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Assessment of heavy metal pollution in soil and bottom sediment of Upper Egypt: comparison study

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Abstract

Background: Aswan and Luxor Governorates are characterized by multifaceted activities such as cement, chemicals, fertilizers, detergents, nitrogen fertilizer factory at Aswan, the sugar and diary factory at Kom Ombo, and several other factories such as the sugar, pulp, paper, ferrosilicon, and phosphate factories at Edfu, urbanization and agriculture. In addition, there is a main sewage station which is used for irrigation of many crops. Assessing the pollution of soil and sediment with some heavy metals in these areas is the main aim of the current work.

Results: The average heavy metals content in the studied cultivated soils and Nile sediments are above the acceptable levels. Generally, Nile sediments and cultivated soils at Aswan and Luxor were unpolluted to moderately polluted with heavy metals. Pollution indices indicated that the studied Nile sediments were at considerably ecological risk from Cd (Er = 138.89) and Zn (Er = 140.52). In contrast, the cultivated soil was at very high ecological risk from Cd (Er = 295.24).

Conclusions: The current research revealed that the soil and sediments in the Upper Egypt are less polluted than Lower Egypt. Thus, the concentrations of toxic elements are increased from south to north direction in Egypt along the Nile River. The sources of the toxic metals may possibly be natural or anthropogenic in the studied area. The anthropogenic source is resulting from paper, pulp, ferrosilicon factories, and phosphate mining at Edfu. In addition, there are some polluting industries such as sand quarry, shale mining, and the nitrogen fertilizer factory at Aswan. On the other hand, the natural sources of toxic waste are the drains during the seasonal flash floods.

Keywords: Heavy metals, Pollution indices, Upper Egypt, Contamination, Cultivated soil

Background

Heavy metals are present in the earth's environment. They are generated from anthropogenic and/or natural activities. Heavy metal pollution of soils and the environment is the result from industrialization, urbanization, and intensified irrigation water (Ali et al. 2019). Heavy metals pollution led to the poor soil health (Abdu, et al., 2017 and Bakshi, et al., 2018), surface and groundwater (Mohankumar, et al., 2016) and food contamination (Tchounwou, et al., 2012), which is a hazard to human health (Jovanović, et al., 2015; Oliver and Gregory, 2015; Sarwar, et al., 2017 and Yang, et al., 2017; Ali and Khan 2019). Therefore, the information of the heavy metal contamination of soils is needed to decide

the combined efforts of governments and scientific communities.

Thus, the aim of this investigation is to defy the soil characterization and environmental assessment of the cultivated soils and Nile sediments of Upper Egypt, (Aswan – Luxor District), located at latitude 23° 58́ 40́́ to 25° 43́ 9́́ N and long. 32° 50́ to 33° S (Fig. 1). The study area characterized by complex activities; including big industries such as cement, chemical, fertilizers, detergents, nitrogen fertilizer factory at Aswan, the sugar and diary factory at Kom Ombo, and several other factories such as the sugar, pulp, paper, ferrosilicon, and phosphate factories at Edfu, urbanization and agriculture. In addition, there is a main sewage station which is used for irrigation of many crops. These studies can provide information about the distribution, speciation, and bioavailability of the heavy metals in the studied area, and the environmental assessment can indicate the sources of

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Fig. 1 Location map of the studied area
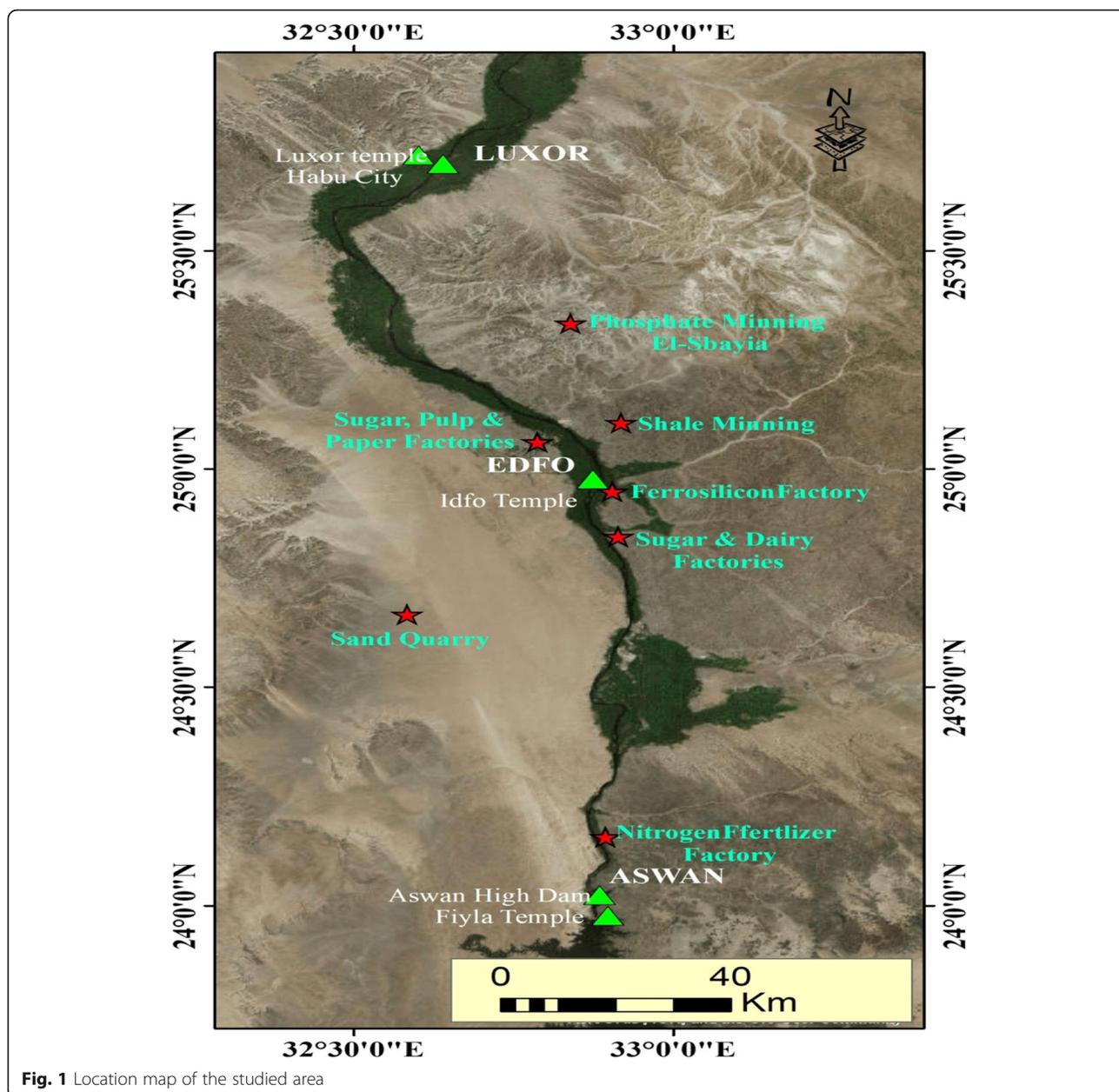
contamination and health hazards and finally, tries to offer some recommendations which facilitate to decrease its effect. In addition, try comparing the contemplation of pollution between Upper Egypt (Aswan and Luxor District) and others in Upper Egypt, as well as Rosetta Branch as Lower Egypt.

