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ORIGINAL PAPER

Assessment of sediment quality of the Qalubiya drain and adjoining soils, Eastern Nile Delta, Egypt

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Abstract
Qalubiya drain suffers from the presence of large quantities of pollutants as a result of receiving industrial and sewage water from several governorates through which it passes. Some of the agricultural fields surrounding the drain are irrigated with untreated water, and the sediments of its banks are also used for soil fertilization. To assess the accumulation risk of pollutants in the soil of these agricultural fields, Fe, Mn, Cu, Zn, Pb, Ni, Cd, Co, Cr, Hg metals were measured by atomic absorption spectrophotometer. Forty-one surface sediment samples collected from the drain banks and the neighboring wastewater-irrigated soils. The potential ecological index results demonstrated that the sediments of the studied drain are at a very high risk of being contaminated with Hg (3695), Cd (3017), Pb (634), Co (572), Cu (343), and at high-risk contamination of Ni (316). Also, there is considered a risk of being contaminated with Cr (84) and Zn (79). However, wastewater-irrigated soils were higher contaminated with Co, Cr, and Hg. The results of contamination factor and enrichment factor indicated that the source of the heavy metals was referred to wastewater plants, illegal domestic sewage pipes, and garbage collection sites. Besides, the Qalubiya drain showed higher levels of Ni, Cu, Zn, Pb, Cd, Co, and Cr than some ecotoxicological values as their levels in shale background, their average concentrations in the earth's crust, the lowest effective level of metals, the severe effect levels, and even the recommended maximum limit of heavy metals.

Keywords Assessment · Sediments quality · Qalubiya drain · Soils · Pollution · Nile Delta

Introduction

Human, agricultural, and industrial activities in addition to the population growth could be affected by increasing the volume of pollutants in the wastewater (Qadir et al. 2010). Therefore, the disposal of these pollutants directly into the riverbed without treatment may cause multiple environmental problems. Untreated wastewater contains a lot of pollutants, especially heavy metals such as Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd, and Co, which may be concentrated directly in the surface sediments (Rattan et al. 2005; Lente et al. 2014; Nour 2019a). As a result, the use of this polluted water for irrigation of agricultural crops or even the use of these pollutant deposited as soil for agriculture will carries a high risk to human and animal health (Khan et al. 2008; Chary et al. 2008; Briki et al. 2015). The assessment of the heavy metals pollution levels in sediment is important to evaluate the potential environmental risks. Consequently, there are many studies proving this concept (Hu et al. 2013; Gu et al. 2016; Nour et al. 2018; Nour 2019b). In addition, the increase in exposure time of pollutants plays an important role in the accumulation of elements in the sediments (Rattan et al. 2005; Abuzaid and Fadl 2018).

The Qalubiya drain flows into the eastern Delta of Egypt through Sharkiya and Qalubiya Governorates and discharges to El-Manzala Lake. The Egyptian Delta is characterized by a high population density and a great industrial and commercial growth, in addition to large cultivated areas. These criteria have made Qalubiya drain the primary target of this area to get rid of wastewater and sewage. Moreover, there are several wastewater plants that dump their water directly into the drain water body. Fortunately, the Delta of Egypt is characterized by being almost rich in fresh water of the Nile River and fertile agricultural lands. This made its residents not keen on relying

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Table 1 The characteristics of the sampling stations at Qalubiya drain

SN.	Lat.	Long.	Characteristic of studied stations
1	30° 33′ 39″ N	31° 36′ 07″ E	Saft sewage station: this station has been stopped for 10 years ago, the drain water body is dark color and it smells foul.
2	30° 32′ 27″ N	31° 35′ 12″ E	4 km south Al-Khith Village: drain water body covered with Nile flower, the drain is surrounding with agricultural fields.
3	30° 31′ 56″ N	31° 31′ 53″ E	Saft Village: 4 km south St. 2, drain water body covered with Nile flower, the drain depth about 1.5–2 m and surrounding with agricultural fields.
4	30° 31′ 29″ N	31° 29′ 33″ E	Mit Abu Ali Village: There is a small bridge on the drain which barried with a large amount of garbage on the surface of water body.
5	30° 30′ 53″ N	31° 27′ 57″ E	Kafr El-Gendy: There is asewer houses pipe (domistic sewage).
6	30° 30′ 53″ N	31° 27′ 23″ E	5 km south St. 5: drain water body covered with few amount of Nile flower, there is asewer houses pipe (domistic sewage).
7	30° 29′ 56″ N	31° 26′ 19″ E	Kafr al-jahaniyah: There is alarge amount of garbage on thesurface water of the drain and sourronding it.
8	30° 30′ 42″ N	31° 25′ 09″ E	Shafiq Village: there is asewer houses pipe (domistic sewage), and also notice the presence of atractor discards garbage in the drain during sampling.
9	30° 30′ 13″ N	31° 24′ 04″ E	Al-Aqoula Village: the drain is ≈ 2 m in the depth and ≈ 14 m in the wide.
10	30° 30′ 36″ N	31° 22′ 58″ E	7 km south St. 9: the water in the drain can hardly be seen from the amount of garbage and Nile flower on the surface of the water.
11	30° 30′ 25″ N	31° 22′ 16″ E	Kafr Shalshalamon sewage station: the presence of the discharge sewage pipe directly in drain water body and there are large quantities of solid wastes.
12	30° 29′ 37″ N	31° 21′ 15″ E	Kafr Shalshalamon: the water movement is fast and free from any rubbish features.
13	30° 28′ 13″ N	31° 20′ 36″ E	Sinhawat Village: the water movement is fast and free from any rubbish features, and there are crops as (corn and eggplant) on the sides of the drain bank that are irrigated directly from the drain.
14	30° 27′ 12″ N	31° 19′ 16″ E	Al-Sanafin Village: the water movement is fast and free from any rubbish features.
15	30° 26′ 47″ N	31° 18′ 06″ E	Sanafin sewage station: the presence of the discharge sewage pipe directly in drain water body and this station is the end point of Sharkiya governorate.
16	30° 26′ 45″ N	31° 16′ 12″ E	Ezbet Abu Ayyad: it is the first station in Qaliubiya governorate and the water movement is fast and free from any rubbish features.
17	30° 26′ 11″ N	31° 14′ 34″ E	Kafr El-Hamam: the water movement is fast and free from any rubbish features.
18	30° 25′ 19″ N	31° 13′ 18″ E	Ezbet El-Belaidy: there is a large quantities of rubble, fires and garbage, in addition to there is more than a sweeping tractor that drains sewage into the drain.
19	30° 32′ 55″ N	31° 35′ 53″ E	El-Rabiia Vallage: agricultural land on the left side of drain and has clover crops.
20	30° 31′ 29″ N	31° 29′ 29″ E	Kafr El-Gendy: agricultural land on the left side of the drain, which has been plented with onion crops.
21	30° 30′ 57″ N	31° 28′ 22″ E	5 km south Kafr El-Gendy: agricultural land on the right side of the drain, which has been planted with wheat plant.
22	30° 29′ 59″ N	31° 26′ 41″ E	Kafr al-jahaniyah: agricultural land on the left side of the drain, which has been planted with green beans plant.
23	30° 27′ 12″ N	31° 19′ 16″ E	Al-Sanafin Village: agricultural land on the right side of the drain, which has been planted with wheat plant.

