Environmental Risk Assessment and Chemical Contamination with Trace Elements Deposited in Drain Sediments South of Manzala Lake (Egypt)

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Abstract

The amounts of six heavy metals (Fe, Cd, Co, Cr, Ni, and Pb) were measured in all 15 sediment samples, which included three drains south of Manzala Lake (Egypt). The possible environmental risks of metals in the sediment of the three drains were investigated using soil indices and risk assessment. Results showed that heavy metal contamination was found at the studied sites along the three drains, and pollution levels varied depending on metals and sites. The mean concentration ($mgkg^{-1}$) ranked in the order of Fe(3950.24) > Cd(22.36) > Cr(21.15) > Co(19.01) > Pb(14.16) > Ni(10.40) for Faraskour drain, Fe (5067.80) > Cd (30.29) > Co (18.97) > Cr (16.90) > Ni(15.03) > Pb(12.16) for Al-Etaiwy drain and Fe(12.56.12) > Cd(19.60) > Co(17.15) > Ni(14.88) > Cr(10.10) > Pb(10.03) for Ramsis drain. The mean ranges of enrichment factor for Cd, Co, Pb, Ni and Cr were 167.46-3858.37, 6.11-51.78, 4.38-31.20, 1.07-11.84 and 0.61-7.43, respectively. The average degree of contamination revealed that the majority of the sites had reached very high levels of pollution, with the exception of site 1, which had reached a moderate level of contamination. The ecological risk of heavy metals can be ranked as follows: Cd>Co>Pb>Ni>Cr, and the PERI were 930.99, 1173.17 and 818.48 in the Faraskour, Al-Etaiwy and Ramsis drains, respectively. To decrease pollution, it was determined that more effective restrictions on Cd and Co were needed.

Keywords: Heavy metals, Pollution indices, Risk, Drains, Nile Delta

1. Introduction

Water is a necessary component for life to exist on this planet. Water covers roughly 71 percent of the Earth's surface, and the oceans store about 97 percent of all water on the globe, while freshwater accounts for only a tiny percentage of all water on the world. Only 3 percent of it is fresh water. Even then, just 1 percent of our freshwater is easily accessible, with much of it trapped in glaciers and snowfields [1, 2].

Today, pollution is occurring on a vast and unprecedented scale around the globe. Pollution is not only bad for the environment, but it is also bad for people. Pollution is defined as the introduction of pollutants into the natural environment that have a negative impact [3, 4]. This pollution has the potential to harm our wildlife, plants, and trees, as well as taint our drinking water. To put it another way, pollution is hazardous to all of us. In 2015, pollution claimed the lives of 9 million people throughout the world [5, 6].

Heavy metals (HMs), which have an atomic density of more than 6 g/cm3, are one of the most persistent contaminants in wastewater [7]. Arsenic, cadmium, chromium, lead, mercury, copper, nickel, and zinc are the most frequent hazardous heavy metals found in wastewater. High levels of heavy metals in water bodies cause significant health and environmental issues, as well as an increase in wastewater treatment costs [8, 9]. Human activities such as rapid industrialization, urbanization, and anthropogenic causes contribute to the existence and accumulation of HMs in the environment. Because HMs are non-biodegradable and toxic, they remain in wastewater [10-12].

Egypt's total canal and drain length is about 4700 km [13]. Aquatic weeds have infested these canals and drains, and environmental factors such as water clarity, depth of water, physico-chemical properties, water quality, water currents, and air temperature affect the degree of the infection. Problems with Egyptian irrigation canals have risen since the building of the Aswan High Dam in 1965 [14]. El-

Gharably *et al*. [15] and El-Amier *et al*. [9], on the other hand, blamed other ecological factors for the development of aquatic weeds in the Nile Delta's irrigation and drainage canals. Aquatic ecosystems are progressively being threatened as the populations grow and rising water demand in agricultural, domestic and industrial affairs [16, 17]. Egypt is the most populous country in the Middle East and North Africa region, with approximately 100 million inhabitants. Because Egypt's geography is mostly desert, 43.1 percent of the population lives in towns on the Nile or the Mediterranean Sea, such as Cairo, Alexandria, or Aswan [18]. The following were our study's objectives: i) to determine the level of pollution of six heavy metals (Ni, Cr, Fe, Co, Cd, and Pb) in three main drains that flow into Manzala Lake via the middle Nile Delta; and (ii) to use several pollutant indices to estimate the environmental risk along these drains.