Materials and methods

Bottom sediment samples were collected from the main Nile path between Luxor and Aswan district. Samples were essentially taken from the upper 30 cm of the Nile sediments at water depth of about 0.5 meter. The cultivated soil samples were collected to represent the

eastern and western flank of the Nile from 7 stations (Fig. 1). The samples were air-dried, ground, passed through a 2 mm sieve, and then oven-dried at 110 °C for 3 h. Each sample was ground to pass through a 63-mesh sieve and homogenized for analysis. For the determination of total metal concentration, exactly 1 g of powdered soil sample was digested with aqua regia (HNO_3 : HCl = 1 : 3). The elements were determined in the extract by the atomic absorption. Single and integrated pollution indices were applied to evaluate the anthropogenic and natural impacts on contents of heavy metals in sediments and soils along Aswan – Luxor District.

Results

Heavy metal concentrations of the cultivated soil (Hapo city, Edfo, High Dam, and Fiyla), and Nile sediments (Aswan – Luxor District), at Upper Egypt, are given in Table 1 and Fig. 2. The average heavy metal concentrations in the studied cultivated soil are 63876 ppm Fe; 3.2 ppm As; 12.04 ppm Pb; 142.5 ppm Cr; 0.57 ppm Cd; 31 ppm Co; 244 ppm Zn; 19 ppm Cu; 57 ppm Ni; and 2367 ppm Mn. In contrast, the average heavy metal contents in the study of Nile sediments are 56060 ppm Fe; 0.24 ppm As; 41 ppm Pb; 110 ppm Cr; 0.78 ppm Cd; 11 ppm Co; 114 ppm Zn; 10 ppm Cu; 16 ppm Ni; 1288 ppm Mn; 0.52 ppm U; and 3.82 ppm Th.

Discussions

Pollution indices are controlling implement for environmental quality evaluation. Generally, the pollution indices for heavy metals in soils and sediments are categorize as single and integrated pollution index (Qingjie, et al., 2008 and Hafizur Rahman, et al., 2012). The current studies, four single indices; index of geoaccumulation (I_{geo}), contamination factor (CF), enrichment factor (EF), and ecological risk factor (Er), as well as, three integrated indices; degree of contamination (DC), pollution load index (PLI), and pollution ecological risk index (PRI), were used.

Index of geoaccumulation (I_{geo})

The index of geoaccumulation (I_{geo}) was firstly defined with Muller (1979) to determine and identify metal contamination of soil and sediments (Loska, et al., 2004; Praveena, et al., 2007 and 2008; Chakravarty and Patgiri, 2009 and Gao and Chen, 2012).

$$I_{geo} = \log_2 (Cn/1.5Bn)$$

where: Cn is the measured concentration of metal in sediment and Bn is the geochemical background concentration of it. In this study, the concentrations of elements in the surface sediment of Lake Nasser (Goher, et al., 2014) and As and Co (Kabata-Pendias, and Mukherjee, 2007) were used as background values: $I_{geo} \leq 0$ practically uncontaminated; $0 < I_{geo} \leq 1$ uncontaminated to moderately contaminated; $1 < I_{geo} \leq 2$ moderately contaminated; $2 < I_{geo} \leq 3$ moderately to heavily contaminated; $3 < I_{geo} \leq 4$ heavily contaminated; $4 < I_{geo} \leq 5$ heavily to extremely contaminated; and $I_{geo} > 5$ extremely contaminated.

The index of geoaccumulation results (Table 2 and Fig. 3) reveals that the sediments and cultivated soils of the Aswan–Luxor area are unpolluted – moderately. But Zn is classified as moderately polluted in cultivated soils (Muller, 1979).

Contamination factor (CF)

It is used to illustrate the contamination of a given toxic element and assess the soil contamination (Hakanson 1980 and Liu, et al., 2005).

$$CF = C_s/C_b$$

where C_s is the concentration of metal in the study samples and C_b is baseline concentration as in index of geoaccumulation. Hakanson (1980) classified the concentration factor as the following; CF < 1 low; 1 < CF < 3 moderate; 3 < CF < 6 considerable, and CF > 6 as high contamination.