on the drain water for agricultural activities. However, it is worth mentioning that there is a notable presence of encroachments on the banks and illegal agricultural irrigation done by the local population in some areas adjacent to the drain. Despite this, studies to assess the environmental effects resulting from the use of wastewater drain and/or drain deposits in agricultural activities are still few (Abdel-Fattah and Helmy 2015; Abuzaid and Fadl 2018; Abdelrazek 2019). For such reasons, the process of assessing the heavy metals in the surface drain sediments and the adjacent wastewater-irrigated

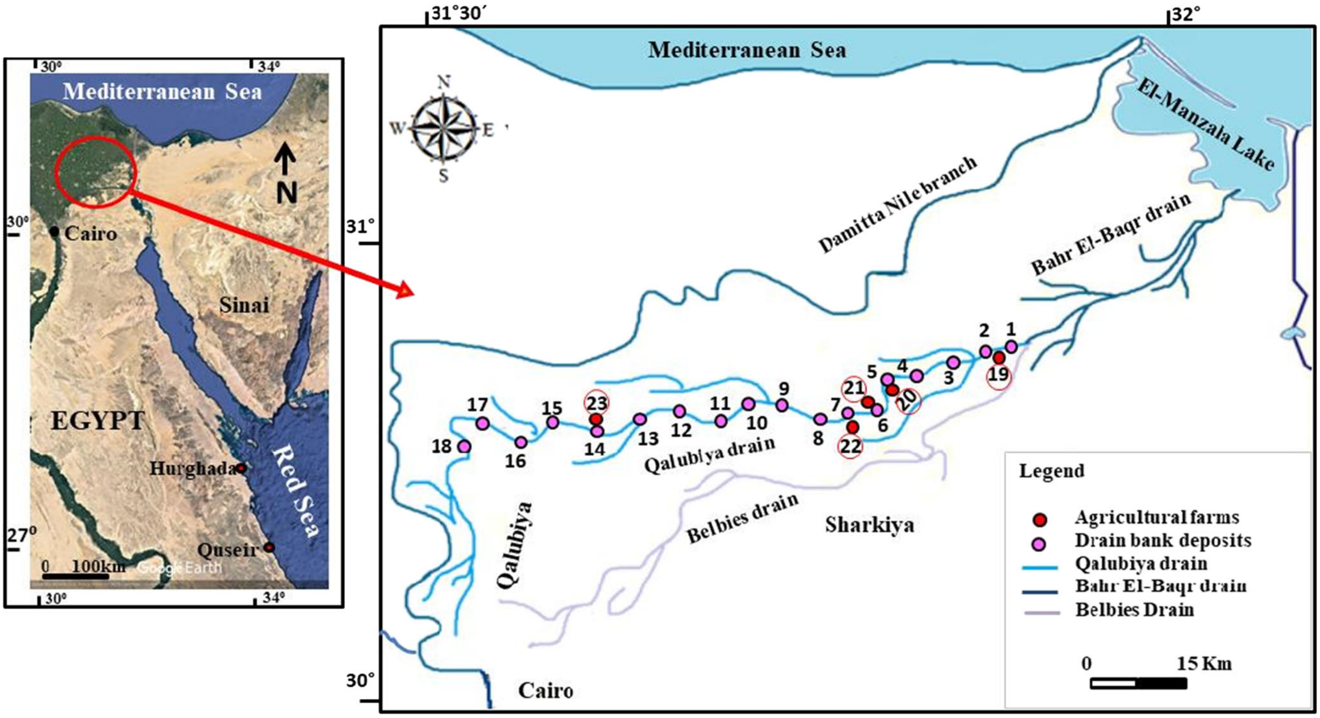

Fig. 1 Sampling stations of Qalubiya drain in the Eastern Delta

farm's soil is an important aim of the current study to determine the extent of the potential risk that may cause health problems for humans, animals, and plants. Although, the field observation of Qalubiya drain indicates the presence of pollution, there are not enough studies to confirm or deny this finding and therefore making this study is important and assisting Governments in the development of the environmental state in this region.

Material and methods

Study area

The Qalubiya drain is a drainage system carrying contaminated water resulted from irrigation return flow, domestic and industrial sewage. It runs through the Qalubiya and Sharkiya Governorates (Fig. 1) between 30° 33′ 34″ to 30° 15′ 01″ N and 31° 36′ 15″ to 31° 07′ 55″ E, surrounded by agricultural fields. This drain extends to about 71 km in length and about 10–20 m in width as well as about 1–3 m in water depth. The Qalubiya drain has been contaminated by treated and untreated wastewater (mixture of agricultural, industrial, and domestic effluents) from the urban and industrial areas of the Qalubiya and Sharkiya Governorates. This drain ends with El-Manzala Lake across Bahr El-Baqar drain in the north. The climate in the study area is characterized by being hot, arid in summer and mild rainy in winter. The mean annual temperature is 20.3 °C and the highest temperature is 36.7 °C which occurs in July, while the lowest temperature is 6.4 °C which occurs in January. The descriptions of the sampling stations are obtained in Table 1. The topography of the study area decreases in elevation towards the north. The sediments of the study area belong to Tertiary and Quaternary deposits of the East Delta region. These sediments represented by the Neonile's deposits split into often in the earlier part of this age (Said, 1993). The Nile Delta is an area of fertile alluvial deposits that consists of Nile deposits due to the frequent flooding during geological periods (Said 1990; Zeydan 2005).

