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Research article

Land use/cover and eco-toxicity indices for identifying metal contamination in sediments of drains, Manzala Lake, Egypt

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ABSTRACT

Six heavy metals in three main drains along the East Nile Delta were estimated to assess the environmental risk and employ land use/cover map of each drain. Composite sediment samples ($n = 3$) were collected from each drain. The elements were analyzed by Atomic Absorption Spectrophotometer. The order of metal ions in the sediments of three drains of Manzala lake take the following order: Fe > Co > Ni > Cr > Cd > Pb in El-Serw drain, Fe > Ni > Co > Cd > Cr > Pb in Hadous drain and Fe > Cd > Ni > Co > Pb > Cr in Bahr El-Baqar drain. Studied Pollution indices indicate that drains discharged into Manzala Lake are mostly contaminated by metals. Geo-accumulation index showed contamination by Cd in all sites especially in site 13 of Bahr El-Baqar drain and low values to others. The mean probable effect level quotient showed percent of 21% in Hadous and El-Serw drains and 73% probability of being toxic in Bahr El-Baqar drain. The mean effect range median quotient also showed 21% in Hadous and El-Serw to 49% probability of being toxic in Bahr El-Baqar drains. Index of anthropogenicity impact indicate that the man-made activity either agricultural, industrial or fisheries impacted in the appearance of metal ions in the following sequence; Cd > Co > Pb > Ni > Cr. Hazard severity according to hazard quotient and modified hazard quotient of Ni and Cd take the following sequence; El-Serw < Hadous < Bahr El-Baqar drains. For Cr is; Hadous < Bahr El-Baqar < El-Serw and Pb is; Hadous < Elserw < Bahr El-Baqar drains. According to contamination severity index showed low for Pb, Ni and Cr and severe for Co and Cd which take the sequence of; Bahr El-Baqar > El-Serw > Hadous.

1. Introduction

Surface waters are the most important economic resource for humans which provide water for agricultural, industrial and anthropogenic activities (Afed Ullah et al., 2018). Evaluating land use and land cover (LU/LC) and water quality relationship is valuable because it will give an idea about freshwater protection which would help us in fulfilling the growing demand of water in various sectors including industrial usage, agricultural consumption, municipal usage, potable water supply, and recreational use. Surface waters have natural sediment and nutrients deposited in them from the land by natural processes. However, as inland uses and land cover changes mostly from human development, land can provide excessive levels of nutrients and sediment to surface waters (Banner et al., 2009). The sources of water quality pollution not only come from rivers and lakes but also from the land use/cover and the production activities of humans (Qiang et al., 2016).

Sediment-associated contaminants especially the heavy metals have the potential to cause direct effects on sediment-dwelling organisms and can indirectly adversely affect a man and other animals at the higher trophic levels. Thus, information on sediment quality conditions is necessary to assess the overall status of aquatic ecosystems (Ogbeibu et al., 2014). The problem of high content of heavy metals in soils is related to the latter's geo- and bioaccumulation ability (Oti Wilberforce, 2015).

Heavy metals are characterized by two main features-the toxic effects on living organisms at relatively low concentrations and bioaccumulative abilities. Being rich in heavy metal sediments, plants and bottom sediments become toxic over time, posing a significant risk to all living organisms. (Osunkiyesi et al., 2008). Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and the diversity of aquatic organisms (Farombi et al., 2007). To determine heavy metal contamination in aquatic ecosystems, sediment quality guidelines and background values are widely used in ecological risk assessments (Burton, 2002).

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Table 1. Description of studied drains.

Drain	Characterization	Inflow %	Sampling No	Ref.
El-Serw	Agriculture drain serves 68,700 feddans (152.8 km^2).	13	1–5	Zahran et al., (2015)
Hadous	Is the largest drain in the eastern delta, serving some of the agricultural lands of about 1756.96 km^2.	49	6–10	
Bahr El-Baqar	Serves an agricultural area of about 119.2 km^2, and receives about 300 million m^3/year of treated and untreated sewage from Cairo.	25	11–15	

Heavy metal bioaccumulation in the food chain can be especially highly dangerous to human health. These metals enter the human body mainly through two routes namely: inhalation and ingestion, and with ingestion being the main route of exposure to these elements in the human population (Iheanacho et al., 2017).

In Egypt, the Nile water and coastal lakes (Manzala, Burullus, Idku and Mariut) and other aquatic ecosystems are directly and/or indirectly affected by various anthropogenic activities, due to hosts a number of highly populated cities. The irrigation and drainage system of East Nile Delta is complicated, and there is a large portion of the agricultural drainage water is reused to supplement the shortage of freshwater, which comprises many major drains south to Manzala lake namely El-Serw, Faraskur, El-Matria, Hadous and Bahr El-Baqar drains. After discharge of wastewater without proper care from different sources (industrial, fertilizer and sewage water), HMs accumulates in the sediment. Over time, the concentration of heavy metals in contaminated sediment frequently exceed those required as nutrients or background levels, resulting in uptake by plants and deposition to unacceptable levels. The research focus on three main drains which are El-Serw, Hadous and Bahr El-Baqar drains. The objectives of this search are: (i) the linkage between metal distribution with the LU/LC areas around studied drains, (ii) Identifying metal contamination, accumulation and ecotoxicology of it using different ecological indices, and (iii) Characterization of the environmental status in every studied drain based on studying metal analysis and data treatment using indices for giving interpretation.

2. Materials and methods

2.1. Study area

The northern Egyptian coastal lagoons (Mariout, Manzala, Idku, Burullus, and Bardawil Lake) are among the most productive natural systems in Egypt and are known globally for their abundant birdlife and fish production. A high level of lake water pollution, due to the industrial, agricultural and sewage wastes poured into the lakes through the drains (El-Shazly et al., 2017; El Kafrawy et al., 2018). The description of each drain is as shown in Table 1, georefernced 5 samples were collected from each drain (Figure 1). The number of sampling sites is 15.