2. Materials and Methods

Study area

The coastal lagoons of northern Egypt (Bardawil, Burullus, Mariout, Manzala, and Idku Lagoon) are one of Egypt's most valuable natural systems, with abundant birds and fish. There is a considerable amount of lake water pollution as a result of industrial, agricultural, and sewage pollutants spilling into the lakes through drains [19, 20]. The Nashart drain, El-Gharbia drain, Elhoks drain, El Shakhlouba drain, Elkashaa drain, Hadous drain, Faraskour drain, Al-Etaiwy drain, Ramsis drain, and Bahr El-Baqar drain are just a few of the main drains in the Nile Delta, which serve 64 percent of Egypt's total agricultural land area of 29,600 km^2. The Nile Delta might benefit from the reuse of drainage water or the specific use of treated wastewater [21].

One of these coastal lakes is Manzala Lake, located at the northeastern part of Nile delta, Egypt. Manzala Lake receiving huge amounts of wastewater from the nearby provinces through many inlets drains found along its south and west coasts.

There are different drains in the southern part of the Lake. The studied three drains are distributed as Figure (1); Faraskour and Al-Etaiwy drains are located at the southwestern part of lake and Ramsis drain in the southeastern part of the lake.
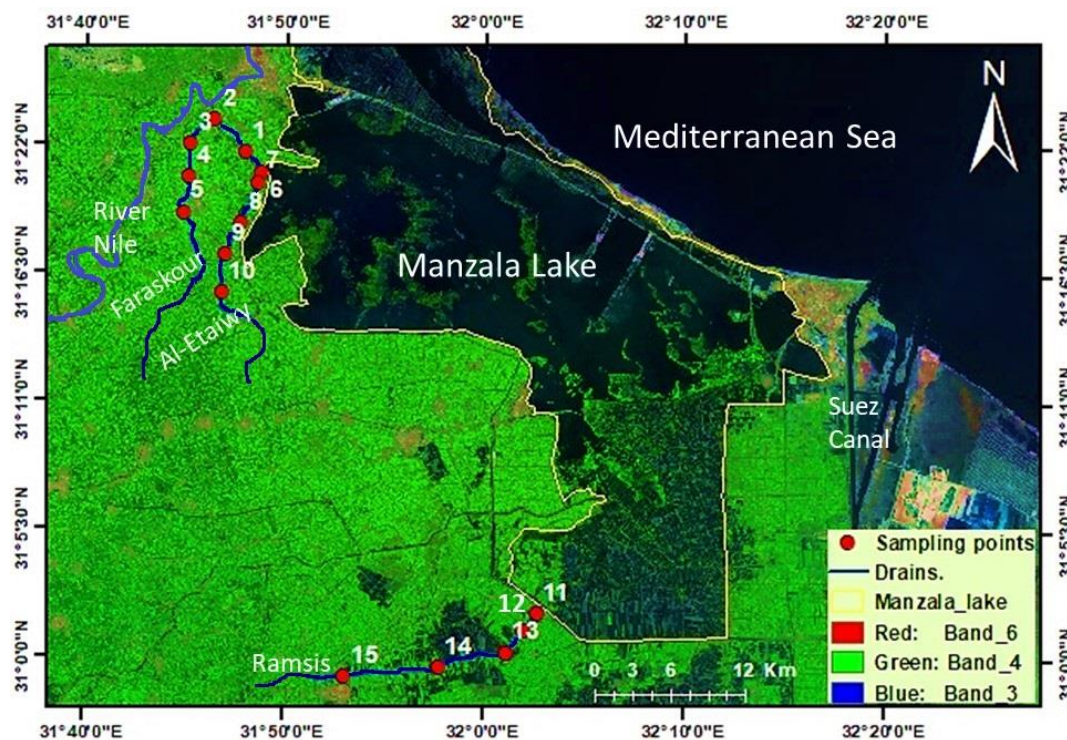
Figur 1. Location map showing studied sites (1-15) along the three drains, south Manzala Lake.

Metal analysis in sediments of drains

Along three drains south of Manzala Lake, fifteen georeferenced sediment samples were collected. The sampling locations were chosen to be 5–10 kilometers apart (Figure 1). A composite sediment sample was obtained at each location by combining three subsamples collected with a stainless hand auger. To eliminate stones and trash, the sediment samples were air-dried for several days at room temperature before being crushed and sieved with a 2 mm sieve. They were then placed in plastic bags to be examined chemically and physically. As reported by

Oregioni and Astone [22]. Soil samples were digested for roughly two hours in a combination of nitric acid, perchloric acid, and hydrochloric acid. The quantities of Ni, Cd, Fe, Co, Cr, and Pb in the investigated heavy metals (mg kg^{-1}) were determined using an Atomic Absorption-Spectrophotometer (ASSU, Buck Scientific Aceusys 211).

