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Heavy metals hazard in Rosetta Branch sediments, Egypt

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Abstract
The chemical concentrations of heavy metals can impact adversely on the sediments quality of the Rosetta Nile branch. To assess the degree of this adversely impact, 20 sediment samples were collected and analyzed for their content of heavy metals. Contamination indices are used to assess the heavy metals; 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). The elemental ratio and I_{geo} have indicated that the Rosetta bottom sediments are mainly moderately polluted by Cu, Co, Ni and Fe, moderately to strongly polluted with Cr and Zn and very strong polluted with Pb and Cd. Consequently, the geochemical enrichment of the studied elements indicated that the investigated area was subjected to chemical weathering and considered moderately-polluted to very strongly polluted. Accordingely, the studied elements classified into two groups; the first group includes Fe, Co, Cr and Ni, which are mainly of natural origin and controlled by the distribution of clay minerals. The second group includes Cu, Zn, Pb, Cd and Zn which originate from the industrial activities and irrigation drainage water .
The study recommendation is the reduction of the anthropogenic effects through preventing irrigation with inadequately treated wastewater and prevents the discharge of industrial wastewater into the Nile, which has led to enhancement of the heavy metals in the freshwater source.

1. Introduction
The Nile River basin is the dominant features of the northeastern basin quarter of the continents of Africa and extends ~ 6825 km. The Nile River divided into two branches; Rosetta and Damietta in the delta. Rosetta branch flows downstream Delta Barrage to the Northwest where it ends with Idina Barrage which releases excess water to the Mediterranean Sea. The Nile Delta soils consist mainly of dark grayish brown sediments suspended from the Nile waters; the dark color can be mainly attributed to the presence of micaceous minerals and hydrated magnetite. The study region suffers from an accumulation of domestic waste because of the absence of integrated management systems. Rain helps release soluble parts of the decomposed material which migrates into the soil. Nile Delta soils can be classified into two categories. The first assemblage consists of montmorillonite, kaolinite and illite in decreasing order of abundance. It characterized the soil layer in the northern Delta area. The second assemblage consists of a mixed layer of illite/ vermiculite and/or illite/ montmorillonite as well as kaolinite in decreasing order of abundance. It is characteristic of the lower units of the deposition. These sediments are comparable in the texture (clayey) and mineralogical composition of the Nile Delta soil (at Tanta) and the White and the Blue Nile Valleys of Sudan [1].
Rosetta branch of the River Nile is subject to pollution as a result of huge amount of pollutants discharged into it from the agricultural drains and industrial activities. Many authors pointed out the pollution of Rosetta branch Sediments with heavy metals [2, 3]. The pollution sources type (urban, industrial and agriculture) and physicochemical characteristics of sediments are the main controllers of heavy metals concentration in Rosetta branch sediments [4]

Pollution indices are powerful tools for environmental quality assessment. Generally, the pollution indices for heavy metals in soils and sediments are classified as two types, single and integrated pollution index [5, 6]. These indices were used everywhere by many authors [e.g. 7, 8] for pollution assessment.

The aim of the present work is the estimating and evaluating the anthropogenic and natural impacts on contents of heavy metals in the sediments of the Rosetta Nile branch (Fig. 1) through the application of single and integrated pollution indices. The obtained results are compared with previously published data.