Table 1 Concentration of the heavy metals (ppm) for the studied sample

| Sample No	Location	type	Fe	As	Pb	Cr	Cd	Co	Zn	Cu	Ni	Mn
1	Luxor	Nile Sediments	22592	0.2	39.8	193.9	0.5	5.5	128.6	6.6	13.7	488.9
2			29446	0.21	40.5	201	0.5	7.5	150	7.5	15.2	497
3			23781	0.31	45.2	210	0.4	9.2	145	6.9	14.3	510.1
4	Aswan		88478	0.01	42.7	15.6	0.8	15.4	72.2	8.7	15.9	2094
5			80435	0.02	60.4	13.2	1.1	12.5	80.5	22	14.8	2140
6			91625	1.3	17.7	25.7	1.4	15.6	105.3	10.7	19.5	1995
Average			56059.5	0.34	41.05	109.9	0.78	10.95	113.6	10.40	15.57	1287.5
7	Habo City	Agricultural Soil	81693	5.3	11.4	150.1	0.7	26.8	135.2	20.8	83.1	1129
8			73839	5.6	13.4	160	0.8	30	140	25	90.5	1340
9			87089	6.2	15.6	145	0.9	32	145	23	94.8	1546
10	Edfo		85960	5.2	9.5	121.4	0.5	34.8	113.1	17.6	71.2	71.2
11	High Dam		41057	0.02	9.1	131.1	0.3	28.6	373	16.3	14.9	1044.9
12			34622	0.03	10.2	140	0.4	30.5	390	17.8	20.5	11054
13	Fiyla		42875	0.04	15.1	150	0.4	35.2	410	12.5	23.3	380.5
Average			63876.4	3.20	12.04	142.51	0.57	31.13	243.8	19.0	56.9	2366.5
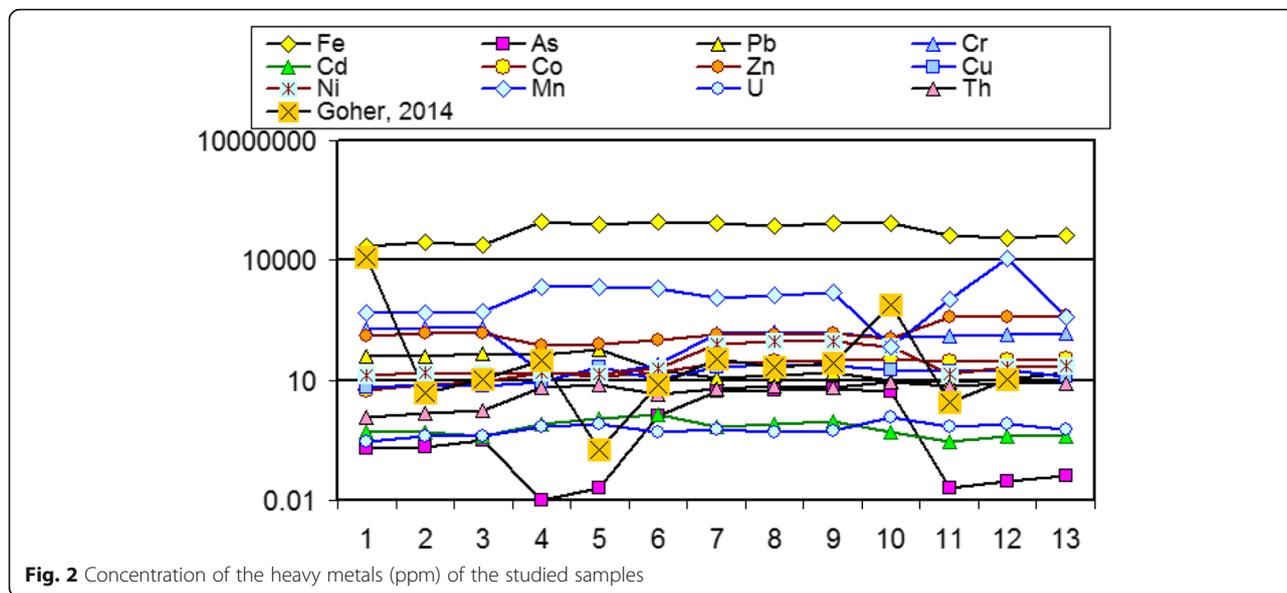
Fig. 2 Concentration of the heavy metals (ppm) of the studied samples

The calculated contamination factor (Table 3 and Fig. 4) indicated that all the sediments samples are low contaminated with As, Cu, and Ni. Fe and Co represented as moderate contamination, and considerably contamination with Pb, Cr, Cd, and Zn. In contrast, the cultivated samples are low contaminated with As and Cu. Fe, Pb, and Ni show moderate contamination, and Cr, Cd, and Co are considerably contaminated and high polluted with Zn.

Enrichment factor (EF)

It is a factor applied to determine if the soils and sediments are enriched in trace elements compared with an uncontaminated reference material and distribution of the elements of anthropogenic origin (Simex and Helz, 1980). Also, it evaluates the degree of contamination in the environment (Franco-Uria, et al., 2009). Fe was chosen as a normalizing element (Loska, et al., 2003 and Seshan, et al., 2010).

EF values < 2 indicate that the metal completely comes from the crust materials; whereas EF > 2 revealed the anthropogenic sources (Liaghati, et al., 2003). The EF values < 2 indicate depletion to minimal enrichment, 2–5 indicate moderate enrichment, 5–20 indicate significant enrichment, 20–40 indicate very high enrichment, and EF > 40 indicate extremely high enrichment. In this study, Fe is also used as