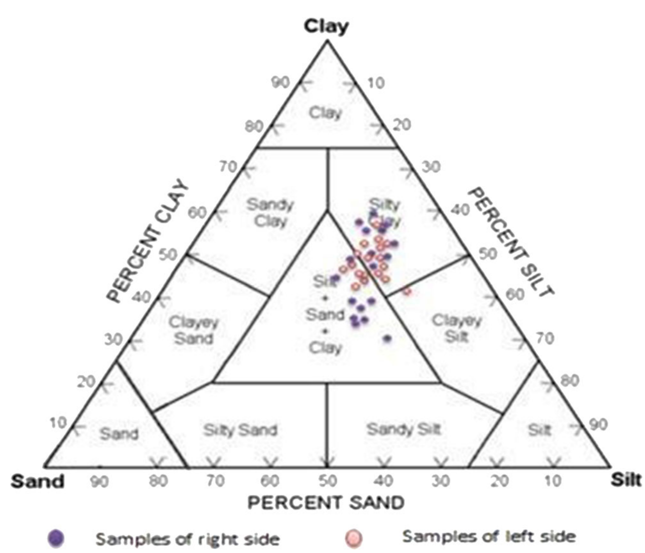

Fig. 2 The Shepard ternary diagram of sediment texture in the studied area

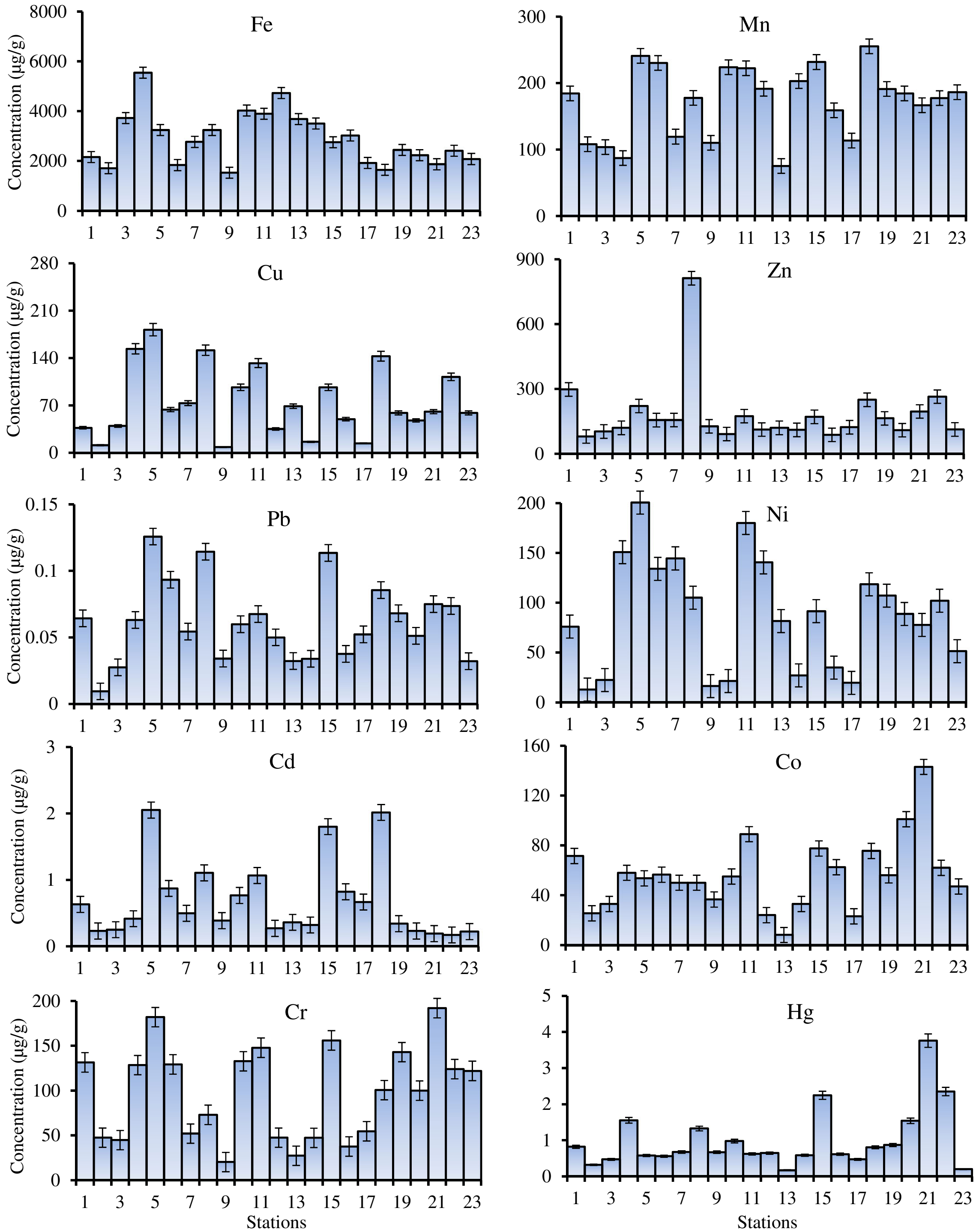

Fig. 3 The average distribution of heavy metals (μg/g) in surface sediments of the studied stations

Through field observations, the studied stations can be divided into five groups, the first one (DSG) is affected by illegal domestic sewage, including stations (1, 5, 6, and 8). The second group (WWG) is affected by the wastewater plants, including stations (11, 15, and 18). The third group (GDG) is affected by garbage dumping areas, including (4, 7, and 10). The fourth group (FPG) is free of direct pollution, including (2, 3, 9, 12, 13, 14, 16, and 17). The fifth group (WWS) is wastewater-irrigated soil, including (19, 20, 21, 22, and 23).

Soil sampling procedure and analyses

A total of 41 surface sediment samples were collected randomly along the Qalubiya drain area (Fig. 1) from 23 stations

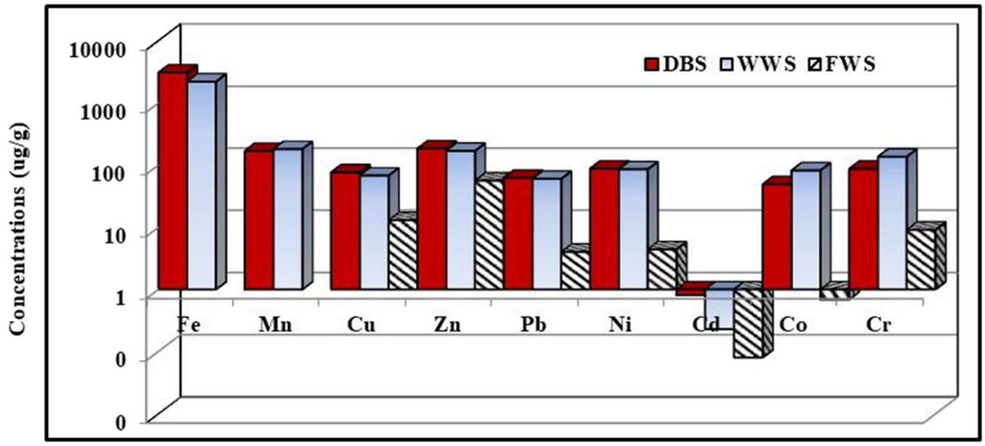

Fig. 4 The comparison of heavy metal concentrations (μg/g) in DBS, WWS and FWS

during July 2019. Thirty-six surface samples were collected from both bank sides of the drain by using a clean cylindrical plastic box which presses to a depth of 0–15 cm in the surface sediment below the water level of the drain. In addition, five wastewater-irrigated soil samples were collected randomly from only adjacent agricultural fields by the same method. The locations of collecting samples in the field were determined by GPS. The pH was calculated in situ with a portable meter Horiba U-51. These samples were transported to the laboratory in plastic bags and then dried at 80 °C in the oven. Soil samples crushed and passed through a 2 mm mesh, and the grain size analysis has been performed using a Vibratory Sieve Shaker. Each bulk sample was ground in a separated agate mortar. An acidic mixture of HF, HNO_3, and $HClO_4$ was used to digest about 0.2 g of each sample according to Oregioni and Astone (1984); then, this solution was filtered and diluted to 25 ml. The elements Fe, Mn, Zn, Cu, Pb, Ni, Cd, Co, and Cr were measured using flame atomic absorption spectrometer. However, the hydride generation system was used for determination of Hg by atomic absorption spectrometer in the central laboratory, Faculty of the Development and Technology, Zagazig University.