2.2. Landsat data and remote sensing indexes and GIS application

Landsat image was downloaded from this site (*http://earthexplorer.usgs.gov*) with path 177 and row 38 of OLI_8 sensor type at the acquisition date of 2018. Clipping the studied areas for each drain was done using ArcGIS. The areas of agriculture, urban, industrial, canals are drawn in Google Earth in KML file then converted in shapefile in ArcGIS program. Normalized different vegetation index (NDVI) and Normalized different water index (NDWI) were measured according to the following Eqs. (1) and (2) respectively;

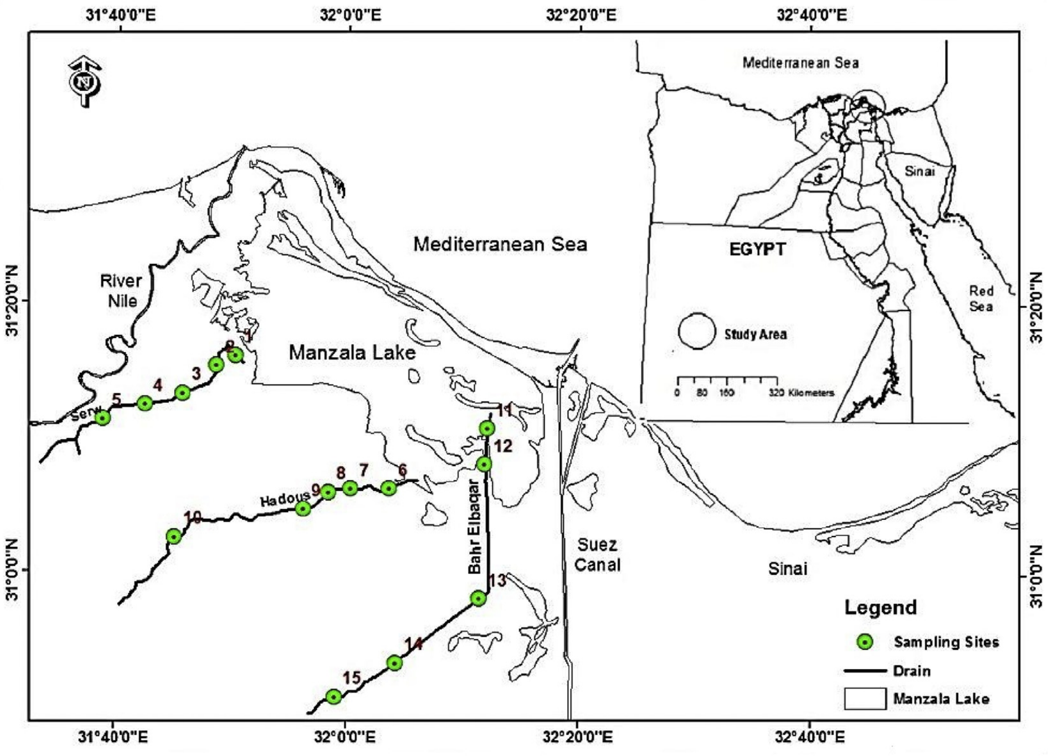


Figure 1. Map shows sampling sites in different drains, south Manzala Lake.

$$\mathrm{NDVI} = \frac{\mathrm{NIR}\ (b5) - \mathrm{Red}\ (b4)}{\mathrm{NIR}\ (b5) + \mathrm{Red}\ (b4)} \tag{1}$$

$$\mathrm{NDWI} = \frac{\mathrm{Green}\ (b3) - \mathrm{NIR}\ (b5)}{\mathrm{Green}\ (b3) + \mathrm{NIR}\ (b5)} \tag{2}$$

2.3. Metal analysis in sediments of drains

A total of 15 sediment samples were taken along three drains south Manzala Lake. Sampling sites were selected to be far between 30 and 40 km (Figure 1). In each site, A composite sediment sample consisted of three subsamples obtained using a stainless hand auger. The sediment samples were airdried for several days at room temperature and then ground and sieved using a 2 mm sieve to remove gravel and debris, and stored in plastic bags for subsequent chemical and physical analyses. Soil samples were digested for about two hours in a mixture of nitric acid, perchloric acid and hydrochloric acid as described by Oregioni and Astone (1984). The studied heavy metals concentrations (μg/g) of Fe, Ni, Co, Cd, Cr and Pb were measured using Atomic Absorption Spectrophotometer (ASS, Buck Scientific Accusys 211).