Table 2 Index of geoaccumulation (I_geo) values for the studied samples

| Sample No	Location	type	Fe	As	Pb	Cr	Cd	Co	Zn	Cu	Ni
1	Luxor	Nile Sediments	0.37	0.01	0.73	1.26	0.57	0.14	0.73	0.06	0.10
2			0.48	0.01	0.74	1.31	0.57	0.19	0.85	0.07	0.11
3			0.38	0.01	0.83	1.37	0.46	0.23	0.82	0.06	0.10
4	Aswan		1.43	0.00	0.79	0.10	0.92	0.39	0.41	0.08	0.11
5			1.30	0.00	1.11	0.09	1.26	0.32	0.46	0.20	0.11
6			1.41	0.05	0.33	0.17	1.60	0.40	0.60	0.10	0.14
Average			0.90	0.01	0.76	0.72	0.90	0.28	0.65	0.10	0.11
7	Habo City	Agricultural Soil	0.13	0.21	0.21	0.98	0.80	0.68	0.77	0.19	0.60
8			1.19	0.22	0.25	1.04	0.92	0.76	0.79	0.23	0.65
9			1.41	0.25	0.29	0.95	1.03	0.81	0.82	0.21	0.68
10	Edfo		1.39	0.21	0.17	0.79	0.57	0.88	0.64	0.16	0.51
11	High Dam		0.66	0.00	0.17	0.85	0.34	0.73	2.12	0.15	0.11
12			0.56	0.00	0.19	0.91	0.46	0.80	2.21	0.16	0.15
13	Fiyla		0.69	0.00	0.28	0.98	0.46	0.89	2.33	0.12	0.17
Average			0.86	0.13	0.22	0.93	0.65	0.79	1.38	0.17	0.41
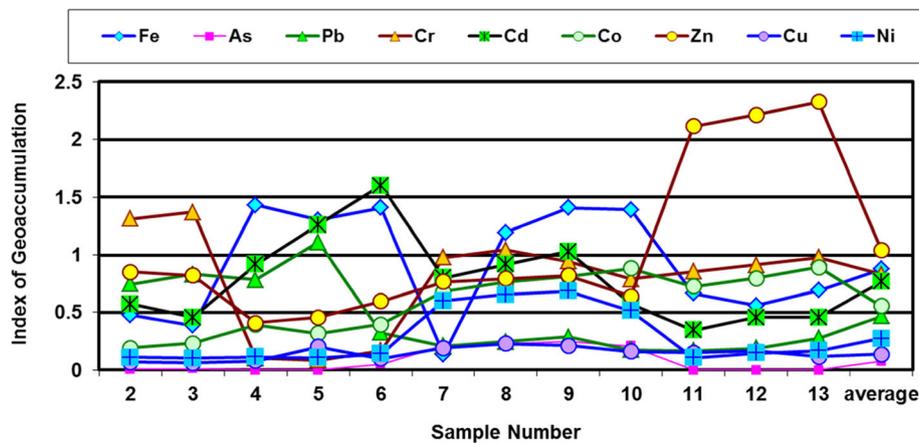
Fig. 3 Index of Geoaccumulation (I$_{geo}$) of the heavy metals of the studied samples

tracer to differentiate natural from anthropogenic components.

Enrichment Factor (EF) = (M/Fe) sample/(M/Fe) background

The enrichment factor of the study sediments (Table 4 and Fig. 5) revealed that they were ranged from low to high enrichment. EF of the all elements is low enrichment. Zn is relatively high enrichment for the cultivated soils.

Ecological risk factor (Er)

The degree of hazard contamination in sediments and soils is indicated by the ecological risk factor (Er), which is suggested by Hakanson (1980):

$$Er = Tr \times CF$$

This factor depends on contamination factor (CF) and the toxic-response factor (Tr), which is calculated by Hakanson (1980). The Tr values were 10, 5, 2, 30, 5, 5, 5, and 1 for As, Pb, Cr, Cd, Co, Cu, Ni, and Zn. Er < 40 indicated low potential ecological risk; 40 ≤ Er < 80 moderate probable ecological risk; 80 ≤ Er < 160 considerable possible ecological risk; 160 ≤ Er < 320 high potential ecological risk, and finally Er ≥ 320 represented a very high potential ecological risk.

The average value of the ecological risk factor (Er) of the studied Nile sediments(Table 5 and Fig. 6) indicated that the area was considerably ecological risk with Zn and Cd (~ 139 and 141, respectively), which is

Table 3 Contamination factor, degree of contamination, and pollution load index pollution of the heavy metals of the study samples

Sample No	Location	type	Fe	As	Pb	Cr	Cd	Co	Zn	Cu	Ni	DC	PLI
1	Luxor	Nile Sediments	0.64	0.04	3.65	6.30	2.86	0.70	3.63	0.30	0.50	18.62	0.95
2			0.84	0.04	3.71	6.53	2.86	0.95	4.24	0.34	0.55	20.07	1.08
3			0.67	0.06	4.14	6.82	2.29	1.16	4.10	0.32	0.52	20.08	1.09
4	Aswan		2.51	0.02	3.91	0.51	4.57	1.95	2.04	0.40	0.58	16.49	0.91
5			2.28	0.01	5.54	0.43	6.29	1.58	2.28	1.01	0.54	19.94	0.91
6			2.60	0.01	1.62	0.83	8.00	1.97	2.98	0.49	0.71	19.22	0.92
			1.59	0.03	3.76	3.57	4.48	1.39	3.21	0.48	0.56	19.07	0.98
7	Habo City	Agricultural Soil	2.32	1.10	1.04	4.87	4.00	3.39	3.82	0.96	3.02	24.52	2.32
8			2.09	1.17	1.23	5.20	4.57	3.80	3.96	1.15	3.28	26.44	2.52
9			2.47	1.29	1.43	4.71	5.14	4.05	4.10	1.06	3.44	27.69	2.66
10	Edfo		2.44	1.08	0.87	3.94	2.86	4.41	3.20	0.81	2.58	22.19	2.09
11	High Dam		1.16	0.00	0.83	4.26	1.71	3.62	10.54	0.75	0.54	23.43	0.85
12			0.98	0.00	0.93	4.55	2.29	3.86	11.02	0.82	0.74	25.20	1.00
13	Fiyla		1.22	0.27	1.38	4.87	2.29	4.46	11.59	0.57	0.85	27.49	1.71
Average			1.81	0.70	1.10	4.63	3.27	3.94	6.89	0.87	2.06	25.28	1.88