Evaluation of pollution indices

In order to assess the impacts of heavy metal pollution in surface sediments and to differentiate between anthropogenic and naturally occurring sources, seven environmental treatments such as the geoaccumulation index (*Igeo*), the contamination factor (CF), the enrichment factor (*EF*), the pollution load index (*PLI*), soil pollution index (*SPI*), the potential contamination index (*Cp*), and the potential ecological risk index (*PERI*) were measured. The calculation of these environmental parameters was based on the equations presented by many authors (Müller 1969; Hakanson 1980; Tomlinson et al. 1980; Simex and Helz 1981; Kabata-Pendias and Pendias, 2001). To emphasize that, many studies have proven that these parameters have an important and effective role in assessing the extent of pollution in the river and marine sediments (Rattan et al. 2005; Abuzaid and Fadl 2018; Nour et al. 2019).

SPSS software (Ver. 25) was used for other statistical analyses such as principal components analysis (PCA), cluster analysis (CA) and Pearson's correlation matrix to determine the geochemical behavior of heavy metals and their related sources. This type of analysis is reliable and used extensively

Table 2 Comparison of heavy metal concentrations (μg/g) in surface sediments of Qalubiya drain with ecotoxicological values

Studied area/ecotoxicological values	Fe	Mn	Cu	Zn	Pb	Ni	Cd	Co	Cr	References
Qalubiya drain bank sediments (DBS)	3052	168.6	76.2	183.9	62.1	87.6	0.81	49.01	86.68	Present work
Wastewater-irrigated soil (WWS)	2206	181.1	67.7	169.1	60.0	85.4	0.23	81.8	136.2	
Fresh water-irrigated soils (FWS)			12.95	56.31	4.05	4.43	0.08	0.69	9.12	Abuzaid (2018)
Average values recorded in shale	47,200	850	45	95	20	68	0.3	19	100	Turekian and Wedepohl (1961)
Average values in the earth's crust	NA	NA	25	70	15	20	0.1	10	155	Kabata-Pendias (2010)
Lowest effect level (LEL)	20,000	460	16	120	31	16	NA	NA	26	USEPA (2001)
Severe effect level (SEL)	40,000	1100	110	820	250	75	NA	NA	110	
Recommended maximum limit (RML) by FAO	5000	2000	100	300	100	50	3	100	50	FAO/WHO (2001)
Recommended maximum limit (RML) by WHO	5000	2000	100	300	100	50	3	100	50	

NA not available

Table 3 Environmental indicator results in the studied area

Metals		Fe	Mn	Cu	Zn	Pb	Ni	Cd	Co	Cr	Hg
Igeo	Aver.	−4.710	−3.000	−0.365	0.071	0.811	−0.713	0.264	0.652	−0.831	0.197
	Max.	−3.456	−2.201	1.990	2.563	2.298	1.192	2.784	2.327	0.560	2.648
	Min.	−6.387	−4.193	−3.027	−1.420	−1.981	−3.503	−1.684	−2.454	−3.541	−1.907
EF	Aver.		3.813	28.002	35.256	56.942	22.086	47.240	54.160	19.250	42.064
	Max.		9.757	107.64	151.21	133.52	66.201	327.34	190.07	53.876	237.39
	Min.		0.650	3.150	7.827	6.955	1.614	5.136	3.473	2.961	5.076
CF	Aver.	0.0625	0.2002	1.6707	1.9168	3.0938	1.2848	2.4528	2.7897	1.0302	2.2530
	Max.	0.1367	0.3261	5.9600	8.8611	7.3750	3.4265	10.333	7.5263	2.2111	9.4000
	Min.	0.0179	0.0820	0.1840	0.5607	0.3800	0.1324	0.4667	0.2737	0.1289	0.4000
SPI	Aver.		0.2836	2.5061	3.6420	6.1877	2.1841	12.264	6.6256	0.9271	30.041
	Max.		0.4620	8.9400	16.836	14.750	5.8250	51.667	17.875	1.9900	125.33
	Min.		0.1162	0.2760	1.0654	0.7600	0.2250	2.3333	0.6500	0.1160	5.3333
PERI				342.50	78.591	634.24	316.05	3017.0	571.89	84.473	3695.0
Cp		0.1367	0.3261	5.9600	8.8611	7.3750	3.4265	10.3333	7.5263	2.2111	9.4000

for indicating the source (Astel et al. 2007), as it indicates the sources of pollution and its pathways (Hu et al. 2013). In the end, the status of heavy metals concentration in the present work were compared with the ones in fresh water-irrigated soils (Abuzaid 2018) as quality control and the ecotoxicological values as their levels in shale (Turekian and Wedepohl 1961), their average concentrations in earth's crust (Kabata-Pendias 2010), the lowest effect level (USEPA 2001), the severe effect levels (USEPA 2001), and even the recommended maximum limit (FAO/WHO 2001).

Results and discussion

The sediment properties include particle size and pH was calculated. These results showed that the sediments of the Qalubiya drain and the soil of agricultural field consist of 46.78–36.26% of clay, 33.59–40.04% of silt, and 19.51–23.58% of sand, respectively. According to the Shepard ternary diagram (1954), the plot shows that two classes of the study samples are texturally classified: silty clay and clayey silt (Fig. 2). Meanwhile, in most studied samples, there are no clear differences between the ratios of sand/mud, which may indicate that they were formed in the same environmental conditions. These results indicate that the mud ratio is the highest in all study samples.