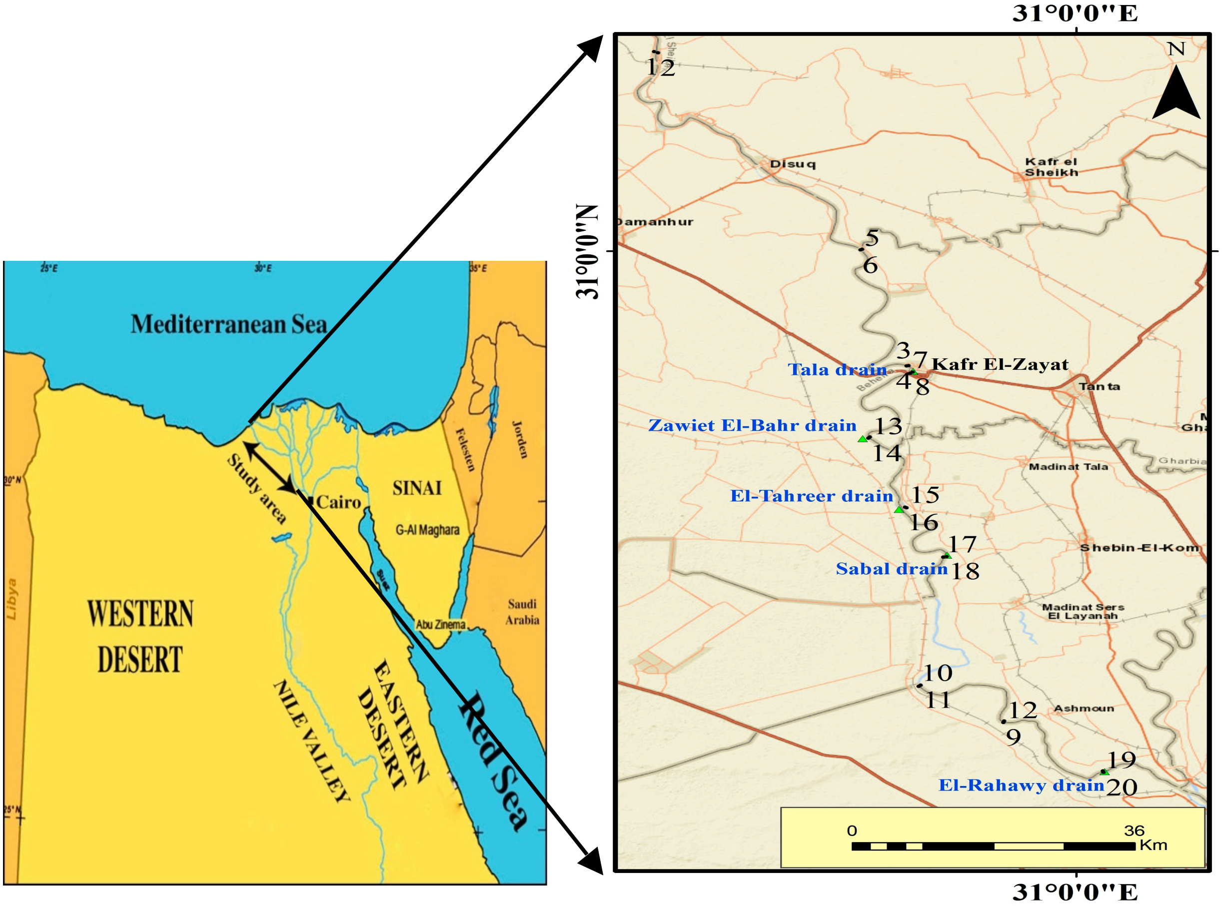

Figure 1. Location map of the collected sediment samples in the study area.

2. Materials and methods

Twenty sediment samples were collected from Rosetta Branch of the River Nile during January 2016. The samples were air-dried, passed with sieve 2mm and mixed well. Then the samples were coned and quartered and one quarter was pulverized. One gram of each sample was digested with aqua regia. After digestion, the samples were analyzed for their content of Fe, Cr, Cu, Co, Ni, Pb, Cd and Zn by using Atomic absorption spectroscopy (Perkin Elmer 400).

2.1. Single pollution indices:

2.1.1. Index of geoaccumulation (I_{geo})

The index of geoaccumulation (I_{geo}) was originally by Muller [9] in order to determine and define metal contamination of soil and sediments [10-13]. It is computed using the following equation: -

$$I_{geo} = \log_2 (C_m / 1.5B_m)$$

where: $\mathbf{C_m}$ is the measured concentration of a given metal in sediment and $\mathbf{B_m}$ represents the geochemical background concentration of it. In this study, the concentrations of elements in **UCC** [14] were used as background values.

2.1.2. Contamination Factor (CF)

It is a factor to define the concentration of metal in the sediments divided by some background base value for each element [15].

$$CF= C_s/C_b$$

Where C_s is the concentration of metal in the study samples and C_b is baseline concentration [14]. Tomlinson et al., [15] classified the contamination factor as the following; CF <1 low; 1<CF<3 moderate; 3< CF<6 considerable and CF> 6 as high contamination [7].

2.1.3. Enrichment Factor (EF)

The behavior of a given element in soil (that is, the determination of its accumulation or leaching) may be established by comparing concentrations of certain heavy metal with a reference element [16]. The obtained result is described as an enrichment factor (EF), given by the following equation [17]:

$$\textit{Enrichment Factor (EF)} = (M_s/Fe_s) / (M_b/Fe_b)$$

Where, M_s and Fe_s are the content of the target element and iron in the examined sediment, respectively and M_b and Fe_b are the content of the target element and iron in the earth's crust. To identify anomalous metal concentration, geochemical normalization of the heavy metals data was used for the conservation element [18, 19]. In this study, Fe was chosen as a normalizing element [18, 19] to differentiate natural from anthropogenic components. The EF values < 2 indicate that the metal is completely from the crust materials or natural processes; whereas EF values >2 indicated anthropogenic sources [20, 21]. 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

2.1.4. Ecological Risk factor (Er)

The ecological risk factor (Er) was indicated the degree of hazard contamination in sediments, which suggested by Hakanson [7]:

$$Er=Tr \times CF$$

The factor depends on contamination factor (CF) and the toxic-response factor (Tr). The Tr values were 2, 5, 5, 5, 1, 5 and 30 for Cr, Cu, Co, Ni, Zn, Pb and Cd, respectively [22] Where Er <40 represented as low potential ecological risk; 40≤ Er < 80 moderate potential ecological risk; 80 ≤ Er < 160 considerable potential ecological risk; 160 ≤ Er < 320 high potential ecological risk and Er ≥320 as a very high potential ecological risk.