Fig. 4 Contamination factor of the heavy metals of the studied samples
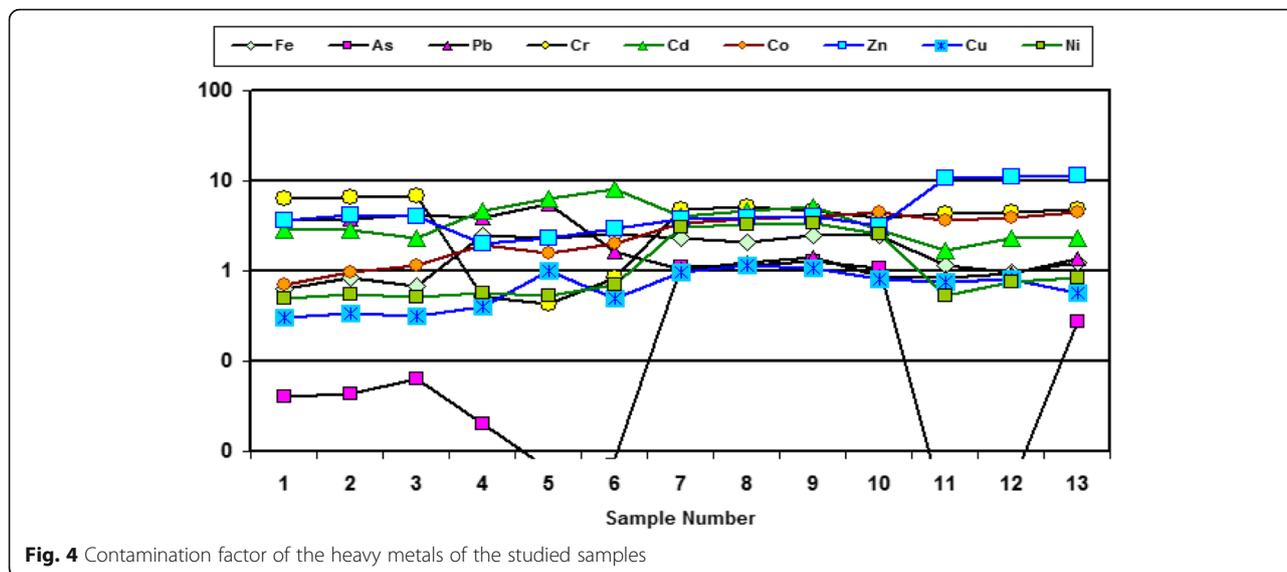
compatible with the results of the index of geoaccumulation (I_{geo}). Er of the studied cultivated soils was a very high ecological risk with Cd (~ 296). In addition, the recorded values of Pb, Cu, and Ni are represented as a low ecological risk.

The integrated pollution indices

The integrated pollution indices (DC, PLI, and PRI) are significant factors to identify the contamination resulting from the increased elements concentrations (Chon et al., 1995; Swapnil et al., 2011; Elnazer et al., 2015; Abou El-Anwar et al., 2018; and Mekky et al., 2019).

Degree of contamination (DC)

The degree of contamination (DC) is defined as the computation of all contamination factors (Hakanson, 1980):

$$DC = \sum_1^n CF$$

The DC values are ~ 19 and 25 for Nile sediments and cultivated soils; respectively, Table 3 indicated that all the studied samples represented as a moderate degree of contamination (Caeiro et al., 2005).

Table 4 Enrichment factor of the sediments of the study samples

| Sample no	Location	Type	As	Pb	Cr	Cd	Co	Zn	Cu	Ni
1	**Luxor**	**Nile Sediments**	0.02	2.01	3.46	1.57	0.38	2.00	0.17	0.27
2			0.02	1.57	2.75	1.20	0.40	1.79	0.15	0.23
3			0.03	2.16	3.56	1.19	0.61	2.14	0.17	0.27
4	**Aswan**		0.00	0.55	0.07	0.64	0.27	0.29	0.06	0.08
5			0.00	0.85	0.07	0.97	0.24	0.35	0.16	0.08
6			0.04	0.22	0.11	1.08	0.27	0.40	0.07	0.10
7	**Habo City**	**Agricultural soil**	0.17	0.16	0.74	0.61	0.52	0.58	0.15	0.46
8			0.20	0.21	0.87	0.77	0.64	0.67	0.19	0.55
9			0.19	0.20	0.67	0.73	0.58	0.58	0.15	0.49
10	**Edfo**		0.16	0.13	0.57	0.41	1.33	0.46	0.12	0.37
11	**High Dam**		0.00	0.25	1.29	0.52	1.09	3.19	0.23	0.16
12			0.00	0.34	1.63	0.82	1.38	3.95	0.29	0.27
13	**Fiyla**		0.00	0.40	1.41	0.66	1.29	3.36	0.17	0.24
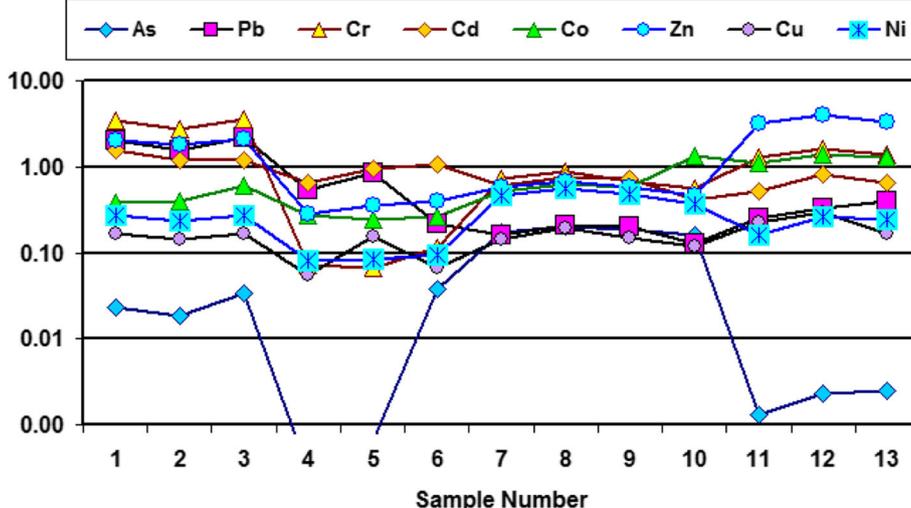
Fig. 5 Enrichment factor of the heavy metals of the studied samples