Heavy metal levels

The distribution of heavy metal concentrations in the Qalubiya drain bank sediments (stations 1–18) and wastewater-irrigated soil (stations 19–23) were obtained in Fig. 3. The results illustrated that the average concentration of Fe in the Qalubiya drain bank sediments (DBS) samples was 1.38 folds higher than its value in wastewater-irrigated soil (WWS) samples. Moreover, the highest concentration of Fe was 6453 μg/g in St. 4, while the lowest value was 846 μg/g in St. 2. Mn contents in DBS samples did not differ much its concentration in WWS samples, as the highest value was 277.2 μg/g in St. 6 and the lowest value was 69.7 μg/g in

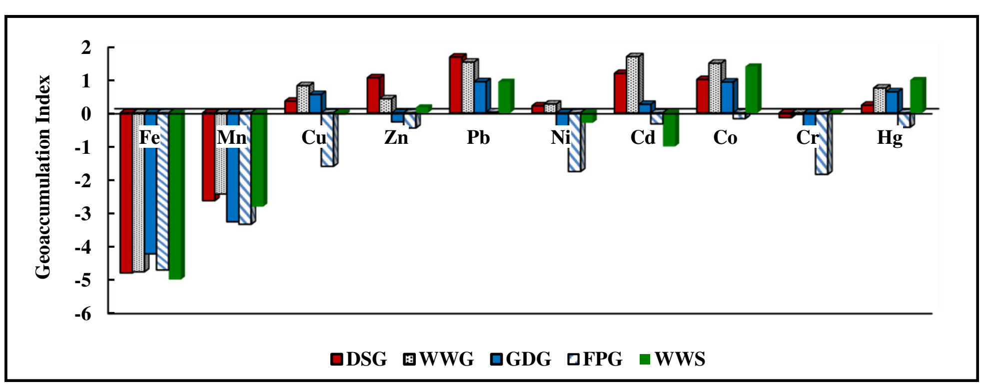

Fig. 5 The geoaccumulation index values of heavy metals in the studied area

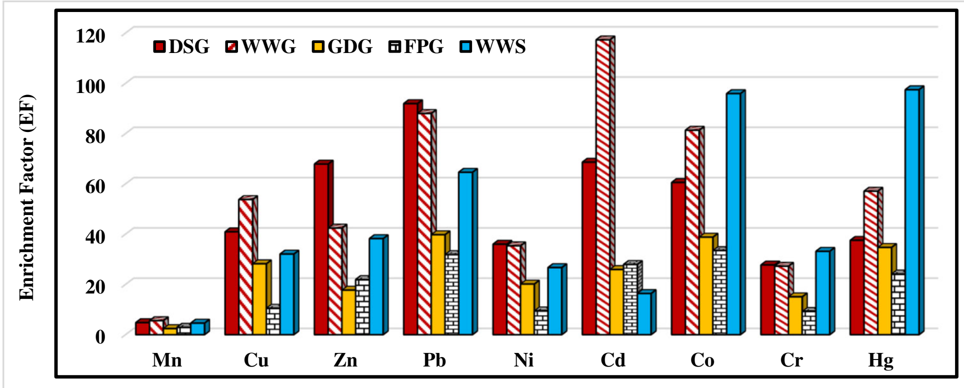

Fig. 6 Enrichment factor values of heavy metals in the studied area

St. 13. The DBS content of Cu was higher than WWS by 1.13 folds, where St. 5 recorded the highest Cu value of 268.18 μg/g and St. 9 recorded the lowest value of 8.28 μg/g. The concentration of Zn in DBS was 1.11 folds higher than its concentration in WWS, where St. 8 recorded the highest value of 841.4 μg/g and St. 16 recorded the lowest value of 53.27 μg/g. Pb and Ni content in DBS has not changed much with the ones in WWS, where St. 5 and St. 2 recorded the highest and the lowest values (147.5–233 and 7.6–9 μg/g), respectively. In addition, Cu, Zn, Pb, and Ni concentrations in both DBS and WWS were (5.5, 3.1, 15.1 and 19.5 respectively) folds higher than in the freshwater-irrigated soil (FWS) according to Abuzaid (2018), (Fig. 4). Simultaneously, the Cd concentration in DBS is far higher than ones in WWS by 3.52 folds and the highest value was recorded at St. 18 (3.10 μg/g), while the lowest value was recorded at St. 3 (0.14 μg/g). Furthermore, Cd levels in both DBS and WWS were (10.1 and 2.8 respectively) folds higher than in FWS.

In contrast, the DBS content of Co, Cr and Hg was lower than the ones in WWS by nearly the half. Moreover, St. 21 recorded the highest value of Co and Hg (143–3.76 μg/g, respectively), while St. 13 recorded the lowest value of these metals (5.2–0.16 μg/g, respectively) in the studied area. In addition, St. 5 and St. 9 recorded the highest and the lowest values (199 and 11.6 μg/g) in the studied stations. However, Co and Cr content in both DBS and WWS was (94.8 and 12.2 respectively) folds higher than in FWS.

These results showed that the Ni concentration in the Qalubiya drain sediments was higher than all ecotoxicological values (Table 2). In addition, the studied area recorded higher concentration of Cu, Zn, Pb, Cd, and Co than their levels in shale (Turekian and Wedepohl 1961), earth's crust (Kabata-Pendias 2010), and even the lowest effect level (USEPA 2001). Meanwhile, Cr content in the sediment of Qalubiya drain was higher than the severe effect levels (USEPA 2001) and the recommended maximum limit (FAO/WHO 2001). Simultaneously, the heavy metal concentrations in 24 samples for Ni, 18 samples for Cd, 7 samples for Cu and one sample for Zn bing above the severe effect level (data > SEL) according to USEPA (2001).

Assessment of sediment contamination

Seven environmental indicators (Igeo, EF, CF, SPI, PERI, PLI, and Cp) were evaluated to assess the quality of sediment in both wastewater-irrigated farm's soil and drain bank surface sediments in the studied area (Table 3). To provide a specific assessment of the studied area, the results of environmental indicators were compared based on five groups of stations' samples (DSG, WWG, GDG, FPG and WWS).

The geoaccumulation index use to evaluate the intensity of heavy metal pollution in sediments and can defined by the following equation: Igeo = log2 (C_n /1.5 × B_n) (Müller, 1969), Where Cn is the concentration of metal (n) and Bn is

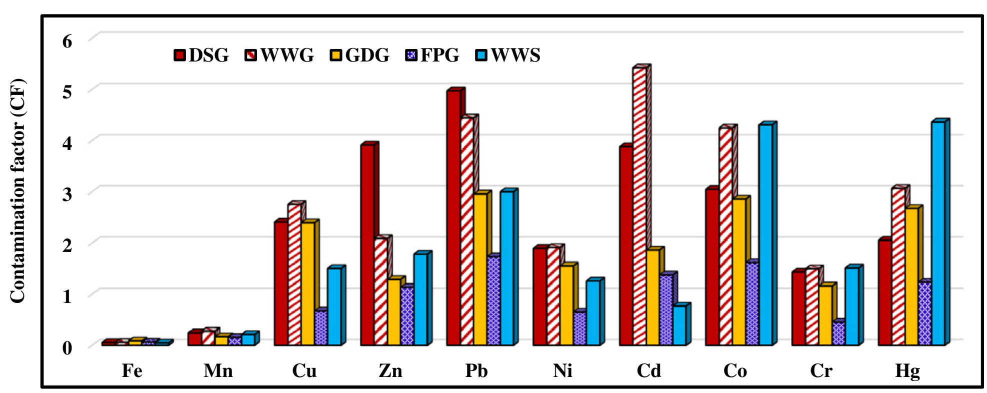

Fig. 7 Contamination factor values of heavy metals in the studied area

Table 4 Comparison of heavy metal concentrations (μg/g) in surface sediments of Qalubiya drain with those of other rivers in the world