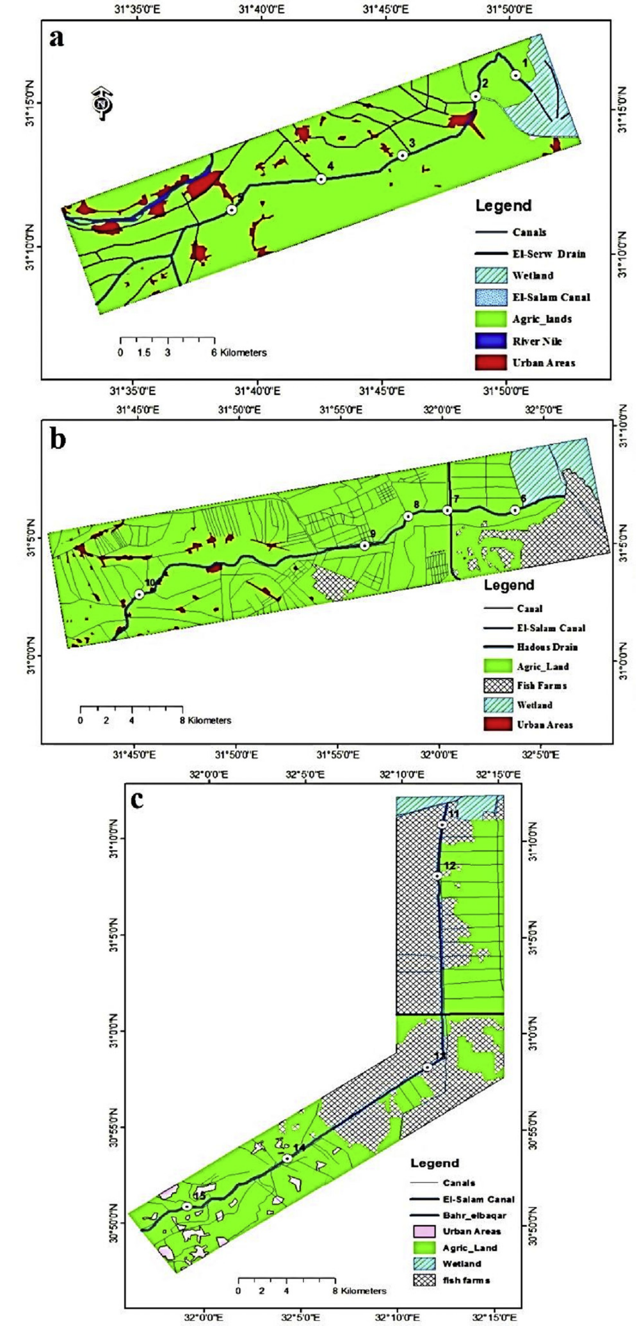


Figure 2. Land use map of the three drains (a: El-Serw, b: Hadous and c: Bahr El-Baqar drains) discharged in Manzala Lake, Egypt.

2.4. Metal pollution indices in sediment

2.4.1. Potential contamination index (PCI)

The potential contamination index of metal i ($\mathrm{PCI_i}$) was calculated according to Davaulter and Rognerud (2001) as the following Eq. (3):

$$\mathrm{PCI_i} = \frac{C_i\mathrm{max}}{C_{\mathrm{bkg}}} \tag{3}$$

Ci (max): the maximum concentration of metal I in the sediment, C_{bkg}: the background concentration of the metal. The contaminated classes according to PCI values are: PCI < 1 indicates low contamination, $1 <$ PCI < 3 as moderate contamination, and PCI > 3 being considered as severe or very severe contamination.

2.4.2. Geo-accumulation index (Igeo)

Geoaccumulation index (Igeo) was used to define metal contamination in sediments. It's calculation is according to Muller (1969) as Eq. (4).

$$I_{\mathrm{geo}} = \log_2\left(\frac{C_n}{1.5B_n}\right) \tag{4}$$

where C_n is the measured concentration of the metal n in the sediment, B_n is the background value for the metal and factor 1.5 is used for possible variations of the background data due to lithological variations.

2.5. Eco-toxicological assessment of heavy metal concentrations

2.5.1. The mean probable effects level quotient ($\mathrm{mPEL_Q}$)

The mean Probable Effects Level quotient ($\mathrm{mPEL_Q}$) was calculated to determine the possible biological effect using the formula of Eq. (5):

$$\mathrm{mPEL_Q} = \frac{\sum_{i=1}^{n}\frac{C_i}{\mathrm{PEL_i}}}{n} \tag{5}$$

where C_i is the metal concentration i, $\mathrm{PEL_i}$ is the probable effect level value for metal i, and n is the sum of the metals considered. Moreover, the $\mathrm{mPEL_Q}$ is classified into four grades: low degree of contamination ($\leq$0.1), medium-low degree of contamination (0.11–1.5), high-medium degree of contamination (1.51–2.3), and high degree of contamination (>2.3), respectively having a 8%, 21%, 49% and 73% probability of being toxic (Carr et al., 1996; Long et al., 2006).

2.5.2. The mean effect range median quotient ($\mathrm{mERM_Q}$)

The mean Effect Range Median quotient ($\mathrm{mERM_Q}$) was calculated according to the following Eq. (6):

$$\mathrm{mERM_Q} = \frac{\sum_{i=1}^{n}\frac{C_i}{\mathrm{ERM_i}}}{n} \tag{6}$$

where ERMi is the ERM for metal i. The four levels classification of mERMQ is: low priority site ($\leq$0.1), medium-low priority site (0.1–0.5), high-medium priority site (0.5–1.5), and high priority site (>1.5) with a 9%, 21%, 49% and 76% probability of being toxic, respectively (Long et al., 2000).

2.5.3. Contamination severity index (CSI)

CSI is calculated based on Eqs. (6) and (7):

$$W_t = \frac{L_{f_i} x E_V}{\sum_{i=1}^{n} \left(L_{f_i} x E_V\right)} \tag{7}$$

$$CSI = \sum_{i=1}^{w} W_t \left[\left(\frac{C_i}{ERL_i}\right)^{1/2} + \left(\frac{C_i}{ERM_i}\right)^{2} \right] \tag{8}$$

where W_t is the weighted value for n number of heavy metals, L_{fi} is the factor loading associated with individual metal, E_v is the eigenvalue, C_i is the measured concentration of metal in sediment, ERL_i is the effects range low and ERM_i is the effects range median. The following tiers are used for CSI values: $CSI < 0.5$ uncontaminated; $0.5 \leq CSI < 1$ very low severity of contamination; $1 \leq CSI < 1.5$ low severity; $1.5 \leq CSI < 2$ low to moderate; $2 \leq CSI < 2.5$ moderate; $2.5 \leq CSI < 3$ moderate to high; $3 \leq CSI < 4$ high; $4 \leq CSI < 5$ very high; and $CSI \geq 5$ ultra-high severity of contamination.