2.2. Integrated pollution indices

Three integrated indices were used for assessing the degree of pollution; degree of contamination (DC), pollution load index (PLI) and pollution ecological risk index (PRI)

2.2.1. The Degree of Contamination (DC)

The degree of contamination (DC) defined as the sum of all contamination factors [7]:

$$\boldsymbol{DC = \sum_1^n \mathrm{CF}}$$

DC values less than (n) indicate the low degree of contamination; n≤ DC<2n, the moderate degree of contamination; 2n≤ DC<4n, the considerable degree of contamination and DC>4n, the very high degree of contamination [23].

2.2.2. Pollution load index (PLI)

The pollution load index (PLI) proposed by Tomilson et al., [15] indicated a number of sympathetic to the public of the area about the quantity of a component in the environment. Thus it is a quick tool in the comparison of pollution status in different localities [24]:

$$\mathbf{PLI = (CF_1 \times CF_2 \times CF_3 \times .... \times CF_n)^{1/n}}$$

Where (n) is the number of metals and CF is the contamination factors**.**

2.2.3. Pollution ecological risk index (PRI).

PRI of the heavy metals is quantitatively evaluated by the ecological risk factor (Er) [7, 25]. The PRI values were compared with the grade of Er metal pollution risk on the environment classified by Hakanson [7] (Table 4).

$$PRI = \sum_1^n Er$$

PRI<150 represented as low contamination; 150 ≤ PRI < 300 moderate contamination; 300 ≤ PRI < 160 considerable contamination and PRI ≥ 600 represented a high contamination [7]

3. Results and discussion

Concentrations of the heavy metals of the sediments at the Rosetta Nile branch are given in Table (1) and Figure (2). Heavy metals content in the studied sediments are varied from 36720 to 97221 ppm and averaging 65387.8 ppm Fe; 169 to 390 with averaging 259.1 ppm Cr; 40 to 170 and averaging 92.8 Cu ppm; 19 to 49 with averaging 32.8 ppm Co; 25 to 80 with average 54.9 ppm Ni; 85 -290 with average 156.3 ppm Zn; 25- 84 with average 45.7 ppm Pb and 8-24 and average 13.5 ppm Cd. The study area contains significantly high concentrations of some potentially toxic metals such as Ni, Co, Zn, Cu, Cr, Pb and Cd which are derived from both natural and anthropogenic sources. Generally, the concentrations of the study sediments are lower than those in the crust continual average [14]. The average values of Cr, Cu, Co, Ni, Zn, Cd and Pb in the study sediments are higher than those of the mean in worldwide Soils; 54, 25, 8, 22, 63, 0.5 and 25 ppm; respectively [26] and those of the toxic-response values (54, 25 and 25 ppm; respectively) [7]. In addition, Cd is higher than the average value worldwide (0.5 ppm) and lower than the toxic-response values (30 ppm). Weathering of sediments is the important factor of dispersion of toxic metals [27, 28].

Table 1: Concentration of the heavy metals (ppm) for sediments of Rosetta Branch

S.No.	Fe	Cr	Cu	Co	Ni	Zn	Pb	Cd
1	56933	180	60	28	69	230	43	8
2	50569	189	75	25	60	192	40	12
3	55318	210	77	19	54	101	75	9
4	36720	187	46	22	40	290	55	10
5	40636	169	54	27	33	85	25	8
6	55545	215	88	30	29	110	32	10
7	46582	290	57	33	41	150	45	10
8	41826	217	89	32	60	142	60	9
9	65495	264	92	34	67	167	31	9
10	63998	190	66	40	48	175	25	17
11	64627	188	40	42	35	90	60	11
12	70013	297	80	34	25	99	49	10
13	72811	390	95	36	52	245	28	12
14	81484	355	99	38	55	261	26	18
15	88758	291	102	29	61	90	54	15
16	87219	279	110	28	67	170	35	14
17	74839	264	156	24	75	150	38	20
18	70712	318	140	41	70	134	53	21
19	86450	299	160	44	77	125	55	23
20	97221	390	170	49	80	120	84	24
Min.	36720	169	40	19	25	85	25	8
Max.	97221	390	170	49	80	290	84	24
Average	65387.8	259.1	92.8	32.8	54.9	156.3	45.7	13.5

3.1. Single pollution indices

The index of geoaccumulation (Table 2 and Fig. 3**)** revealed that the sediments of the Rosetta area were unpolluted – moderately polluted with Fe, Cr, Co, Ni and Zn with I_{geo} values 0.38, 0.56, 0.14, 0.39 and 0.47, respectively. While, it was moderately polluted with Cu (I_{geo} ≈1.07) and strong polluted with Pb (I_{geo} ≈17.62) and Cd **(**I_{geo} ≈29.08**)**.