Metal pollution indices in sediment

To compute pollution quantification for each metal (Co, Cd, Ni, Fe, Cr, and Pb) along the drains, the enrichment factor (Ef), contamination factor (Cf), geoaccumulation index (I*geo*), ecological risk factor (Er), degree of contamination (Dc), and prospective ecological risk index (PERI) were employed. Table 1 shows the categorization of pollution indicators as well as the sediment quality associated with them.

Enrichment factor (Ef)

The probable sources (natural or anthropogenic) of elements in sediments were determine by enrichment factor (E*f*). The Ef of elements is express by the equation of Franco-Uria *et al.* [23].

$$\mathrm{E}f = \left(\frac{\mathrm{C_{sample}}}{\mathrm{Fe_{sample}}}\right) \Big/ \left(\frac{\mathrm{C_{ref}}}{\mathrm{Fe_{ref}}}\right)$$

C*sample*: concentration of element in the soil sample that was analysed; Fe*sample*: in the soil sample under study, the concentration of the reference metal; C*ref*: the reference environment's element content (background); Fe*ref* (background), reference element content in the reference environment. Iron (Fe) is considered a normalization element for the following reasons: Fe is connected to fine to medium solid elements, has a geochemistry comparable to many heavy metals, and has a steady natural concentration in the investigated area [24].

Contamination factor (Cf) and degree of contamination (Dc)

The contamination status of the sediment was determined using the contamination factor and degree of contamination [25, 26].

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$$\mathbf{Cf} = C_{sample} / C_{ref}$$

$$\mathbf{Dc} = \sum_{i=1}^{n} \mathbf{Cfi}$$

Geo-accumulation index (Igeo)

The geo-accumulation index is used to assess the present state of the environment and metal pollution in relation to natural environments. To assess the degree of pollution, it uses chemical data. The I_{geo} values were determined according to the equation of Muller [27] and Lu and Bai [28].

$$Igeo = Log2\, (C_{Sample}/1.5Bn)$$

C_{sample} represents the metal content in the sediment, Bn denotes the geochemical background value in average shale of element *n*, and 1.5 is the background matrix correction due to terrigenous effects.

Ecological risk assessment of heavy metal concentrations

The ecological risk index (Er) of single heavy metals in the sediments was used to characterize the potential ecological risk index (PERI). The PERI was used to determine the ecological sensitivity of heavy metal contamination in stream sediments based on heavy metal toxicity and environmental responses [25, 29].

$$RI = \sum_{1}^{n} Er$$

$$Er = Ti \times Cf$$

C*f*: the contamination factor; T*i*: the toxic-response factor for a specific metal.

Table 1. Classes of used indices and ecological risk for metals in the present study.

Ef		I*geo*	
Classes	**Sediment quality**	**Classes**	**Sediment quality**
EF < 2 = natural,		I*geo* $\leq$ 0	Uncontaminated
EF > 2 = anthropogenic		0 < I*geo* < 1	Uncontaminated to moderately contaminated
Ef < 1	Depletion or no enrichment	1 < I*geo* < 2	Moderately to heavily contaminated
Ef < 2	Minor enrichment	2 < I*geo* < 3	Moderately to strongly contaminated
Ef = 2-5	Moderate enrichment	3 < I*geo* < 4	Strongly contaminated
Ef = 5-10	Moderately severe enrichment	4 < I*geo* < 5	Strongly to extremely contaminated
Ef = 10-25	Severe enrichment	I*geo* > 5	Extremely high contaminated
Ef = 25-50	Very severe enrichment		
Ef > 50	Extremely severe enrichment		
C*f*		**D*c***	
Classes	**Sediment quality**	**Classes**	**Sediment quality**
CF < 1	Low contamination factor	DC < 8	Low DC
$1 \leq CF \leq 3$	Moderate contamination factor	$8 \leq Dc < 16$	Moderate DC
$3 \leq CF \leq 6$	Considerable contamination factor	$16 \leq Dc < 32$	Considerable DC
$6 \leq CF$	Very high contamination factor	Dc > 32	Very high
E*r*		**PERI**	
Classes	**Sediment quality**	**Classes**	**Sediment quality**
Er < 40	Low ecological risk	PERI < 150	Low risk
$40 \leq Er < 80$	Moderate ecological risk	$150 \leq PERI < 300$	Moderate
$80 \leq Er < 160$	Considerable ecological risk	$300 \leq PERI < 600$	Considerable
$160 \leq Er < 320$	High ecological risk	$PERI \geq 600$	Very high.
$Er \geq 320$	Very high ecological risk		