Studied area/worldwide sites	Fe	Mn	Cu	Zn	Pb	Ni	Cd	Co	Cr	References
Qalubiya drain bank sediments (DBS)	3052	168.63	76.22	183.90	62.14	87.64	0.81	49.01	86.68	Present work
Wastewater-irrigated soil (WWS)	2206	181.05	67.68	169.11	59.98	85.40	0.23	81.8	136.2	
Soil irrigated with wastewater in Al-Qalyubia	NA	NA	73.18	170.49	56.26	63.08	0.5	33.76	78.65	Abuzaid and Fadl (2018)
Soil irrigated with wastewater in Accra, Ghana	164.38	39.39	7.21	6.03	9.31	5.0	0.07	0.73	0.51	Lente et al. (2014)
Bahr El Baqar drain sediments, Egypt	47.45	58.98	65.7	90.56	36.64	73.22	14.69	89.72	106.96	Omran (2016)
Soil bank of Terat Ismailiya, Egypt	NA	194.8	32.6	117.8	31.8	32.1	0.23	29.4	NA	Nour et al. (2013)
Sediment arround sewage station, Libya	2829	47.07	10.96	37.28	28.2	NA	2.82	19.6	NA	Nour (2019a)
Soil banks of Euphrates River, Iraq	2249.5	228.2	18.91	48	22.6	67.1	1.87	28.16	58.4	Salah et al. (2012)
Soil bank of Yaounde Lake, Cameroon	71,200	777	73	164	113.0	10.7	9.03	13.2	NA	Leopold et al. (2008)
Soil bank of Seine River, Paris	NA	NA	33	153	41.0	NA	0.6	NA	NA	Le Cloarec et al. (2009)
Soil bank of Uppanar River, India	NA	NA	6.52	6.93	6.6	NA	0.41	NA	NA	Ayyamperumal et al. (2006)
Soil bank of Nakdong River, South Korea	NA	NA	6.41	16.77	4.7	NA	0.11	NA	NA	Chung et al. (2016)

NA not available

the background concentration of the metal (n). The average value of *Igeo* ranged from 0.071 to 0.811 and showed that the studied area was uncontaminated to moderately contaminated with Pb, Co, Cd, Hg, and Zn. The order of *Igeo* index for these metals in sample groups is as follows: DSG > WWG > GDG > WWS > FPG (Fig. 5). These results revealed a great similarity between the concentration of cobalt and mercury in agricultural soil samples and drain samples (WWG). This may indicate a presence of human pollution sources.

The results of the enrichment factor which calculated by using the equation: $EF = M_x \times Fe_r / M_r \times Fe_x$ (Zoller et al. 1974), where M_x and Fe_x are metal and Fe concentrations in the soil sample, respectively, while M_r and Fe_r are the concentrations of the metal and Fe in a shale as a reference value, showed that the studied area was extremely severed with Pb and Co (*EF* > 50), and very severed with Cd, Hg, Zn and Cu (*EF* = 25–50). Moreover, it was severely enriched with Ni and Cr (*EF* = 10–25), and moderately enriched with Mn. Meanwhile, *EF* results of Mn, Cu, Zn, Pb, Ni and Cd according to classification sample groups were enriched in WWG and DSG. In contrast, Co, Cr, and Hg were higher enriched in WWS than other sample groups (Fig. 6). The results of *EF* for all studied metals were >1.5, which indicated that the origin of the heavy metals in the studied area was delivered from anthropogenic sources (Zhang and Liu 2002).

Contamination factor is useful to evaluate the extent of metal contamination in the environment and calculated using the equation: $CF = M_x / M_r$ (Hakanson 1980), where M_x and M_r are the average concentrations of the metal contaminants in the soil samples and shale as background reference material, respectively. The results of CF revealed that the studied area was considerably contaminated with Pb (CF = 3–6) and moderately contaminated with Co, Cd, Hg, Zn, Cu, Ni, and Cr (CF = 1–3). In details, CF data almost confirmed the results of EF, where it indicated that the source of the elements was referred to wastewater plants, illegal domestic sewage pipes and garbage collection sites (Fig. 7). However, the concentrations of Hg, Co, and Cr were similar between the presence of their concentrations in the wastewater-irrigated farm's and the drain sediments, especially adjacent to wastewater plants.

Soil pollution index (SPI) is used to identify single element contamination indices in soil. SPI was calculated using the equation: SPI = Metal content in soil / Permissible levels of metals in sediments according to USEPA (1983). The results of SPI (Table 4) indicated that the studied area is highly contaminated with Hg, Cd, Co, Pb, and Zn (SPI > 3), but moderately contaminated with Cu and Ni ($1 < SPI \leq 3$). Moreover, this result was confirmed by the results of the potential ecological risk index (PERI). The PERI was calculated according to Hakanson (1980) as follows: PERI = ni (Trf × Cf). The PERI results (Table 3) demonstrated that the studied area is at a very high risk of being contaminated with Hg, Cd, Pb, Co