2.5.4. Hazard quotients (HQ)

HQ is calculated using the Eq. (9):

$$HQ = \frac{C_{metal}}{SQG} \tag{9}$$

where, C_{metal} is the observed concentration of a metal in sediment and SQG is the sediment quality guideline (Urban and Cook, 1986). The SQG adopted for calculating the HQ in this study was the threshold effects level (TEL) (Macdonald et al., 2000). Feng et al. (2011) indicated another classification to HQ is $HQ < 0.1$ no adverse effects; $0.1 < HQ < 1$ potential hazards; $1 < HQ < 10$ moderate hazards; and $HQ > 10$ high hazards.

2.5.5. Modified hazard quotient

According to the study of Benson et al. (2018), who put a basis for the newly heavy metal index to calculate the hazard quotient using metal concentration and threshold limits according to Macdonald et al. (2000). This index is as the following Eq. (10):

$$mHQ = \left[C_i \left(\frac{1}{TEL_i} + \frac{1}{PEL_i} + \frac{1}{SEL_i} \right) \right]^{½} \tag{10}$$

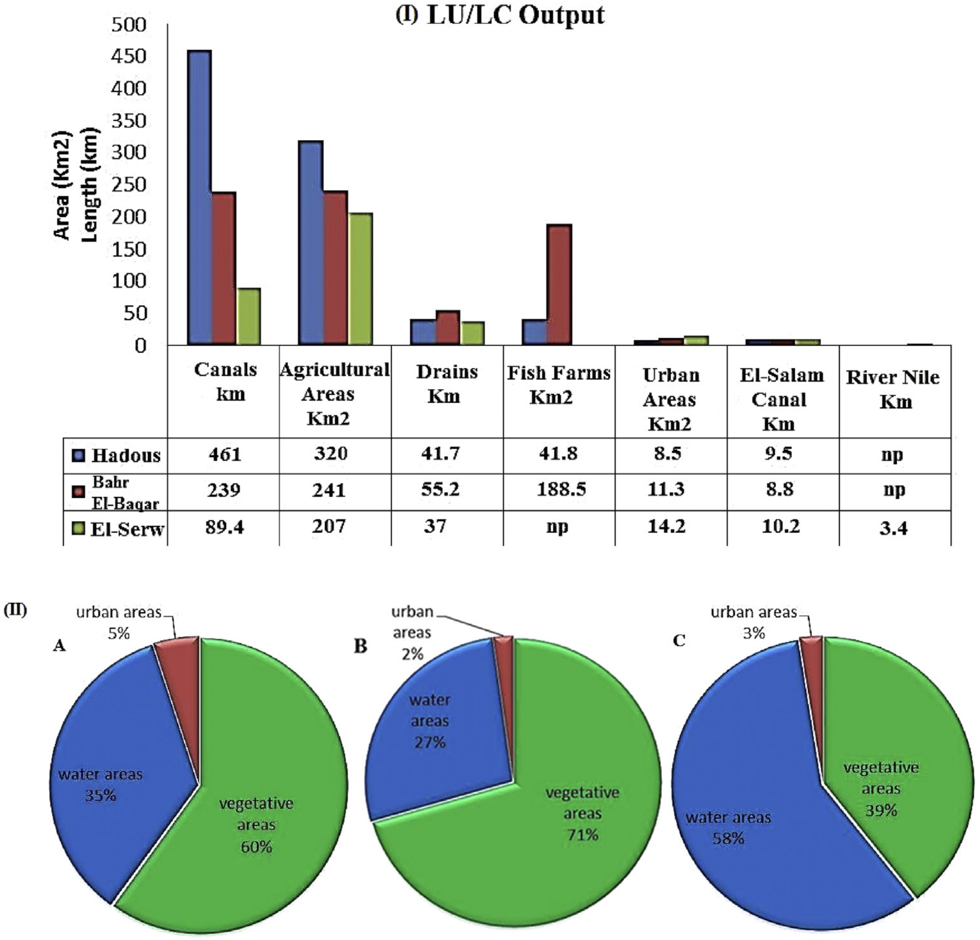
Classification of modified hazard quotient (mHQ) is as follow: $mHQ > 3.5$ Extreme severity of contamination, $3.0 < mHQ < 3.5$ Very high severity of contamination, $2.5 < mHQ < 3.0$ High severity of contamination, $2.0 < mHQ < 2.5$ Considerable severity of contamination, $1.5 < mHQ < 2.0$ Moderate severity of contamination, $1.0 < mHQ < 1.5$ Low severity of contamination, $0.5 < mHQ < 1.0$ Very low severity of contamination and $mHQ < 0.5$ Nil to very low severity of contamination.

2.5.6. Anthropogenicity index (Apn%)

It is calculated as the following Eq. (11):

$$Apn\ \% = \frac{\mu}{B_n}\ x\ 100 \tag{11}$$

where: μ: measured concentration, while B_n = background value.



	Canals km	Agricultural Areas Km2	Drains Km	Fish Farms Km2	Urban Areas Km2	El-Salam Canal Km	River Nile Km
🟦 Hadous	461	320	41.7	41.8	8.5	9.5	np
🟥 Bahr El-Baqar	239	241	55.2	188.5	11.3	8.8	np
🟩 El-Serw	89.4	207	37	np	14.2	10.2	3.4

Figure 3. (I) Land use/cover output to different activities, (np: non-present). (II) Charts represent land use/cover to water, urban and vegetative areas within; A) Elserw B) Hadous and C) Bahr El-Baqar drains.

2.6. Statistical analysis

Mean heavy metals concentrations were subjected to one-way ANOVA (SPSS 16 for Windows) to analyze the correlation between heavy metals in sediments of the three drains. Cluster analyses based on Bray–Curtis similarity index and Principle component analysis (PCA) were calculated using the PAST program (multivariate statistical package, ver. 1.72).

3. Results and discussion

3.1. Land use/cover in studied areas

The length of the studied area for each drain ranged between 37, 41.7 and 55.2 km for El-Serw, Hadous and Bahr El-Baqar drains, respectively. According to Figure 2, the areas of agricultural areas represent (89.4, 461 and 239 km^2); urban areas are (14.2, 8.5 and 11.3 km^2); Fish farms are (ND, 41.8 and 188.5 km^2); El-Salam canal (ND, 9.5 and 8.8 km^2) and River Nile (3.4 km, ND and ND) for El-Serw, Hadous and Bahr El-Baqar drains, respectively.