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

3. Results and Discussion

Heavy metals concentration in sediments

Heavy metal concentrations and bioavailabilities in sediments are not fixed in time; they are influenced by a variety of factors [30, 31]. Table 2 shows the typical amounts of HMs (Fe, Cd, Cr, Co, Ni, and Pb) in surface sediments from 15 sites throughout the three drains. We found significant differences in Fe and Pb concentrations between the various streams (Faraskour, Al-Etaiwy, and Ramsis drains) in our study, but no significant differences in Cd, Cr, Co, or Ni. Generally, the mean concentration (mg kg^{-1}) ranked in the order of Fe(3950.24) > Cd (22.36) > Cr(21.15) > Co(19.01) > Pb(14.16) > Ni(10.40) for Faraskour drain, Fe(5067.80) >

Cd(30.29) > Co(18.97) > Cr(16.90) > Ni(15.03) > Pb(12.16) for Al-Etaiwy drain and
Fe(12.56.12) > Cd(19.60) > Co(17.15) > Ni(14.88) > Cr(10.10) > Pb(10.03) for
Ramsis drain. The concentration of heavy metals in the sediment of the three drains is
higher than that of the River Nile (Damietta branches) as a background and reference
point, thus indicating significant pollution. In particular, Cd, Cr, and Co
concentrations are greater than other heavy metals, which is consistent with discharge
and human activities along the three drains. The lower concentrations of other heavy
metals are most likely due to less discharge.

Table 2. Descriptive data of heavy metal (mg/Kg) in the sediment samples from
different sites of the studied drains in the Nile Delta.

Stations	Statistic	Heavy metals (mg/Kg)					
		Fe	Cr	Co	Cd	Ni	Pb
Faraskour drain (n=5)	Min	2746.12	3.84	8.38	3.30	5.03	11.62
	Max	5812.13	44.04	28.78	45.08	17.18	17.14
	Mean	3950.24[a]	21.15[a]	19.01[a]	22.36[a]	10.40[a]	14.16[a]
	±SD	1347.65	18.32	7.51	18.50	4.40	2.27
	Median	3149.63	16.48	19.46	12.25	10.02	14.65
	%CV	34.12	86.59	39.52	82.73	42.32	16.05
Al-Etaiwy drain (n=5)	Min	3819.47	6.45	13.36	15.72	8.36	10.01
	Max	7238.18	41.52	26.57	43.09	24.51	14.41
	Mean	5067.80[a]	16.90[a]	18.97[a]	30.29[a]	15.03[a]	12.16[ab]
	±SD	1381.38	14.10	5.02	11.96	7.38	1.78
	Median	4882.32	11.51	17.79	34.47	12.21	11.96
	%CV	27.26	83.47	26.45	39.50	49.12	14.66
Ramsis drain (n=5)	Min	1092.78	1.40	8.93	11.74	5.55	6.52
	Max	1596.76	17.61	25.91	30.49	21.20	16.44
	Mean	1256.12[b]	10.10[a]	17.15[a]	19.60[a]	14.88[a]	10.03[b]
	±SD	199.01	6.71	7.20	7.07	5.87	4.06
	Median	1205.63	12.53	15.95	18.02	15.90	8.51
	%CV	15.84	66.48	41.99	36.05	39.47	40.50
p-value		0.0005***	0.47ns	0.88ns	0.45ns	0.41ns	0.04*
Permissible limits worldwide							
EU (2002)		-	150	11.6	3	75	300
CSQGD (2007)		-	64	40	1.4	50	70
Average Shale		47200	90	19	0.3	68	20
Toxic response factor		-	2	5	30	5	5

CV: Coefficient of variation, SD: Standard deviation, (CSQGD): Canadian soil quality guidelines for the protection of
environmental and human health document (2007); EU: European Union Standard (2002); Average shale, after Turekian
and Wedepohl (1961); ***: significant at $p \leq 0.001$, **: significant at $p \leq 0.01$, *: significant at $p \leq 0.05$, ns: non-
significance.

Spatial distribution of heavy metals

The total content of heavy metals concentration fluctuations at sites 1-15 but middle stream in Faraskour and Ramsis drains (sites 3 and 13), and downstream in Al-Etaiwy drain (site 6) attained the highest content (Figure 2). The observation from the obtained data of all the measured heavy metals that cadmium, as it showed higher values other than the rest of the measured elements (Table 2). Our findings revealed that iron is the most prevalent element in the sediments, with concentrations ranging from 1092.78 mg/kg in Ramsis drain to 7238.18 mg/kg in Al-Etaiwy drain (Table 2). Fe is a prevalent element in all environments, and after oxygen and silicon, it is the third most plentiful element in the Earth's crust [32]. Anthropogenic activities have an impact on Fe distribution in the water stream (steel industry, sewage, etc.) [33]. Farhat [32] who claimed that iron and manganese are intimately linked in a geochemical cycle, agreed with El-Alfy et al. [34] and Bessa et al. [35].