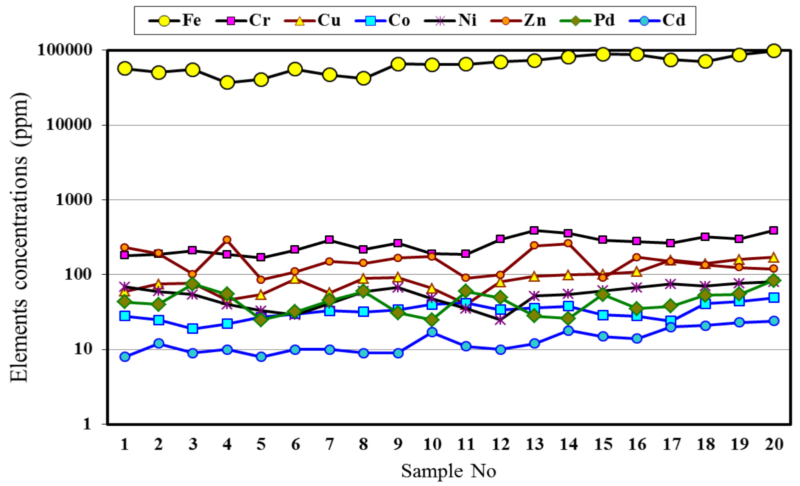

Figure 2: Concentration of the heavy metals (ppm) of the sediments of Rosetta Branch

Table 2: Index of Geoaccumulation (I_{geo}) values for sediments of Rosetta Branch

S.No.	Fe	Cr	Cu	Co	Ni	Zn	Pb	Cd
1	0.32	0.39	0.69	0.12	0.49	0.69	16.6	17.2
2	0.29	0.41	0.87	0.11	0.43	0.57	15.44	25.8
3	0.31	0.46	0.89	0.08	0.39	0.3	28.95	19.35
4	0.21	0.41	0.53	0.09	0.29	0.86	21.23	21.5
5	0.32	0.37	0.63	0.11	0.24	0.25	9.65	17.2
6	0.32	0.47	1.02	0.13	0.21	0.33	12.35	21.5
7	0.27	0.63	0.66	0.14	0.29	0.45	17.37	21.5
8	0.24	0.47	1.03	0.14	0.43	0.42	23.16	19.35
9	0.37	0.58	1.07	0.14	0.48	0.5	11.96	19.35
10	0.36	0.41	0.76	0.17	0.34	0.52	9.65	36.55
11	0.37	0.41	0.46	0.18	0.25	0.27	23.16	23.65
12	0.4	0.65	0.93	0.14	0.18	0.3	18.91	21.5
13	0.41	0.85	1.1	0.15	0.37	0.73	10.81	25.8
14	0.46	0.77	1.15	0.16	0.39	0.78	10.03	38.7
15	0.51	0.63	1.18	0.12	0.44	0.27	20.84	32.25
16	0.5	0.61	1.27	0.12	0.48	0.51	13.51	31.1
17	0.43	0.58	1.81	0.1	0.54	0.45	14.67	43
18	0.4	0.69	1.62	0.17	0.5	0.4	20.45	45.15
19	0.49	0.65	1.85	0.19	0.55	0.37	21.23	49.45
20	0.55	0.85	1.97	0.21	0.57	0.36	32.42	51.6
Min.	0.21	0.37	0.46	0.08	0.18	0.25	9.65	17.20
Max.	0.55	0.85	1.97	0.21	0.57	0.86	32.42	51.60
Average	0.38	0.56	1.07	0.14	0.39	0.47	17.62	29.08

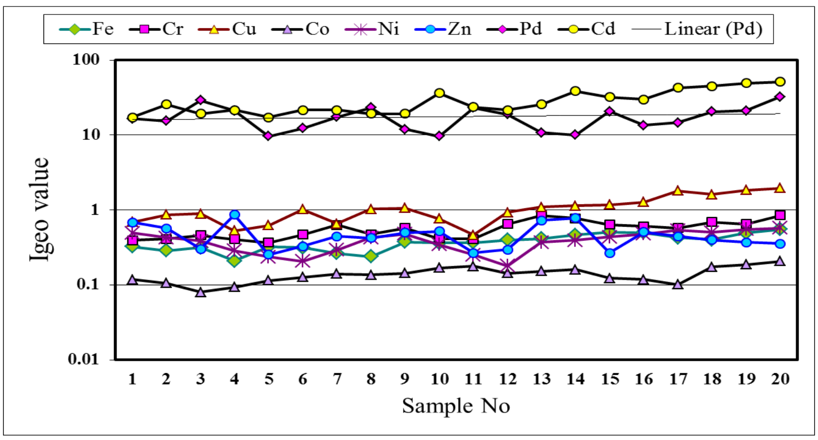

Figure 3: Index of Geoaccumulation (I_{geo}) of the heavy metals of the sediments of Rosetta Branch

The calculated contamination factor (Table 3 and Fig. 4) indicated that all the sediments samples are very high polluted with Pb (Cf ≈ 87.79) and Cd (Cf ≈ 150), where CF> 6. Also, the sediments show low contamination with Co (Cf ≈ 0.70), considerable contamination with Cu (Cf ≈ 5.36) and moderate contamination with Fe (Cf ≈ 1.86), Cr (Cf ≈ 2.82), Ni (Cf ≈ 1.96) and Zn (Cf ≈ 2.03).