Calculating the different indices as NDVI and NDWI using ArcGIS 10.5 aid in identifying the vegetation and water cover areas. Also, the area of urban was calculated. It is obvious that the vegetation cover represents 60, 71 and 39 %. While the water surface areas differ from 35, 27 and 58 % The area of urban areas were 5, 2 and 3% for El-Serw, Hadous and Bahr El-Baqar drains, respectively (Figure 3).

3.2. Environmental assessment of heavy metals in sediments

The order of metal ions in the sediments of three drains of Manzala lake take the following order: Fe > Co > Ni > Cr > Cd > Pb in El-Serw drain, Fe > Ni > Co > Cd > Cr > Pb in Hadous drain and Fe > Cd > Ni > Co > Pb > Cr in Bahr El-Baqar drain. The sequence of metal enrichment and abundance is related to the land use activities around the studied sites. It's obvious that iron is the most enriched in three drains as a normal in earth crust, followed by Co in El-Serw drain, may attributed to using fertilisers in the large agricultural areas in surrounded sites (Reimann and de Caritat, 1998), Ni in Hadous drain, as Nickel can end up in surface water when it is a part of wastewater streams and the larger part of Ni compounds that are released to the environment will adsorb to sediment particles and become immobile as a result (Wuana and Okieimen, 2011) and Cd in Bahr El-Baqar, which characterized by more treated and untreated wastewater that add Cd to the water and sediment of drain. Statistical analysis of p-value showed non significant difference between mean concentrations of metal ions within three drains.

From Table 2, Co exceeds the limits of European Union (2002). While the mean value of Cd in three drains is more than the mentioned limits, but Cr and Pb values are within the limit. The sediment quality guidelines SQGs are important tools for determining the magnitude of sediment pollution associated with a particular heavy metal through comparison of the detected metal concentration in sediment with the correlative reference criteria. The threshold effect level (TEL) and probable effect level (PEL) for some substances with potential environmental risks were applied to facilitate the interpretation of sediment quality (Macdonald et al., 2000).

According to the limits of sediment quality guidelines SQGs (Table 3), it indicated that 13.33% of samples is lower than ERL, 46.66% of samples is higher than TEL and 100 % of samples are lower than MET, ERM, PEL, SEL, TET and GBC for Ni. For Cd, 86.66, 100, 100, 73.33, 100, 60, 86.66 and 100% of samples are higher than ERL, TEL, MET, CRM, PEL, SEL, TET and GBC. While for Pb and Cr, 100% of samples are lower than used limits of SQGs. It's observed that Cd represent the highly hazard contaminant in this research, Cd in low concentrations can promote the activity of some microorganisms (Shi and Ma, 2017).

The calculated potential contamination index showed in Table 2 for metal ions of Ni, Co, Cd, Cr and Pb indicated low contamination for Pb, Cr and Ni in three drains, except for Co which give moderate contamination and severe contamination by Cd. This severity of contamination by Co and Cd take the sequence of; Bahr El-Baqar > El-Serw > Hadous.

Geoaccumulation index (Igeo) for measured metals showed unpolluted degree for all metals at all sites except for Cd, that there is accumulation for this metal in the drains. It showed unpolluted to a moderate degree in sites 1 of El-Serw drain and 9 of Hadous, other sites are moderately polluted by Cd except for site 13 of Bahr El-Baqar drain which gives moderately to strong polluted degree of metal accumulation (Figure 4). The high level of Cd in sediments of Bahr El-Baqar drain may be attributed to increased rate of non-treatment industrial waste which is discharged. This is agreed with El-Amier et al. (2018) who obtained high levels of Cd contamination at Mareotis coast.

Hwang et al. (2009) stated that contaminant levels in the surface sediments remain relatively constant over a period because toxic chemical input has been leveled and bioturbation mixes the surface sediments. The mean probable effect level quotient (mPELq) ranged between low to medium degree of contamination is Hadous and Elserw drains with 21% probability of being toxic. While in Bahr El-Baqar, it ranged between low to medium in sampling sites of 11, 14 and 15. In sites 12 and 13 showed a high degree of contamination with percent of 73% probability of being toxic. the mean effect range median quotient (mERMq) values as shown in Figure (5) showed medium-low priority in Elserw and Hadous. It

Table 2. Microelement content (mg kg^{-1}) of sediment samples from different stations (S1-S15) representing three main drains of Manzala Lake, Egypt.

Drains	Station	Fe	Ni	Co	Cd	Cr	Pb
El-Serw	S1	1599	14.07	10.94	1.07	4.37	2.38
	S2	891	18.88	20.97	8.22	15.93	12.85
	S3	1306	10.05	14.17	9.41	2.42	11.62
	S4	1243	24.96	11.44	12.33	5.23	9.18
	S5	3250	9.42	23.45	16.45	30.37	6.71
	Mean	1657.80	15.48	16.19	9.50	11.66	8.55
	PCI	0.07	0.37	1.23	54.83	0.34	0.64
	±SE	185.00	1.30	1.14	1.14	2.34	0.84
Hadous	S6	632	31.74	14.77	13.41	8.15	4.71
	S7	875	11.3	19.51	13.17	13.63	4.52
	S8	4196	12.62	8.44	9.03	4.92	6.43
	S9	722	22.51	9.61	1.35	6.52	1.62
	S10	607	14.28	19.64	12.07	13.89	15.33
	Mean	1406.40	18.49	14.39	9.81	9.42	6.52
	PCI	0.09	0.47	1.03	44.70	0.00	0.00
	±SE	312.59	1.72	1.06	1.01	0.82	1.04
Bahr El-Baqar	S11	5934	9.79	15.5	14.02	2.94	13.42
	S12	1691	27.88	12.77	32.54	5.4	10.15
	S13	6013	6.82	24.78	45.66	34.26	12.6
	S14	743	27.75	17.43	10.85	7.26	14.63
	S15	2618	34.64	22.17	5.16	4.96	8.94
	Mean	3399.80	21.38	18.53	21.65	10.96	11.95
	PCI	0.13	0.51	1.30	152.20	0.00	0.00
	±SE	488.27	2.46	0.98	3.38	2.62	0.47
p-Value		0.19^{ns}	0.63^{ns}	0.49^{ns}	0.17^{ns}	0.94^{ns}	0.15^{ns}
Permissible limits worldwide							
EU (2002)		-	75	11.6	3	150	300
CSQGD (2007)		-	50	40	1.4	64	70
Average Shale		47200	68	19	0.3	90	20
Toxic response factor		-	5	5	30	2	5