For the Faraskour and Al-Etaiwy drains, the distribution of Cd, Cr, Co, Ni, and Pb showed an incremental rise in concentrations from downstream to middle stream, while the distribution of heavy metals fluctuated across five sites in the Ramsis drain (Figure 2). Because the cadmium background levels were low, any increased Cd concentrations were likely due to runoff from agricultural area that employed fertilizers, herbicides, and pesticides. Agricultural activities, notably the use of ammonium fertilizers, as well as industrial processes such as chromium plating, metal finishing, leather tanning, and paint manufacturing, might have contaminated the environment with Cr in the studied areas [36, 37]. Organic substances, carbonates, and Fe/Mn oxides account for the majority of Co and Ni metal measurements [38]. In soils, Co has a poor mobility and a high adsorption; however its mobility improves in wet, acidic soils [39]. The sites along three drains, which received significant amounts of sewage effluent and agricultural runoff, are mostly blocked.

The greatest Pb concentration (17.14 mg/kg) was found in the middle stream of the Faraskour drain, while the lowest concentration (6.52 mg/kg) was found

downstream of the Ramsis drain. The major source of Pb has been recognised as anthropogenic output, such as automobile exhaust and car batteries, industrial effluents, sewage sludge, fertilizer, and pesticide application, according to several studies [40]. Generally, the mean values of Cr, Ni and Pb in sediments of the three drains are within EU [41] and CSQGD [42], Cd higher than EU [41] and CSQGD [42], and Co higher than EU [41] but lower than CSQGD [42] (Table 2).
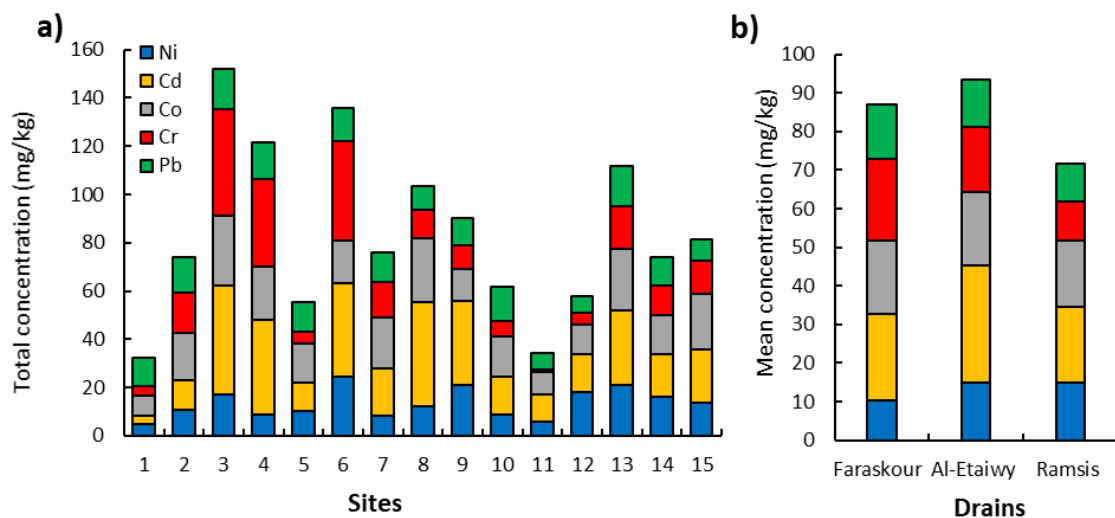
Figure 2. Spatial distribution of heavy metals in the sediment of the three drains **a)** different sites and **b)** three drains in the east Nile Delta

Correlation matrix between heavy metals

Table 3 displays the correlation coefficients as a linear correlation matrix. Cr was positively correlated ($p \leq 0.05$) with Co, Cd, and Pb (r = 0.610, 0.743, and 0.641, respectively) in a Pearson correlation coefficient (r) analysis of heavy metals (Table 3). Zhang *et al*. [43] and El-Amier *et al*. [31] reported the positive correlation of Cr with Co, Cd, Zn, Pb and Cu contents. El-Amier *et al*. [31] and Alhassan *et al*. [44], in contrast to our findings, found that Cr is negatively correlated with Ni. Cobalt had a strong positive linear correlation with Cd and Pb (r = 0.707 and 0.562, respectively), while cadmium had a weak positive linear correlation with Ni (r = 0.566). El-Amier

et al. [31] reported that Ni presence is not linked with Pb, Cr, Fe and Co in the sediment of drains.

