	Value	Ecological risk
Ef	EF < 2 = natural, EF > 2 = anthropogenic		Er	Er < 40	Low ecological risk
	Ef < 1	Depletion or no enrichment		40 ≤ Er < 80	Moderate ecological risk
	Ef < 2	Minor enrichment		80 ≤ Er < 160	Considerable ecological risk
	Ef = 2-5	Small enrichment		160 ≤ Er < 320	High ecological risk
	Ef = 5-10	Moderately severe enrichment		Er ≥ 320	Very high ecological risk
	Ef = 10-25	Severe enrichment			
	Ef = 25-50	Very severe enrichment			
	Ef > 50	Extremely severe enrichment			
Cf	CF < 1	Low contamination factor	PERI	PERI < 150	Low risk
	1 ≤ CF ≤ 3	Moderate contamination factor		150 ≤ PERI < 300	Moderate
	3 ≤ CF ≤ 6	Considerable contamination factor		300 ≤ PERI < 600	Considerable
	6 ≤ CF	Very high contamination factor		PERI ≥ 600	Very high
Dc	DC < 8	Low DC			
	8 ≤ Dc < 16	Moderate DC			
	16 ≤ Dc < 32	Considerable DC			
	Dc > 32	Very high			
Igeo	Igeo ≤ 0	Uncontaminated			
	0 < Igeo < 1	Uncontaminated to moderately			
	1 < Igeo < 2	contaminated			
	2 < Igeo < 3	Moderately to heavily contaminated			
	3 < Igeo < 4	Moderately to strongly contaminated			
	4 < Igeo < 5	Strongly contaminated			
	Igeo > 5	Strongly to extremely contaminated			
		Extremely high contaminated			

Abbrivation: Enrichment factor (EF), Contamination factor (CF), Degree of contamination (Dc), Geoaccumulation index (Igeo), Ecological risk factor (Er) and Potential ecological risk index (PERI).

Table S4. Various indicators used in the present study to assess the potential of the two macrophytes species for phytoremediation.

Index	Formula	References
Bioaccumulation factor (BAF)	$\mathbf{BAF} = \frac{C_r}{C_{sample}}$	Baker (1981); Ghosh and Singh (2005)
Enrichment factor (EF)	$\mathbf{EF} = \frac{C_S}{C_{sample}}$	
Translocation Factor (TF)	$\mathbf{EF} = \frac{C_S}{C_r}$	

Abbreviation: C*sample*: metal concentration in sediment analyzed sample; Cr: metal's concentration in roots of the studied macrophytes species; Cs: metal's concentration in shoots of the studied macrophytes species.

Table S5. Microelement concentrations (mg kg^{-1}) in roots and shoots of three studied emergent hydrophytes naturally growing along studied drains.

Plant species	Plant part	Drain	Metals								
			Fe	Mn	Zn	Cu	Cr	Co	Cd	Ni	Pb
Cyperus alopecuroides	Root	El-Bustan (n=2)	1072.80	651.12	64.22	64.12	23.87	18.97	28.52	60.40	13.57
		Gamasa (n=3)	1807.50	785.82	98.93	98.82	58.57	53.67	63.22	95.11	44.61
		Belqas (n=1)	978.11	256.43	29.53	32.43	19.18	14.28	21.83	45.71	9.21
		Kitchener (n=2)	1186.14	764.46	77.56	77.45	37.21	32.31	41.86	73.74	23.24
		Mean	1261.14 ^{A}	614.46 ^{A}	67.56^{A}	68.20^{A}	34.71^{A}	29.81^{A}	38.86^{A}	68.74^{A}	22.66^{A}
		±SE	93.51	61.47	7.28	6.95	4.41	4.41	4.56	5.24	3.94
	Shoot	El-Bustan (n=2)	750.30	95.62	34.15	7.32	3.09	3.12	3.61	2.35	2.81
		Gamasa (n=3)	951.96	430.28	17.39	3.94	2.40	0.48	4.33	3.15	1.93
		Belqas (n=1)	345.17	124.49	35.87	12.30	4.25	4.58	11.35	2.87	6.48
		Kitchener (n=2)	853.76	432.08	19.19	5.74	2.62	2.28	5.36	2.11	2.13
		Mean	725.30^{B}	270.62 ^{B}	26.65^{A}	7.32^{B}	3.09^{B}	2.62^{B}	6.16^{B}	2.62^{A}	3.34^{AB}
		±SE	66.61	46.44	2.43	0.90	0.21	0.43	0.88	0.12	0.53
Persicaria salicifolia	Root	El-Bustan (n=2)	582.66	383.23	47.03	13.87	6.44	1.54	8.75	57.64	16.32
		Gamasa (n=3)	606.29	406.87	70.67	26.44	26.37	19.07	32.39	81.27	39.96
		Belqas (n=1)	591.78	392.35	56.15	15.92	15.56	9.66	17.87	66.76	25.44
		Kitchener (n=2)	593.57	294.15	57.95	17.72	17.36	11.46	19.67	68.56	27.24
		Mean	593.57^{B}	369.15 ^{B}	57.95^{A} ^{B}	18.49^{B}	16.43^{B}	10.43^{B}	19.67^{B}	68.56^{B}	27.24^{B} ^{C}
		±SE	2.43	12.73	2.43	1.38	2.04	1.80	2.43	2.43	2.43
	Shoot	El-Bustan (n=2)	496.73	170.42	32.73	2.90	5.29	1.19	7.16	41.01	8.32
		Gamasa (n=3)	556.17	273.49	37.45	7.61	10.01	1.29	11.88	45.73	13.03
		Belqas (n=1)	292.41	151.73	69.11	8.49	1.90	6.16	18.90	14.54	12.63
		Kitchener (n=2)	489.42	162.99	23.09	5.42	9.91	5.10	10.92	26.41	5.69
		Mean	458.68^{B}	189.65 ^{B}	40.59^{B}	6.10^{B}	6.78^{B}	3.43^{B}	12.22^{B}	31.92^{C}	9.92^{C}
		±SE	28.70	14.10	4.98	0.62	0.98	0.64	1.22	3.55	0.88
	P-value		0.0002***	0.0139*	0.0431*	0.0001***	0.0032**	0.0060**	0.0058**	0.000***	0.0135*

Different superscript letters within each element and factor mean values significance. Significance level fixed at *p*-values < 0.05. ***: significant at $p \leq 0.001$, **: significant at $p \leq 0.01$, *: significant at $p \leq 0.05$.