SE: standard error; EU: European Union Standard (2002); (CSQGD): Canadian soil quality guidelines for the protection of environmental and human health document (2007); Average shale, after Turekian and Wedepohl (1961); PCI: potential contamination index: ns: non significance.

Table 3. Threshold, mid-range and extreme effects sediment guidelines for selected metals (mg/kg).

SQG		Pb	Cd	Ni	Cr	Ref.
ERL		35	5	30	80	Macdonald et al. (2000)
TEL		35	0.6	18	37.3	
MET		42	0.9	35	55	
ERM		110	9	50	145	
PEL		91.3	3.53	36	90	
SEL		250	10	75	110	
TET		170	3	61	100	
GBC	Shale standard	20	0.3	68	90	Turekin and Wedephol, 1961
	Earth Crust	12.5	0.15	75	100	Taylor, 1964

ERL = effects range low, ERM = effects range median, PEL = probable effect level, TEL = threshold effect level, SEL = severe effect level, MET = minimal effect threshold, TET = toxic effect threshold, GBG = geochemical background.

showed high medium priority in Bahr El-Baqar with 49% probability of being toxic.

Contamination severity index (CSI) is a newly proposed index developed by Pejman et al. (2015) for ecological risk assessment of heavy metal pollution in sediments. According to Figure (6), Mean values of CSI in El-Serw showed uncontaminated for Pb and Cr. And showed low severity of contamination for Ni; moderate and high severity for Cd. In Hadous drain, un-contamination level for Pb and Cr, very low severity for Ni and moderate to high for Cd. The order of CSI for Ni and Cd is El-Serw < Hadous < Bahr El-Baqar; for Cr, Hadous and Bahr El-Baqar < El-Serw and for Pb, Hadous < El-Serw < Bahr El-Baqar.

In aquatic ecosystems, the relative toxicities of trace metals to the environment and organisms can be evaluated from the hazard quotients (HQ) values. From Figure (7), The hazard quotient HQ for Ni in sampling sites ranged between potential hazard in site 13 to moderate hazard in site 15. For Cd, HQ it varied from the moderate hazard in site 9 to high hazard in site 13. While for Cr, HQ varied from no adverse effect in site 11 to potential hazard in site 15. For Pb, it ranged between no adverse effect in site 9 to potential hazard in site 10.

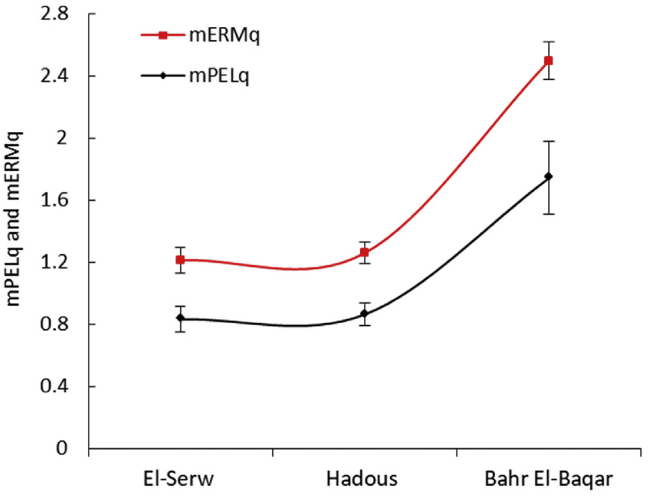


Figure 5. Values of mean probable effect level quotient (mPELq) and mean The mean effect range median quotient (mERMq) of metals in sediments of El-Serw, Hadous and Bahr El-Baqar Drains.

The lowest mHQ of Ni was obtained in sampling site 13 with considerable severity contamination, while the highest mHQ was on site 15 with extreme severity contamination. For Cd, mHQ ranged between moderate severity contamination in sampling site 1 in Elserw drain to extreme severity in Bahr El-Baqar drain. For Cr, mHQ ranged between very low contamination severity in site 3 of Elserw drain to extreme severity contamination in site 13 of Bahr El-Baqar. While mHQ of Pb ranged between very low severity in site 9 of Hadous drain to 3.2 in site 10 of the same drain.

The HQ and mHQ of Ni and Cd take the following sequence; Elserw < Hadous < Bahr El-Baqar drains. But for Cr is; Hadous < Bahr El-Baqar < Elserw and Pb is; Hadous < Elserw < Bahr El-Baqar drains (Figure 7). Benson et al. (2018) stated the mHQ is reliable and useful pollution tools that can be used to estimate the extent of pollution state, site-specific status and aggregative contamination effects by heavy metals in aquatic ecosystems.