Pollution load index (PLI)

The pollution load index (PLI) proposed by Tomlinson et al., (1980), gives a simple and proportional means for assessing the level of heavy metal pollution. Thus, it is a distinctive index in the comparison of pollution rank in different localities (cf. Abou El-Anwar et al., 2018, and Mekky et al., 2019):

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 x.........x\ CF_n}$$

where n is the number of metals and CF is the contamination factors. PLI > 1 indicates pollution exists; PLI < 1 indicates no metal pollution (Chakravarty and Patgiri, 2009); and PLI = 1 indicates heavy metal loads close to the background level (Cabrera et al., 1999). The average value of PLI of the studied sediment samples (0.98) and soil cultivated is equal to 1.88 (Table 3). The values of PLI indicated the high load of heavy metals in the investigated cultivated soil than the Nile sediments samples. Consequently, it revealed the role of external discrete sources; vehicle exhaust and agricultural effect on soil pollution (cf. Elnazer, et al., 2015; Abou El-Anwar et al., 2018 and Mekky et al., 2019). Cd, Cr, Zn, and Ni possibly represented the main sources for the environmental pollution in Habo City and Edfo area.

Table 5 Ecological risk factor (Er) and pollution ecological risk index (PRI) of the study samples

| S. No.		Type	Pb	Cr	Cd	Zn	Cu	Ni	PRI
1	**Luxor**	**Nile Sediments**	25.54	64.89	166.67	67.91	8.31	8.03	341.35
2			25.99	67.2695	166.67	79.21	9.44	8.91	357.49
3			29.01	70.2815	133.33	76.57	8.69	8.39	326.26
4	**Aswan**		27.40	43.8758	100.00	196.97	20.52	9.32	398.09
5			38.76	46.8543	133.33	205.94	22.41	8.68	455.98
6			11.36	50.2011	133.33	216.50	15.74	11.43	438.57
Average			26.34	57.23	138.89	140.52	14.18	9.13	386.29
7	**Habo City**	**Agricultural soil**	7.32	50.23	233.33	71.39	26.19	48.73	437.19
8			8.60	53.5478	266.67	76.57	31.47	53.07	489.92
9			9.49	48.5277	300.00	76.57	28.96	55.59	519.13
10	**Edfo**		6.10	40.6294	166.67	59.72	22.16	41.75	337.02
11	**High Dam**		2.68	5.22091	266.67	38.13	10.95	8.74	332.38
12			3.00	4.4177	366.67	42.51	27.70	12.02	456.31
13	**Fiyla**		4.44	8.60112	466.67	55.60	13.47	33.37	582.15
Average			5.95	30.17	295.24	60.07	22.99	36.18	450.59
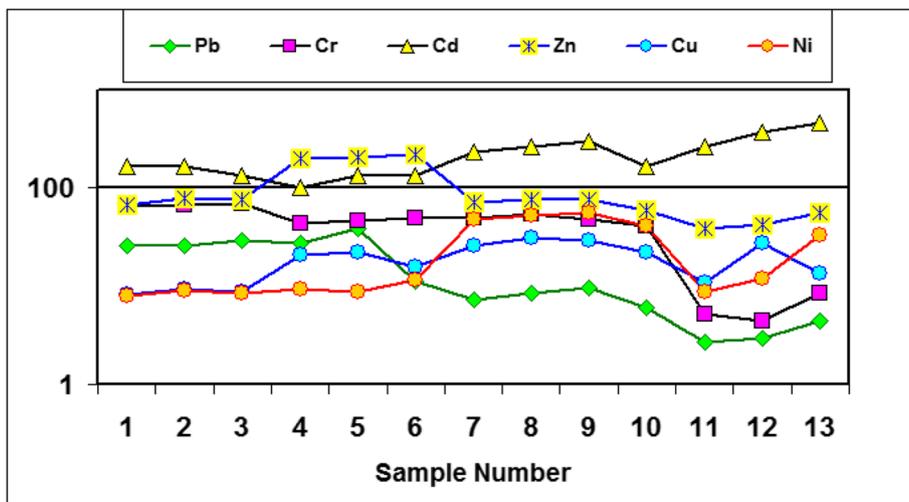
Fig. 6 ecological risk factor (Er) and pollution ecological risk index (PRI) of the study samples

Pollution ecological risk index (PRI)

PRI of the heavy metals is quantitatively evaluated by the ecological risk factor (Er) (Hakanson, 1980; Zhu et al., 2008). The PRI values were compared with grade of Er metal pollution risk on the environment classified by Hakanson (1980) and Shi et al., (2010).

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

PRI < 150 represented as low contamination; 150 ≤ PRI < 300 moderate contamination; 300 ≤ PRI < 600

considerable contamination and PRI ≥ 600 represented a high contamination (Hakanson, 1980).