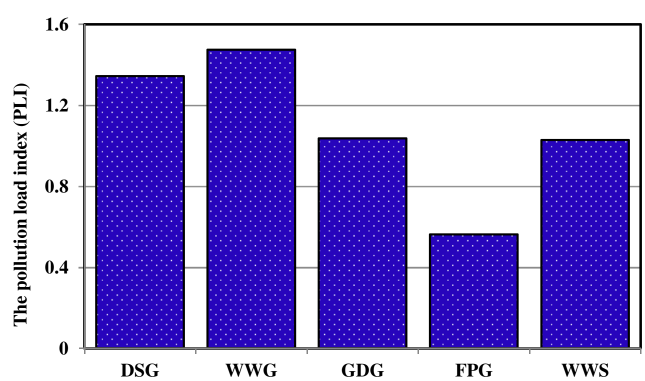

Fig. 8 The potential contamination index of heavy metals in the studied area

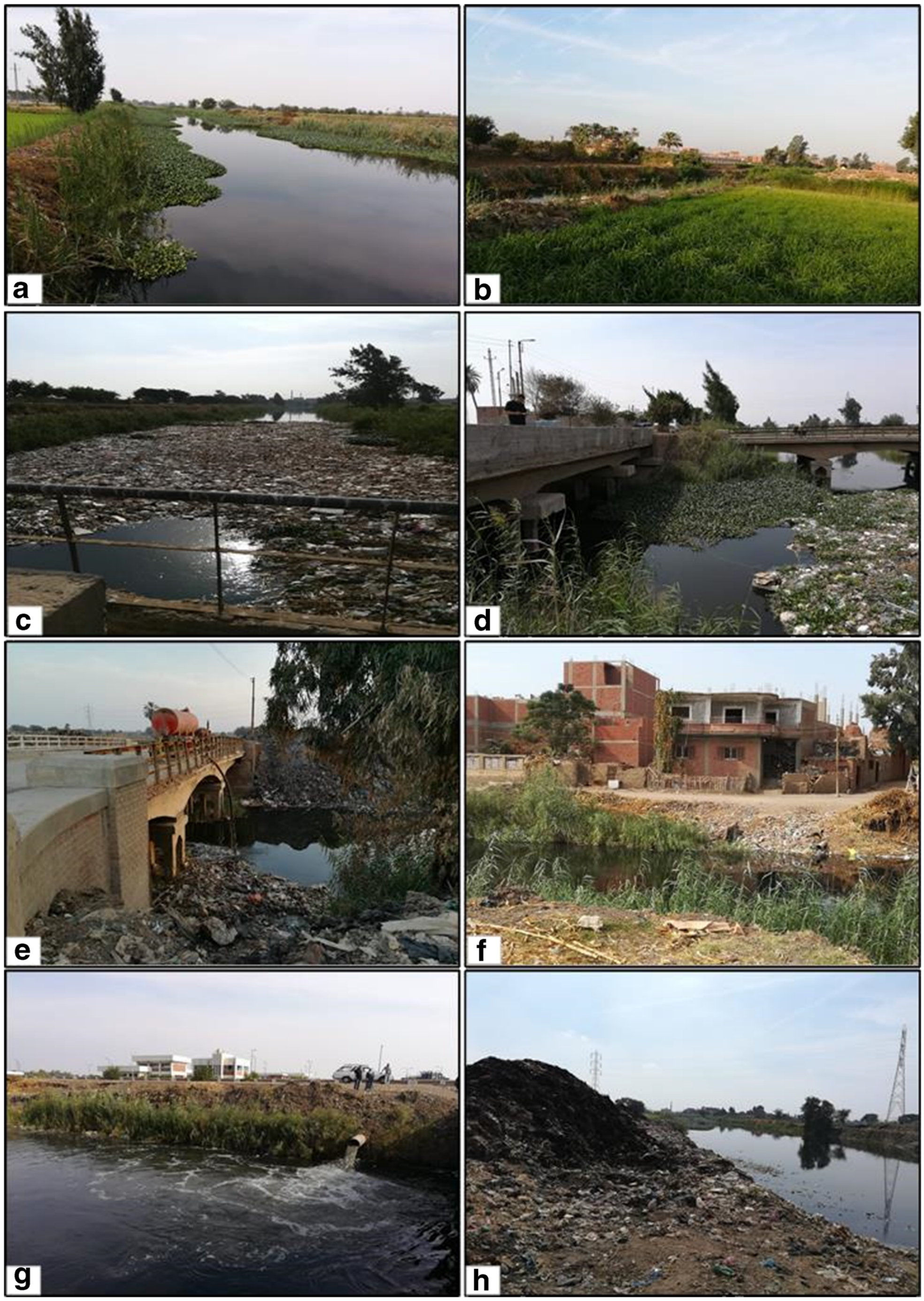

Fig. 9 Some aspects of pollution in the study area

and Cu. In addition, the Qalubiya drain area is high risk contaminated with Ni and considered risk contaminated with Cr and Zn.

To estimate the overall pollution status of the samples, the pollution load index (PLI) of the metal contaminants was calculated using equation of Chen et al. (2009): $PLI = (CF1 \times CF2 \times CF3 \times \ldots\ldots\ldots CFn)^{1/n}$. The results of the pollution load index showed that the studied area has only a baseline level of pollutants that was presented (Tomlinson et al. 1980), where PLI = 1. Moreover, Fig. 8 implied that heavy metal pollution exists in stations of WW-G (PLI = 1.5), DS-G (PLI = 1.34), and WWS (PLI = 1.03) according to (Tomlinson et al. 1980), where PLI > 1. And confirmation of that, the potential contamination index (Cp) indicated that Kafr El-Gendy (St. 5), which suffers from the impact of domestic sewage pollutants, is severe to very severely contamination with Pb, Ni, and Cu and moderately contaminated with Cr. In addition, Shafiq Village (St. 8) is severely to very severely contamination with Zn and Ezbet El-Belaidy (St. 18) is severe to very severely contamination with Cd. While the agricultural field soil in

Table 5 Loading component matrix of heavy metals in studied area

Metals	PC1	PC2	PC3	PC4	PC5
Fe	−0.850	0.052	0.894	0.166	0.133
Mn	0.378	0.113	0.820	0.047	−0.098
Cu	0.537	−0.288	−0.052	0.366	0.544
Zn	−0.467	−0.070	−0.131	0.529	0.483
Pb	0.445	0.484	−0.116	−0.535	0.322
Ni	0.705	−0.441	−0.104	0.334	−0.188
Cd	−0.168	0.594	−0.093	0.485	−0.486
Co	−0.004	0.820	−0.099	0.354	0.210
Cr	−0.742	−0.493	0.091	0.001	−0.052
Hg	0.511	−0.162	−0.175	0.262	−0.290
% of variance	21.91	18.27	15.73	12.69	10.63
Cumulative %	21.91	40.18	55.91	68.61	79.24

Extraction methods: principal component analysis

a. 5 components extracted

station 5 km south Kafr El-Gendy is severe to very severely contamination with Hg and Co. In addition, Mit Abu Ali Village (St. 4) and station-6 5 km south Kafr El-Gendy are low contaminated with Fe and Mn, respectively.

Comparison of heavy metals with worldwide

The similarity and the difference between the concentration of heavy metals in the studied area and the similar areas around the world are illustrated in Table 4. The presented results indicate that most heavy metals content in the studied area was higher than their concentration in soil irrigated with wastewater in Ghana (Lente et al. 2014), Bahr El Baqar drain sediments, Egypt (Omran 2016), soil bank of Terat Ismailiya in Egypt (Nour et al. 2013), sediment around wastewater plant in Libya (Nour 2019b), soil banks of Euphrates River in Iraq (Salah et al. 2012), soil bank of Seine River in Paris (Le Cloarec et al. 2009), soil bank of Uppanar River in India (Ayyamperumal et al. 2006), and in the soil bank of Nakdong River in South Korea (Chung et al. 2016), whereas the average concentration of some heavy metals in the studied area recorded lower levels than in other worldwide sites, such as the soil bank of Yaounde Lake in Cameroon for Fe, Mn, Pb, and Cd (Léopold et al. 2008).

Detection of pollution sources

The field observations of the studied area (Fig. 9) revealed that the main sources of pollutants with heavy metals are due to the presence of domestic, industrial, and economic sewage in addition to agricultural activities and throwing huge amounts of garbage. The environmental statistics confirm these field observations.