The enrichment factor was assessed the degree of contamination and distribution of the elements of anthropogenic origin [29]. Also, it is a vital tool to evaluate the magnitude of contamination in the environment [30]. The enrichment factor of the study sediments (Table 4 and Fig. 5) revealed that they were ranged from minimal to extremely high enrichment. It was minimal for Cr, Co, Ni and Zn, moderate for Cu and extremely high enrichment for Pb and Cd.

Table 3: Contamination factor, degree of contamination, pollution load index and pollution ecological risk index of the heavy metals of the sediments of Rosetta Branch

S. No.	CF								DC	PLI
	Fe	**Cr**	**Cu**	**Co**	**Ni**	**Zn**	**Pb**	**Cd**		
1	1.62	1.96	3.47	0.60	2.46	2.99	82.69	88.89	184.67	4.9
2	1.43	2.05	4.34	0.53	2.14	2.49	76.92	133.33	223.25	5.0
3	1.57	2.28	4.45	0.40	1.93	1.31	144.23	100.00	256.18	4.7
4	1.04	2.03	2.66	0.47	1.43	3.77	105.77	111.11	228.28	4.5
5	1.15	1.84	3.12	0.57	1.18	1.10	48.08	88.89	145.93	3.5
6	1.58	2.34	5.09	0.64	1.04	1.43	61.54	111.11	184.75	4.3
7	1.32	3.15	3.29	0.70	1.46	1.95	86.54	111.11	209.53	4.8
8	1.19	2.36	5.14	0.68	2.14	1.84	115.38	100.00	228.74	5.1
9	1.86	2.87	5.32	0.72	2.39	2.17	59.62	100.00	174.95	5.3
10	1.82	2.07	3.82	0.85	1.71	2.27	48.08	188.89	249.50	5.1
11	1.83	2.04	2.31	0.89	1.25	1.17	115.38	122.22	247.11	4.5
12	1.99	3.23	4.62	0.72	0.89	1.29	94.23	111.11	218.08	4.7
13	2.07	4.24	5.49	0.77	1.86	3.18	53.85	133.33	204.78	6.0
14	2.31	3.86	5.72	0.81	1.96	3.39	50.00	200.00	268.06	6.4
15	2.52	3.16	5.90	0.62	2.18	1.17	103.85	166.67	286.05	5.8
16	2.47	3.03	6.36	0.60	2.39	2.21	67.31	155.56	239.92	6.0
17	2.12	2.87	9.02	0.51	2.68	1.95	73.08	222.22	314.45	6.3
18	2.01	3.46	8.09	0.87	2.50	1.74	101.92	233.33	353.92	6.9
19	2.45	3.25	9.25	0.94	2.75	1.62	105.77	255.56	381.59	7.3
20	2.76	4.24	9.83	1.04	2.86	1.56	161.54	266.67	450.49	8.3
Min.	1.04	1.84	2.31	0.40	0.89	1.10	48.08	88.89	145.93	3.50
Max.	2.76	4.24	9.83	1.04	2.86	3.77	161.54	266.67	450.49	8.30
Average	1.86	2.82	5.36	0.70	1.96	2.03	87.79	150.00	252.51	5.47

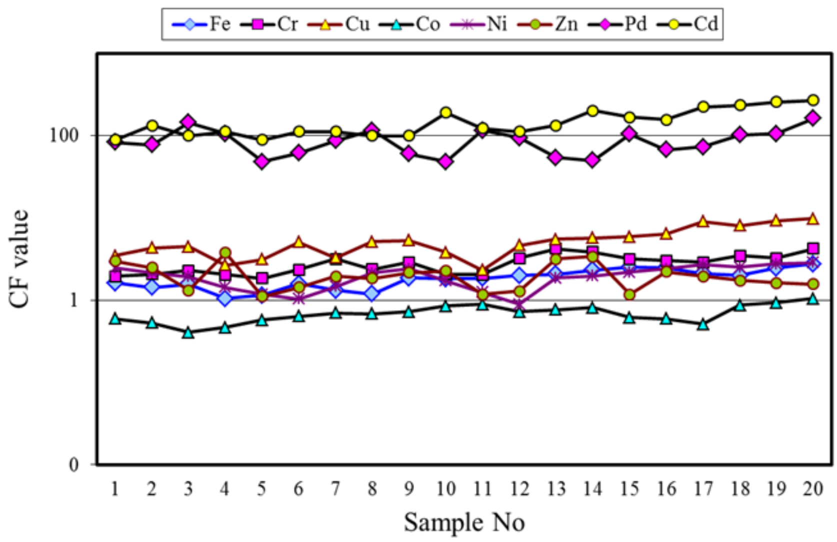

Figure 4: Contamination factor of the heavy metals of the sediments of Rosetta Branch