The positive correlations among metals may reflect the fact that these metals had similar pollution levels, the same behavior during transport, and common sources or at least one major source [45].

Table 3. Pearson correlation matrix of heavy metals from the three studied drains in Nile Delta.

| Heavy metals	Fe	Cr	Co	Cd	Ni	Pb
Fe	1					
Cr	0.512	1				
Co	0.238	0.610*	1			
Cd	0.312	0.743**	0.707**	1		
Ni	0.108	0.443	0.291	0.566*	1	
Pb	0.478	0.641*	0.762**	0.389	0.201	1

**, *: correlation is significant at the 0.01 level or 0.05 (2-tailed), respectively.

Assessment of heavy metal pollution

Enrichment factor (Ef)

The EF was used to assess the impact of anthropogenic contamination on sediment heavy metal concentrations. In this work, iron was utilized as a reference element to calculate EF values [46]. The examined metal mean values were ranked in descending order for their EF values, as follows: Cd > Co > Pb > Ni > Cr (Figure 3). The measured ranges of EF for Cd, Co, Pb, Ni and Cr were 167.46-3858.37, 6.11-51.78, 4.38-31.20, 1.07-11.84 and 0.61-7.43, respectively. In the present study, the E*f* fluctuation from depletion to extremely severe enrichment along the three drains. A heavy metal with an EF between 0.05 and 1.50 is entirely derived from crustal materials and natural processes, according to Liu *et al*. [46]. Whereas a heavy metal with an EF more than 1.50 is totally derived from non-crustal materials, such as direct and indirect anthropogenic sources. On this basis, the heavy metals analyzed were

most likely delivered to the three drains by anthropogenic sources (Figure 3). Metals' bioavailability and toxicity in sediment samples are determined not only by their quantities, but also by their chemical forms [47].
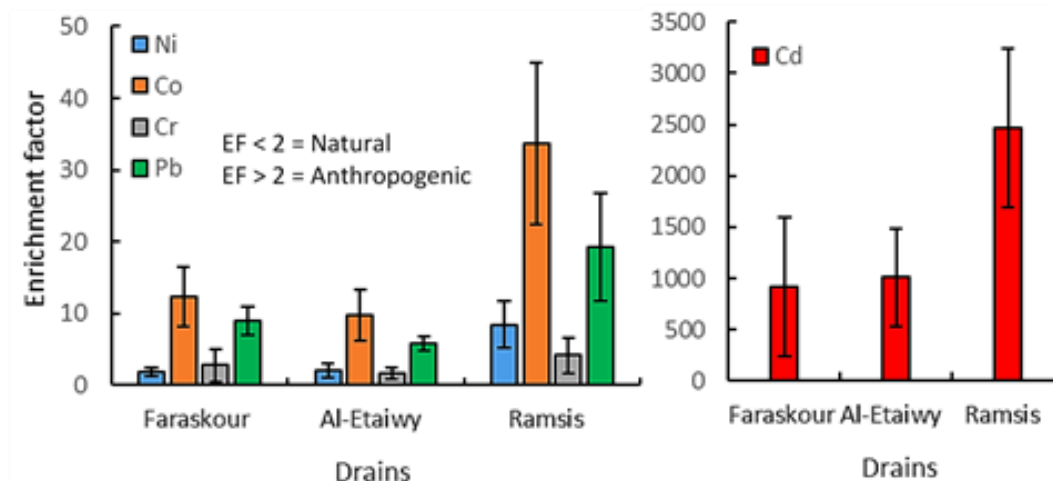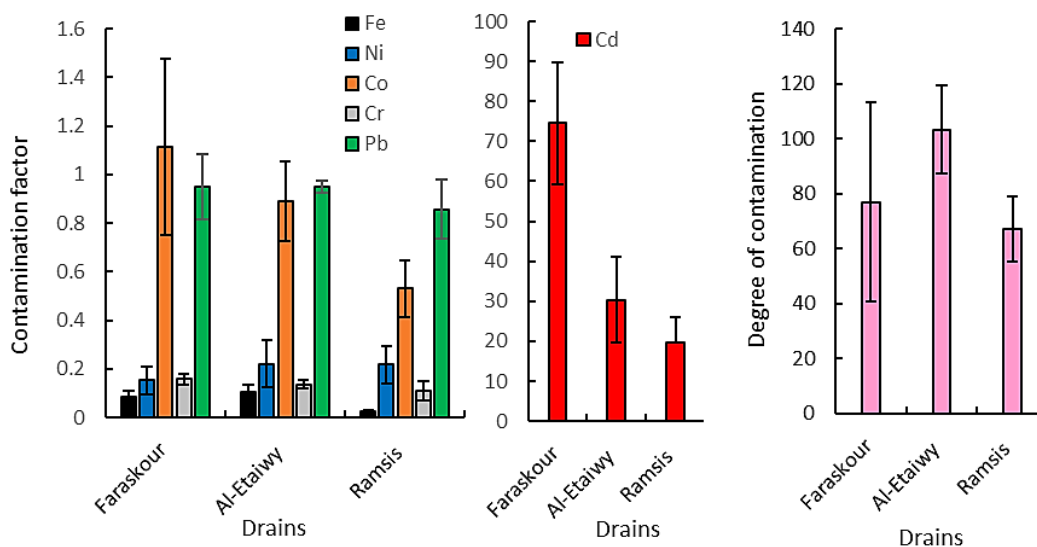