Principal component analysis (PCA) was used to explain the interconnected elements and their potential sources (Table 5). These results arranged metals in five components with 79.24% of cumulative percentage: PC1 explains 21.91% of the variance and clarified positive loading for Ni (0.71), Cu (0.54) and Hg (0.51), while it showed negative loading for Fe (−0.85) and Cr (−0.74). PC2 illustrates 18.27% of the variance and gave positive loading for Co (0.82), Cd (0.59) and Pb (0.49). PC3 reveals 15.73% of the variance and indicated

Table 6 Correlation matrix of heavy metals in studied area

	pH	Sand	Silt	Clay	Fe	Mn	Cu	Zn	Pb	Ni	Cd	Co	Cr	Hg
Ph	1													
Sand	−0.151	1												
Silt	−0.223	0.568**	1											
Clay	0.213	0–.877**	−0.893	1										
Fe	0.273	−0.062	−0.453	0.298	1									
Mn	−0.207	0.268	0.08	−0.193	−0.126	1								
Cu	0.062	0.192	−0.195	0.009	0.358	0.391	1							
Zn	0.028	0.051	0.035	−0.048	−0.047	0.191	0.469*	1						
Pb	−0.059	0.168	0.012	−0.099	0.001	0.623**	0.734**	0.582**	1					
Ni	0.062	0.343	0.018	−0.198	0.320	0.375	0.717**	0.245	0.641**	1				
Cd	0.050	−0.056	−0.367	0.245	−0.045	0.610**	0.642**	0.305	0.737**	0.435*	1			
Co	−0.124	0.305	0.419*	−0.411	−0.225	0.427*	0.285	0.126	0.412	0.273	0.168			
Cr	−0.146	0.439*	0.395	−0.47	−0.039	0.593**	0.545**	0.118	0.659**	0.496*	0.358	0.703**	1	
Hg	−0.188	0.12	0.372	−0.283	−0.086	0.139	0.226	0.219	0.408	0.116	−0.031	0.754**	0.551**	1

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

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

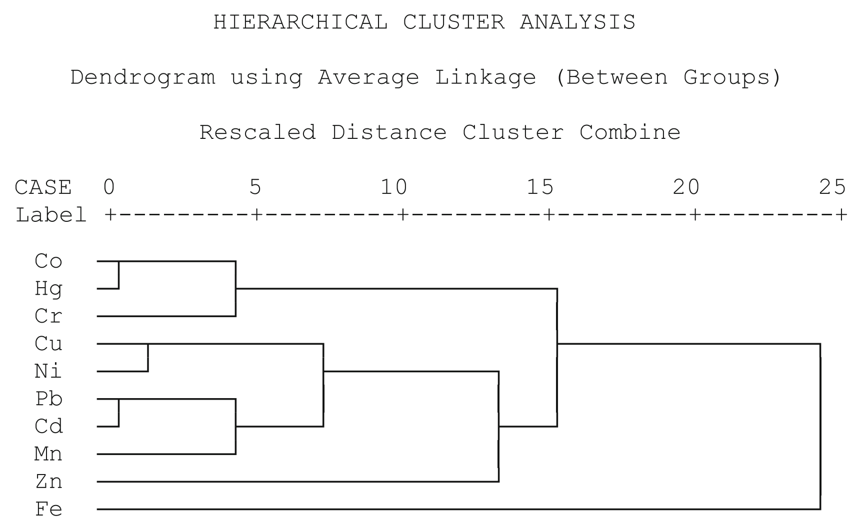

Fig. 10 Dendrogram cluster analysis for heavy metals in studied area

positive loading for Fe (0.89) and Mn (0.82). PC4 explains 12.69% of the variance and clarified positive loading for Zn (0.53) and Cd (0.49). PC5 shows 10.63% of the variance and indicated positive loading for Cu (0.54) and Zn (0.48). Cu, Zn, and Cd were given positive loading in more than one component, that refer to their non-point sources as industrial, domestic, and agricultural activities in addition to dumping garbage. Moreover, Pearson's correlation coefficient (PC) illustrated that the correlations among Fe with other heavy metals were not significant (Table 6), suggesting that the inputs of heavy metals originated mainly from human activities (Chen et al. 2009). Significant positive correlations ($P < 0.01$) showed among Co with Hg and Cr, Pb with Cd, Cr, and Ni, Cu with Pb, Ni, and Cr, Mn with Pb, Cd, and Cr, Zn with Pb, and Cr with Hg. This result indicates that these metals had similar geochemical behavior (Gu et al. 2016). In addition, there are positive correlations ($P < 0.05$) were observed among Ni with Cr and Cd, Cu with Zn, and Mn with Co. This result indicated that these metals originated from anthropogenic sources (Briki et al. 2015; Nour and Nouh 2020). Furthermore, the results of cluster analysis showed variables dendrogram (Fig. 10). These results corresponded with the results of other statistics (PCA and PC), where it presented in five subgroups. Wherever, there is a strong correlation between Co-Hg-Cr, Cu-Ni, Pb-Cd-Mn, Zn, and Fe. This may indicate that there are different sources of pollutants.

There are many studies that indicate a positive relationship between the percentage of clay and an increased concentration of heavy metals in sediments (Windom et al. 1989; Chung et al. 2016). However, there is almost homogeneity in the grain size of the studied sediments, there are no clear differences in the relationship of the heavy metal's distribution in sediments. The pH levels of the sediments in the studied area ranged from 7.8 to 8.7 and this indicates that they are of medium alkalinity and suggest the effect of wastewater in the drain, especially the industrial ones (Santhiya et al. 2011, Sungur et al. 2014 & 2015). As a result of the degree of pH in the environment, most studied heavy metals will be immobile and precipitate (Smith and Giller 1992). Therefore, this would be an obstacle for crops to uptake them (Khan et al. 2008).

Conclusion

The sediments of the studied area are mostly consisting of silt clay and clayey silt, giving them an advantage in the accumulate heavy metals. To evaluate the potential contamination risk with heavy metals in the study area, several environmental indicators as geoaccumulation index (Igeo), contamination factor (CF), potential contamination index (Cp), and enrichment factor (EF) were measured. The results of the present study showed that Qalubiya drain sediments suffer from the presence of extremely severed with Pb and Co, very severed with Cd, Hg, Zn, and Cu, and severely enriched with Ni and Cr. This is due to the presence of direct drainage of wastewater plants in the flow, the presence of illegal domestic and industrial sewage in several sites along with the drain flow, as well as the presence of garbage dumps around the drain. The potential contamination index (Cp) indicated that the sites were affected by domestic and industrial sewage is enriched in Cu, Zn, Pb, Ni, and Cd. Besides, this study proved that the wastewater-irrigated soils were enriched in Co, Cr, and Hg. Moreover, the concentrations of all studied metals were much higher than the ones in fresh water-irrigated soil. The Qalubiya drain showed higher levels of Ni, Cu, Zn, Pb, Cd, Co, and Cr than some ecotoxicological values as their levels in shale background, their average concentrations in earth's crust, the lowest effective level of metals, the severe effect levels, and even the recommended maximum limit of heavy metals.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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