Table 4: Enrichment factor of the sediments of Rosetta Branch

S. No.	Cr	Cu	Co	Ni	Zn	Pb	Cd
1	1.22	2.15	0.37	1.53	2.13	51.03	54.04
2	1.44	0.3	0.37	1.5	2	53.45	91.27
3	0.54	2.84	0.26	1.24	0.51	91.61	62.58
4	1.96	2.56	0.45	1.38	4.16	101.2	104.74
5	1.6	2.71	0.5	1.03	1.1	41.57	75.72
6	1.49	3.23	0.41	0.66	1.04	38.93	69.24
7	2.39	2.5	0.53	1.11	1.69	65.27	82.57
8	2	4.34	0.58	1.82	1.79	96.93	82.76
9	1.55	2.87	0.39	1.29	1.34	31.98	52.85
10	1.14	2.1	0.47	0.95	1.44	26.39	102.17
11	1.12	1.26	0.49	0.69	0.73	62.73	65.46
12	1.63	2.33	0.36	0.45	0.74	47.29	54.93
13	2.06	2.66	0.37	0.9	1.77	25.98	63.39
14	1.68	2.48	0.35	0.85	1.69	21.56	84.96
15	1.26	2.35	0.25	0.87	0.53	41.11	65
16	1.23	2.57	0.24	0.97	1.03	27.11	61.74
17	1.36	4.25	0.24	1.27	1.05	34.31	102.78
18	1.73	4.04	0.44	1.25	1	50.64	114.22
19	1.33	3.78	0.38	1.13	0.76	42.99	102.33
20	1.54	3.57	0.38	1.04	0.65	58.38	94.95
Min.	0.54	0.30	0.24	0.45	0.51	21.56	52.85
Max.	2.39	4.34	0.58	1.82	4.16	101.20	114.22
Average	1.51	2.74	0.39	1.10	1.36	50.52	79.39

Note: n.a = Not available

The calculated ecological risk factor (Er) of the study samples revealed that the area was at a very high ecological risk with Pb and Cd (439.6 and 4350; respectively) which is compatible with the results of the index of geo- accumulation Index (I_{geo}). In addition, the recorded values of Cr, Cu, Co, Ni and Zn have a low ecological risk in the study area (Table 5 and Fig. 6).

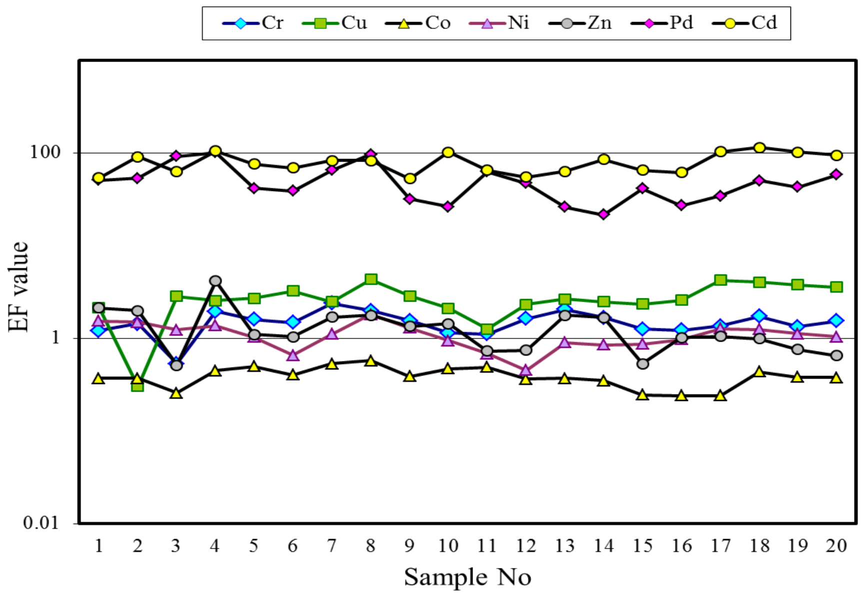

Figure 5: Enrichment factor of the heavy metals of the sediments of Rosetta Branch

Table 5: Ecological risk factor (Er) and Pollution ecological risk index (PRI) of the study sediments