PRI calculation results of samples in Table 5 showed that the studied soil and sediments represented considerable contamination ecological risk (Hakanson, 1980). The cultivated soils are highly ecological risk than it of the studied sediments (PRI = ~ 451 and 386, respectively). The ecological risk comes mainly from the soil pollution with Cd, Cr, Zn, and Ni. These metals have danger effect on plants and human health, and much attention must be paid to the study area quality.
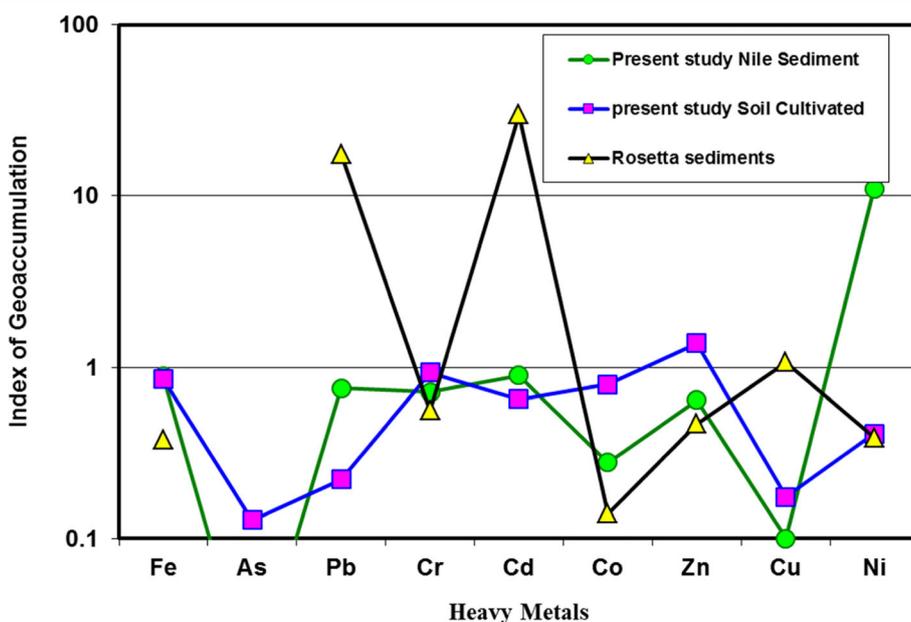
Fig. 7 Comparison of the geoaccumulation index of the study of Nile sediment and soil cultivated with Rosetta samples

Fig. 8 Comparison of the contamination factor of the study of Nile sediment and soil cultivated with Rosetta samples.
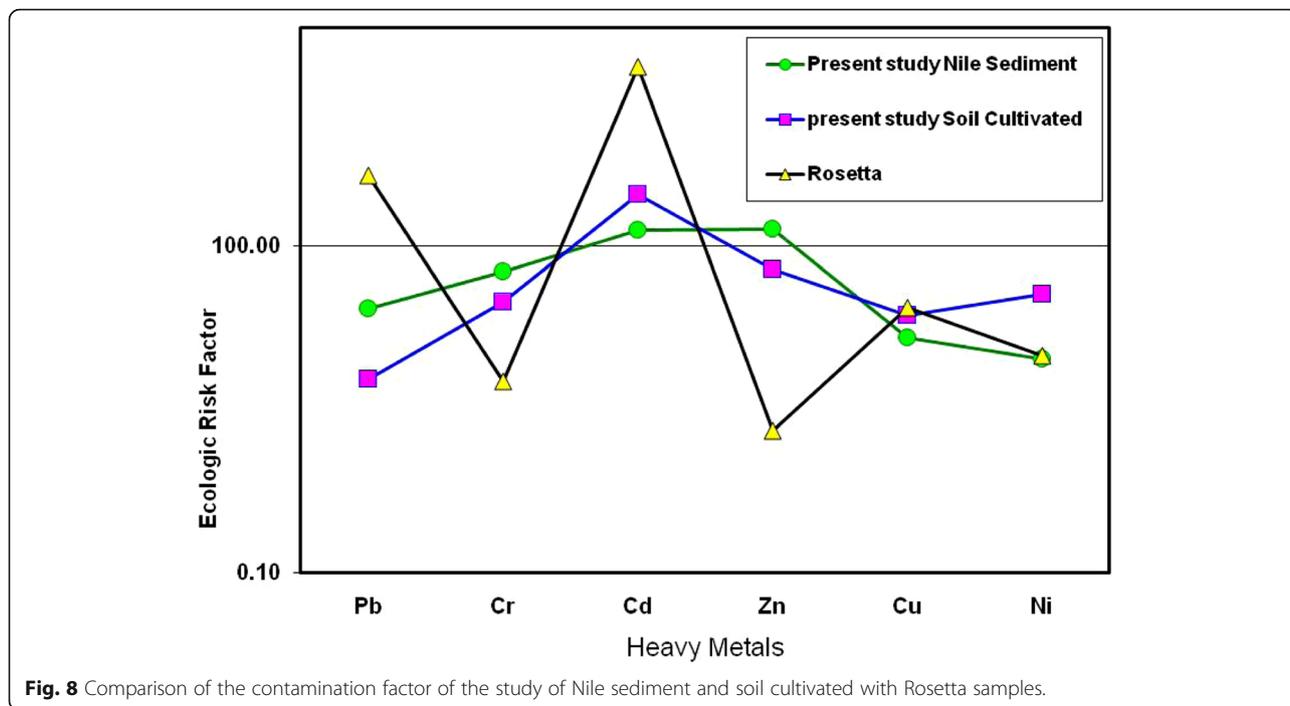
Comparison study samples with others in Lower and Upper Egypt

The I_{geo} value indicated that the Rosetta bottom sediments (Lower Egypt, studied with Abou El-Anwar, et al., 2018) are mainly (very strong) polluted with Pb and Cd, and moderately polluted with Cu than the studied Nile

sediments at Aswan and Luxor District (Fig. 7). Also, the calculated (CF) and (Er) revealed that the Rosetta bottom sediments are more polluted with Pb, Cd, and Cu (Figs. 8 and 9) than the studied samples.