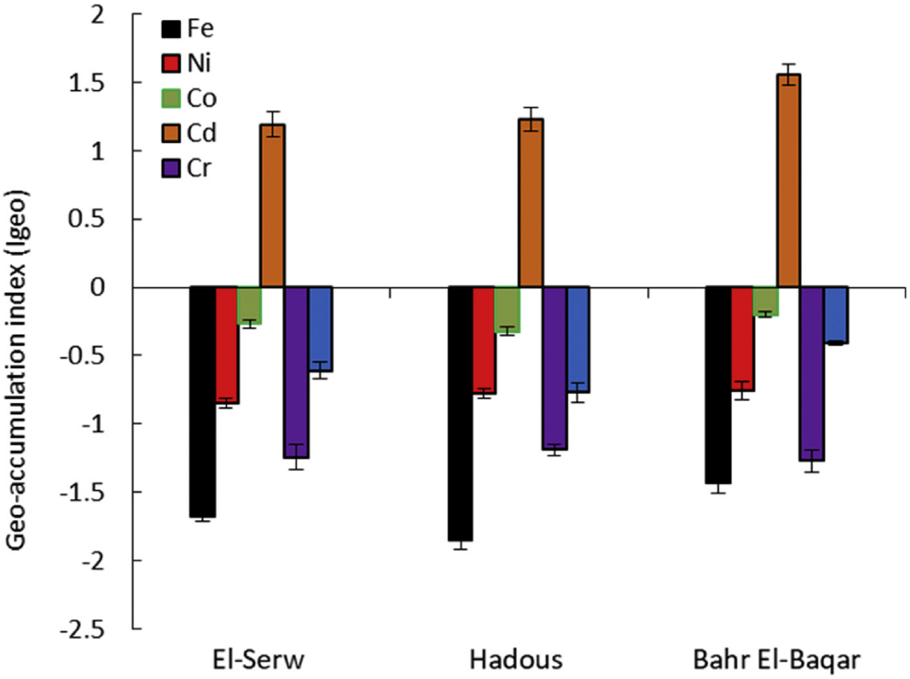


Figure 4. Average values of Geo-accumulation index (Igeo) of metals in sediments of El-Serw, Hadous and Bahr El-Baqar Drains.

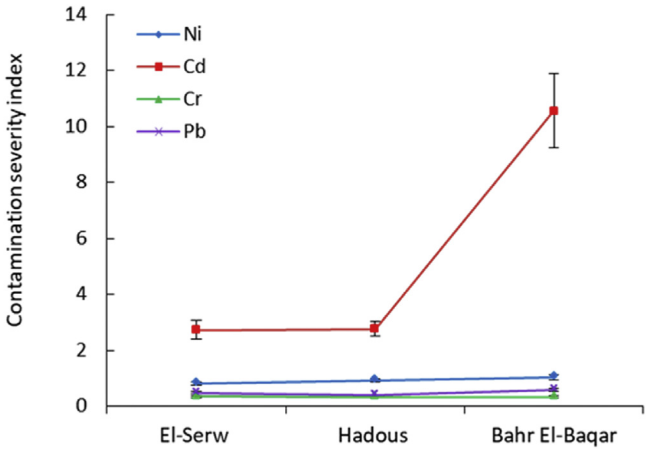


Figure 6. Contamination severity index (CSI) of metals in sediments of El-Serw, Hadous and Bahr El-Baqar drains.

Anthropogenicity (Apn%) measures the effect of the anthropogenic activities on the metal concentrations in a percentage. The anthropogenicity percentage showed as Figure (8) that the lowest Apn % for Ni was at site 10 (Hadous drain), while the highest value was obtained at site 13 of Bahr El-Baqar drain. Apn of Co varied between the low value at site 8 (Hadous) and site 13 of Bahr El-Baqar. While Apn of Cd recorded the lowest impact at site 1 of El-Serw drain to site 13 of Bahr El-Baqar drain. Apn for Cr varied in the effectivity of man-made activities between low at site 3 of Elserw and site 13 of Bahr El-Baqar drain. Finally, Pb produced from different activities, the lowest percent appeared in site 9 of Hadous drain and site 11 of Bahr El-Baqar drain. It's obvious that the heavy metal concentrations most influenced by man-made activities in the sediments of the three drains are Cd > Co > Pb > Ni > Cr. So the highest percentage or extent of anthropogenic addition on the environment showed that Cd has the highest percentage, followed by Co may be attributed to the agricultural activities that distributed in high percent as obtained in the land use/cover maps (El-Amier et al., 2017). Heavy metals introduced by anthropogenic activities has posed a considerable ecological risk to the biota in terms of the speciation (especially for Cd), and deserved enough attention (Li et al., 2016). Recent studies indicate that cadmium poses a serious ecological threat and contributes greatly to the toxicity response rates, as it is even more toxic than arsenic and lead (Min et al., 2013; Zeng and Wu, 2013).

3.3. Principle component analysis (PCA)

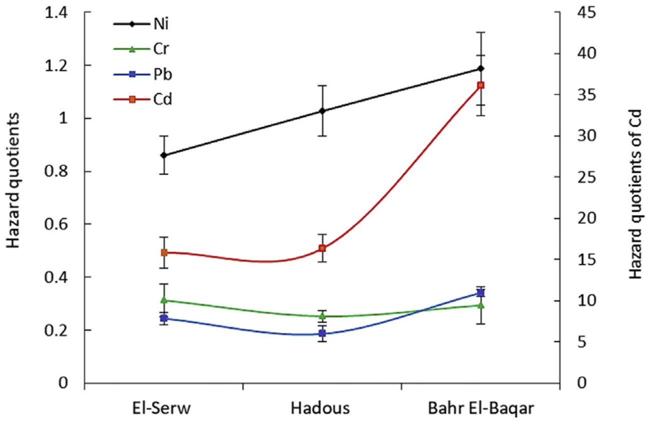


Figure 7. Hazard quotients and modified hazard quotients (HQs and mHQs) of metals in sediments of El-Serw, Hadous and Bahr El-Baqar drains.