	Er							PRI
S. No.	Cr	Cu	Co	Ni	Zn	Pb	Cd	
1	3.92	17.35	3	12.3	2.99	413.45	2666.7	3119.71
2	4.1	22.25	2.65	10.7	2.49	384.6	3999.9	4426.14
3	4.56	22.25	2	9.65	1.31	721.15	3000	3760.92
4	4.06	13.3	2.35	7.15	3.77	528.85	3333.3	3892.78
5	3.68	15.6	2.85	5.9	1.1	240.2	2666.7	2936.23
6	4.68	25.45	3.2	5.2	1.43	307.7	3333.3	3680.96
7	6.3	16.45	3.5	7.3	1.95	432.7	3333.3	3801.5
8	4.72	25.7	3.4	10.7	1.84	576.9	3000	3623.26
9	5.74	26.6	3.6	11.95	2.17	298.1	3000	3348.16
10	4.14	19.1	4.25	8.55	2.27	240.4	5666.7	5945.41
11	4.08	11.55	4.45	6.25	1.17	591.9	3666.6	4271
12	6.46	23.1	3.6	4.45	1.29	471.15	3333.3	3843.35
13	8.48	27.45	3.85	9.3	3.18	266.9	3999.9	4321.41
14	7.72	28.6	4.05	9.8	3.39	250	6000	6303.56
15	6.32	29.5	3.1	10.9	1.17	519.25	5000.1	5570.34
16	6.06	31.8	3	11.95	2.21	336.55	4666.8	5058.37
17	5.74	45.1	2.55	13.4	1.95	365.4	6666.6	7100.74
18	6.92	40.45	4.35	12.5	1.74	509.6	3999.9	7575.46
19	6.5	46.25	4.7	13.75	1.62	528.85	7666.8	8268.47
20	8.48	49.15	5.2	14.3	1.56	807.7	8000.1	8886.49
Min.	3.68	11.55	2	4.45	1.1	240.2	2666.7	2936.23
Max.	8.48	49.15	5.2	14.3	3.77	807.7	8000.1	8886.49
Average	5.63	26.85	3.5	9.8	2.03	439.6	4350	4986.7

3.2. The integrated pollution indices

The integrated pollution indices (DC, PLI and PRI) are important factors to identify multi-element contamination resulted from the increased toxic elements [8, 31, 32].

The DC values ~ 252.51 (Table 3) indicated that all the study samples can be considered a very high contaminated degree. High values of Cd and Pb are the main reason for the wide range of high contamination level of the study area.

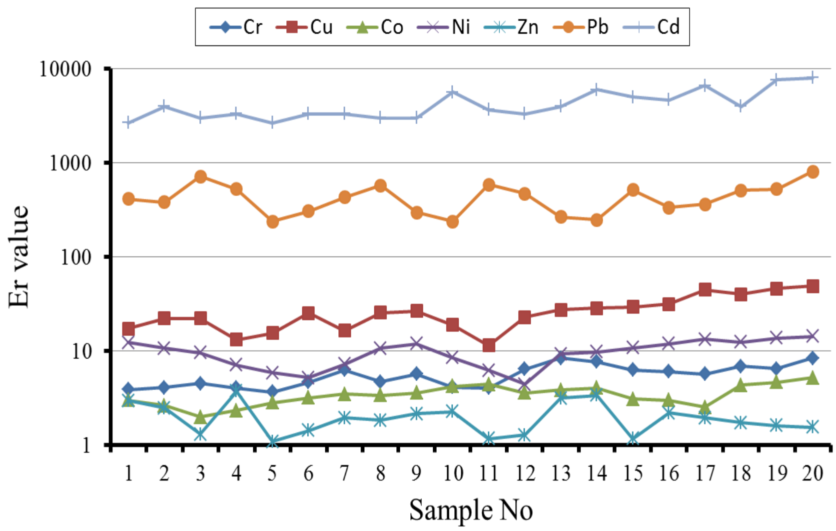

Figure 6: Ecological risk factor (Er) and Pollution ecological risk index (PRI) of the study sediments

The calculated PLI was greater than 3; PLI > 1 indicated that high load of heavy metals in the investigated area. So, it is revealed the role of external discrete sources; vehicle exhaust and agricultural activities on soil pollution [8]. Angula [33] mentioned that PLI can be estimated the contamination of metals status and essential action must be taken into consideration.

PRI calculation results of samples (Table 5) showed that the study sediments represented a very high ecological risk. The ecological risk comes mainly from sediment pollution with Pb and Cd. These two metals have dangers effect on plants and human health and much attention must be paid to the study area quality.

3.3. Comparison of the current results with previous work:

The concentrations of Cu, Pb and Zn in bottom Nile sediments in the Kafr El Zayat area are recorded 33, 39 and 91ppm; respectively [34]. El-Amier and Abd El-Gawad [35] and El-Amier et al. [3] recorded lower concentrations of metals in Rosetta bottom sediments than the current study. Where, El-Amier and Abd El-Gawad [35] recorded about 99.06, 32.43, 0.59, 2.68, 49.16, 21.31 and 1.63 ppm and El-Amier et al. [3] recorded 27.83, 4.1, 0.61, 2.38, 4.38, 4.53 and 0.45 of Fe, Cu, Co, Ni, Zn, Pb and Cd, respectively. On the other hand, the current study recorded lower concentrations of Cd and Pb than Yehia and Sebaee [36]. Pb contents in Lower Egypt (in the north) range from 8 to 87 ppm, whereas the bottom sediments in the Kafr El Zayat area show higher Pb contents (58 - 87 ppm) [2]. Abu Khatita [37] was recorded the high concentration of Cu (139 ppm) at the rubber factory followed by the industrial zone adjacent to the brick factory (130 ppm) and at Tanta city close to the flax and oil factory (101 ppm). Also, he mentioned that the contents of Fe in the surface soil, cultivated soil, industrial and urban samples were 63, 77, 60 and 60 ppm; respectively, which were very lower than the recorded concentrations in the present study. Wherever, the average concentration of the heavy metals in the study samples shows high contents than those recorded by Wahid and Shahaeen [38] for Rosetta sediments.