While, comparing the studied cultivated soils with other localities along the Nile Valley; Sohag, El Minya,

Fig. 9 Comparison of the ecologic risk factor of the study of Nile sediment and soil cultivated with Rosetta samples
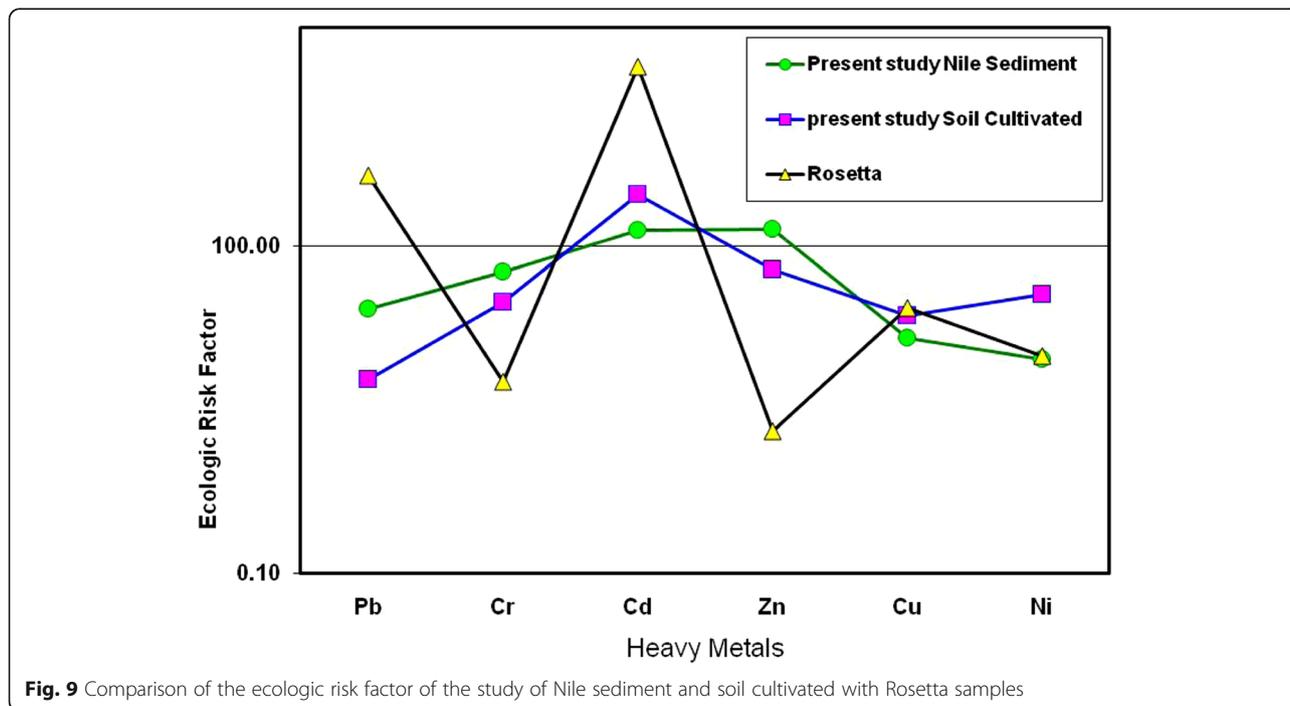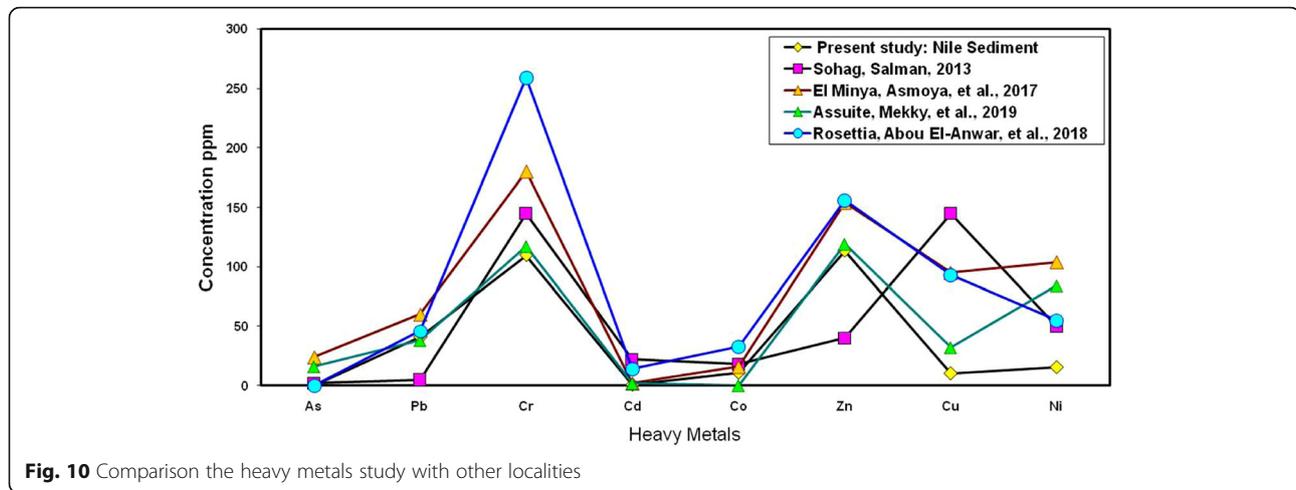
Fig. 10 Comparison the heavy metals study with other localities

and Assiut (Salman 2013, Asmoay 2017 and Mekky, et al., 2019, respectively), Governorates as well as the Rosetta soils (as Lower Egypt, Abou El-Anwar, et al., 2018) indicated that generally, the studied soil decreases in pollution than the lower Egypt and other local adjacent localities (Fig. 10). But, the concentration of Zn and Co is higher than Sohag and Assiut Governorates, respectively.

Conclusions
The calculated pollution indices indicated moderately load of heavy metals in the studied area. In addition, the studied cultivated soil has very high ecological risk with Cd. PLI values revealed high load of heavy metals in the investigated cultivated soil samples than the Nile sediments.

Cd, Cr, Zn, and Ni possibly represented the main sources for the environmental pollution, especially in Habo City and Edfo area. Thus, it is recommended to advice the farmers to decrease to the use of illegal harmful chemical, organic fertilizers and pesticides. Consequently, these anthropogenic elements are resulting from the industrial activities and irrigation drainage water.

Generally, all the concentration of the heavy metals is the studied sediments which are lower than those of the Nile Rosetta sediments (Abou El-Anwar, et al., 2018). Thus, the effect of pollution on cultivated soils and sediments increases from south to north trend of Egypt.

Author's contributions
Single author. The author read appoved the final manuscript.

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