Figure 3. The enrichment factor of the heavy metals in the sediment samples collected from several sites in the east Nile Delta's drains

Contamination factor (Cf) and degree of contamination (DC)

By comparing the metal content in the sediment to the metal concentration in the unpolluted sediment, the contamination factor (Cf) is used to assess sediment contamination. For measuring heavy metal contamination in soil, the quantity of metals in the Earth's crust is utilized as a reference value [25]. The current findings show that the mean Cf values for Cr, Co, Pb, and Ni at all sites are less than one (low contamination). On the other hand, Cd showed very high contamination factor ($6 \leq CF$) at all sites (mean Cf = 80.27), with the highest concentrations at sites 3 and 8 in Faraskour and Al-Etaiwy drains, respectively. Meanwhile, the C*f* values of metals varied dramatically between the sites investigated (Figure 4).

Furthermore, the average degree of contamination (Dc) revealed that the majority of the sites had Dc > 32 (i.e., very high degree of contamination), with the

exception of site 1, which had Dc = 11.89 (moderate degree of contamination) (Figure 4). According to Hakanson [25] and Caeiro *et al*. [26], the results pointed to significant anthropogenic contamination. Contaminants are transported downstream from upstream sources and deposited (such as agricultural land, sewage, and tributaries).


Figure 4. Heavy metal contamination factors and degree of contamination in sediment samples collected from several sites in the east Nile Delta's drains

Geo-accumulation Index (Igeo)

The I*geo* is the most reliable and widely used index for determining heavy metal accumulations in aquatic sediments. The I*geo* was computed using the element's geochemical background value in the average shale [29]. According to the current Igeo findings for the examined metals, the sediments in the studied drain can be classified as class 0 (Igeo < 1; i.e., uncontaminated; Fe, Ni, Cr, Co and Pb). Meanwhile, the Igeo value for Cd fall into class 2 (1 < Igeo < 2; i.e., moderately to heavily contaminated) in all sites, except site 1 at Faraskour drain fall into class 1 (0 < Igeo < 1; uncontaminated to moderately contaminated). These groups denote various levels of sediment quality and pollution in certain areas. As a result,

according to Müller [48], the Manzala Lake drains are free of Fe, Cr, Co, Ni, and Pb, but moderately to heavily polluted with Cd, in the sequence Cd > Pb > Co > Cr > Ni > Fe (Figure 5).