Table 6 and Figure (7) show the distribution of the trace elements in the study area in comparison with the concentration in surface and core industrial samples in Kafer El-Zayat [37]. The concentrations of Cr and Cu are more enrichment in the studied sediments than surface and core industrial samples in Kafer El-Zayat. Pb and Zn were lower than their content in the surface soil of the industrial area and higher than their content in the core samples.

The concentrations of heavy elements in the investigated samples are enrichments as a result of the anthropogenic activities (agrochemical applications, industrial and traffic emissions and domestic wastes).

Table 6: Comparison the studied heavy metals with surface and core industrial samples from Kafer El-Zayat.

	Cr	Cu	Co	Ni	Zn	Pb	Cd
Present study *(ppm)*	261	94	33	55	159	46	14
Surface industrial sample *(ppm)*[37]	115	63	27	66	225	51.16	n.a
Core industrial sample *(ppm)* [37]	151	88	36	78	114	22.3	n.a

Note: n.a = Not available

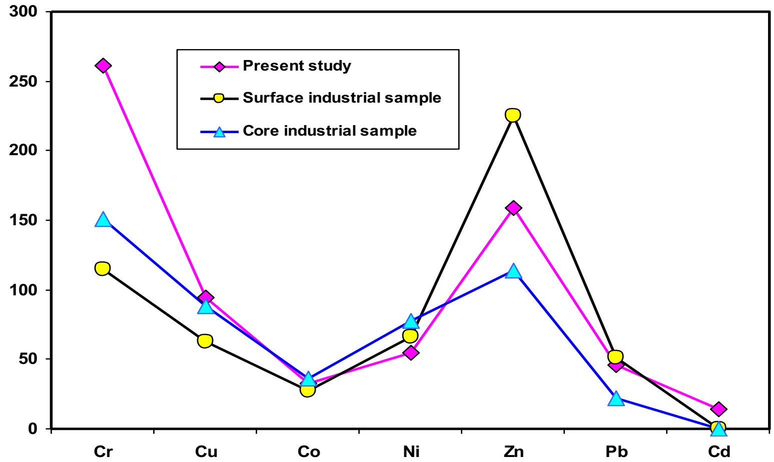

Figure 7: Comparison the heavy metals study with surface and core industrial samples from Kafer El-Zayat

3.4. Sources of heavy metals

Naturally, sediments contain usually significant contents of elements, but anthropogenic accompaniments can cause their disturbance. The geochemical studies of the Rosetta branch sediments reveal that the study sediments subjected to anthropogenic inputs. Also, Zn and Cu, Pb (159, 94 and 46 ppm; respectively) in the study sediments are comparable to the content of the cultivated soils from Tanta city 185, 93 and 52 ppm;

respectively [37]. This area represents the commercial zone of the Nile Delta region where the traffic is very busy. The elements Pb and Zn are resulting from vehicle traffic and fuel oil combustion as sources. This indicates that these elements are particularly enriched in soil as a result of varying industrial activities.
The study trace elements are classified into two sets of elements. The first set includes Fe, Co, Cr and Ni, which is predominantly of natural origin and is controlled by the distribution of clay minerals. The second set of elements includes Cu, Zn and Pb, which are affected predominantly by anthropogenic sources. The elements dispersed by industrial activities are Cu, Pb and Zn; the elements dispersed by traffic emissions and fuel oil combustion as sources are Pb, Zn and some Cu. In addition, elements influenced by agrochemicals and drain water irrigation are Cu, and Pb. Thus the Kafr El Zayat industrial zone is responsible for the high concentration of these elements. The domestic wastes, agriculture and industrial output along the Rosetta district led to a relative enrichment of the heavy metals in the northern part than those of the southern. The industrial sector of Kafer El-Zayat and fertilizers are represented the most important factors affecting the pollution of the environment.

Conclusions

The Nile Delta suffers from different pollution sources as result of the increasing number and different types of industries and uses the drain water supply and the increasing waste deposits. The enhancement of the heavy metals in the study sediments is attributed to the anthropogenic sources; domestic wastes, fertilizers, agriculture irrigation, and industrial output. Environmental efforts must be done to keep the heavy metal concentration under permissible levels where the geochemical results indicate rising trend. The irrigation of farmlands by drain waste water which has not been adequately treated should be forbidden.

Extensive efforts and development must be carried out in Kafr El Zayat city to reduce the number of vehicles in order to diminish the quantity of emissions. Laws should be enacted to prevent the output of the industrial wastewater to the Nile River. This excessive discharge leads to an increase in heavy metal levels in the water, which in turn can be ingested through eating the fish from this water.

In the study area, there are several sources for the potentially toxic metals. Consequently, the authors believe that the pollution in the study area is resulting from more than one anthropogenic source; the atmospheric deposition, irrigation with waste drain water from various industrial areas, which affected in the growing plants in the zone.

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