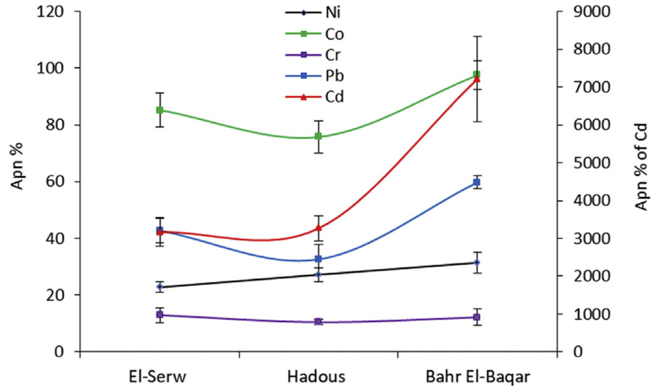


Figure 8. Anthropogenic percentage (Apn%) for influenced heavy metals of sediments in El-Serw, Hadous and Bahr El-Baqar drains.

PCA applied for metal ions being measured in this study namely; Fe, Co, Ni, Cd, Cr and Pb. The eigen values of PC1 are considered to be very significant variables that could be associated with potential human-induced sources of the investigated heavy metals. The eigenvalues, therefore, were used in calculating the net ecological contamination index. The first two axes explained nearly 66.49% from data variance as shown in Figure (9). A percent of 47.6 % of data variance explained by axis PC1 and showed a positive correlation between Co, Cd and Pb and sites 2 and 10 of Hadous and El-Serw drains may be attributed to the use of agricultural fertilizers. PC2 explained 18.89 % of data variance and showed positive correlation within Ni and Pb that related to sites 2, 10 (Hadous and El-Serw drains) and sites 14, 15 related to Bahr El-Baqar drain (Figure 9).

3.4. Cluster analysis (CA) and linkage to LU/LC maps

The similarity analysis as shown in Figure (10), indicate relative relations within the land uses and activities obtained from the metal ions analysis. Sampling sites of 3 & 4; 11 & 13 were similar and 6 & 10 of the same drains. With the differentiated distribution of sampling sites also as sites 6, 9, 10 (Hadous drain) are similar with site 14 (Bahr El-Baqar drain), may be attributed to the same use in land cover. As these sites characterized by agricultural activity. Site 2 of Elserw drain and site 7 of Hadous are lies in the same area of Elsalam canal. The affectivity of urban activity also observed in this analysis as site 5 of El-Serw drain and site 15 of Bahr Elbaqar drain were located nearby urban areas in LU/LC maps and may have similar results. Saleem et al. (2018) observed relatively high content of HMs at sites which were adjacent to urban and

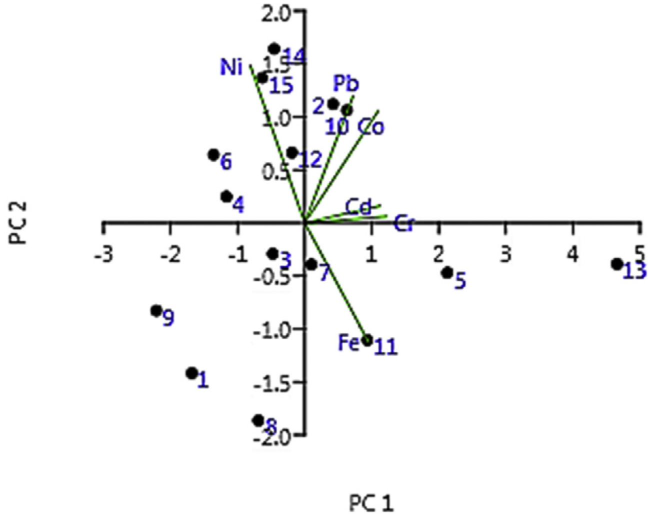


Figure 9. Principle component analysis (PCA) of metal ions with different sampling sites distributed at studied three drains.

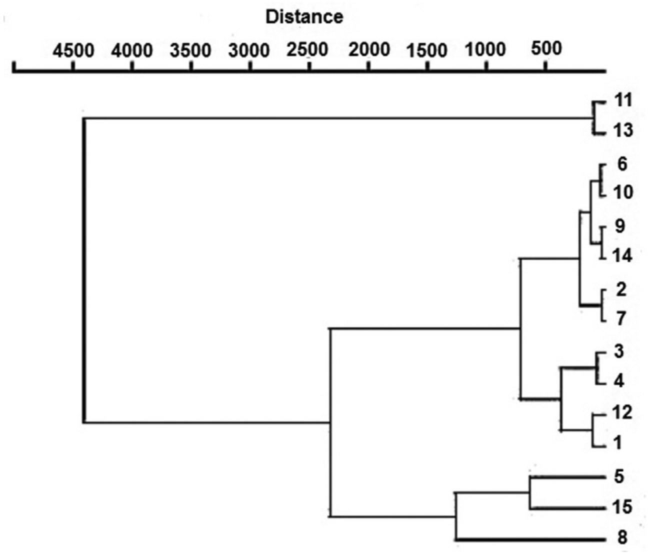


Figure 10. Cluster analysis or similarity for the different sampling sites based on the results of metal ions.

semi-urban areas. Cd, Cr, Cu, Ni, and Pb indicate their origin mainly from natural sources. Also the impact of the areas immediately adjacent to the reservoirs is marked; moreover, in the case of Ni the number of road and river crossings plays an important role (Sojka et al., 2018).

4. Conclusion

The land use/cover maps and metal contamination indices aid in identifying the metal toxicity impacts in the studied drains. Remote sensing and GIS applications calculated the areas of different land uses and coverage. NDVI and NDWI calculated the vegetation and water areas in surrounded areas. Cd was the most contaminant in calculated indices, also Bahr El-Baqar drain enriched by most metals as it carries more different wastewaters either from industrial, fishfarms or agricultural wastes.

Declarations

Author contribution statement

Muhammad A. El-Alfy, Yasser A. El-Amier, Toka E. El-Eraky: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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