We can see from the above pollution indices that Igeo has the similar trend as Ef and Cf, implying that the drains emptying into Manzala Lake are largely uncontaminated (i.e., of natural origin), with the exception of moderate to high Cd contamination (i.e., anthropogenic origin).
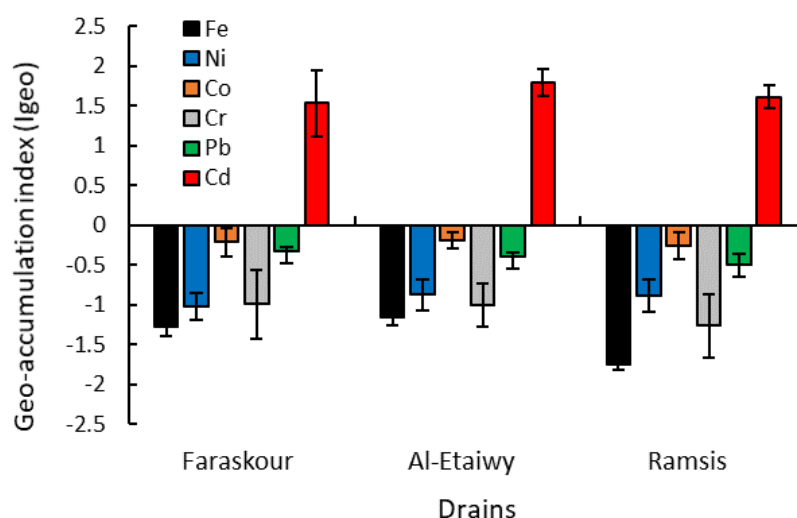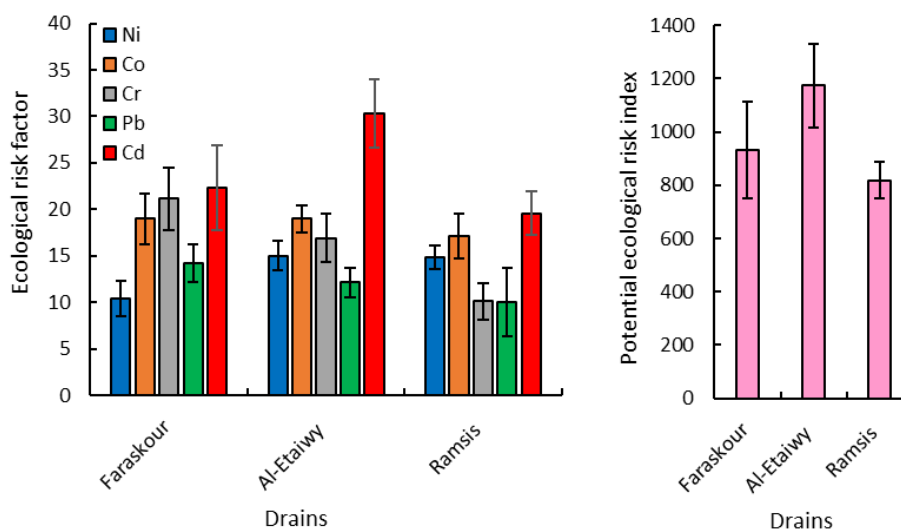

Figure 5. I_{geo} of heavy metals in the sediment samples from several sites of the studied drains in the east Nile Delta.

Ecological Risk Assessment

The potential ecological risk index (PERI) was used to characterize the ecological risk index (Er) of single heavy metals in sediments. The PERI was used to determine the ecological sensitivity of heavy metal contamination in stream sediments based on heavy metal toxicity and environmental responses [25]. Figure 6 depicts the results of the Er and PERI evaluations. The following is a ranking of the Er of heavy metals in drain sediments: Co > Pb > Ni > Cr > Cd (Figure 6). The Er index for Cr had a mean value of less than 40 (Er 40; i.e., low ecological risk). The

mean Er values of Ni and Pb were 52.03, 75.14, 74.40 and 70.80, 60.78, 50.13 for Faraskour, Al-Etaiwy and Ramsis drains, respectively (i.e., moderate ecological risk $(40 < Er < 80)$) (Figure 6). The mean values of the Er index for Co was higher than 80 ($80 \leq Er < 160$; i.e considerable ecological risk). Furthermore, Cd is one of the most dangerous heavy metals, surpassing the geochemical background value in the average shale. As a result, the toxicity levels for Cd in the middle Nile Delta required to be investigated further in order to assess their distribution on a larger scale, evaluate their possible consequences, and devise a plan for controlling these pollutants.

The PERI values in the Faraskour, Al-Etaiwy, and Ramsis drains were 930.99, 1173.17, and 818.48, respectively. The three drains investigated in the middle Nile Delta have extremely high levels of sediment ecological damage. When comparing the Al-Etaiwy drain to the others, we observed that the potential ecological risk is higher [31].

Figure 6. Ecological risk factor and potential ecological risk index of heavy metals in the sediment samples from several sites of the studied drains in the east Nile Delta.

4. Conclusion

The degree of heavy metal pollution varies depending on the metal species and the site. For the Faraskour and Al-Etaiwy drains, the distribution of Cd, Cr, Co, Ni, and Pb showed an incremental rise in concentrations from downstream to middle stream, while the distribution of heavy metals fluctuated across five sites in the Ramsis drain. As a result, effective measures to limit Cd, Co, and Cr pollution in the study area should be implemented. In comparison to the others, the Al-Etaiwy drain poses a significant risk to the environment. Thus, it is recommended to conduct an urgent and systematic study of heavy metals in the sediments of drains in the Nile Delta and to assess the source of pollution because it can significantly reduce the toxicity of these elements, and thus contribute to improving the environmental risks of the local residents in the Nile Delta.

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