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Assessment of Trace Metal Pollution in the Bottom Sediments of Manzala Lagoon, Egypt

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Abstract

The target of this investigation is to assess concentrations of trace metals in bottom sediemts from Manzala Lagoon (ML). The southern part is characterized by a lower salinity and a higher percentage of clay, while the northern part is characterized by a higher salinity and higher percentage of sand. This lagoon receives great amounts of contaminants from different sources (domestic, agricultural and industrial). This investigation is based on 6 trace metals, including Cu, Mn, Zn, Pb, Ni and Cd. Relying on the pollution indices, the lagoon is categorized into the following parts: the northern part with the lowest degree of contamination, the central part with a considerable degree and the southern one which records the highest levels. Cd represents the most dangerous toxic metal in this study.

Keywords: Manzala Lagoon, trace metals, pollutants.

Introduction

ML is the largest coastal lagoon in Egypt. It occurs in the north-eastern corner of the Nile delta. It has a length of about 60 km and a width of 40 km. According to Ayache et al. (2009) the existence of more than 1000 islands reduced the area of open water to nearly 500 km^2. Therefore, it is subdivided into many basins (e.g., Bahr Al-Hadawi, Bahr Al-Mihayjar, Bahr Ash-Sharak, Bahr Janb At-Timsah, Bahr Al-Bashmur, Bahr Az-Zarqah, Bahr Ad-Dibju As-Saghir, Bahr Ad-Dibju Al-Kabir, Bahr Ad-Diju, Bahr Al-Hamrah, Bahr Kurmullus, Bahr Al-Milh, Bahr Al-Bashtir, Bahr Al-Kur).

The lagoon is surrounded to the North by the Mediterranean Sea, to the East by Suez Canal and the Damietta Branch to the West (Fig. 1), while the southern shores represent the north boundary of Sharkiya and Dakahiliya Governorates. It is linked to the Mediterranean Sea through El-Boughaz inlets.

The southern area of the studied lagoon is exposed to the invasion of about 3.7 km^3 of fresh water annualy through some drains, including El-Serw, El-Gammaliya, Hadus-Ramses, El-Matariya and Bahr El Baqar (Abdel-Satar, 2001; Elewa et al. 2007).

Therefore, salinity records its lowest value low near the southern drains, but it records its highest value in the north. In addition, the lagoon is highly eutrophic with nutrients and other toxic compounds, especially in southern parts (Elmorsy et al. 2017). The climate of the study area belongs to the Mediterranean climate which is characterized with arid to semi-arid conditions.

The important of ML arises from the high production of fishes. In addition, it has a precise location for waterbirds.

The most effective challenges facing the lagoon are the reduction of Manzala area, pollution and the spread of aquatic plants. The area of Manzala was changed throughout the last decades (Oczkowski & Nixon, 2010). The southern and western borders were subjected to a greater loss due to land reclamation, silting and the spread of many islands (Dewidar & Khedr, 2001).

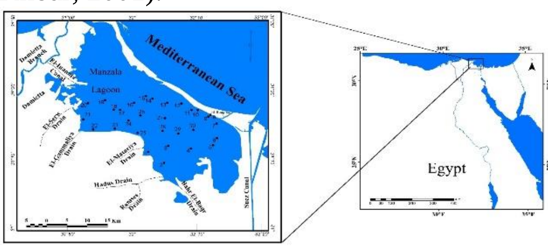

Fig .1. location map of study area

Materials and methods:

30 samples were taken from the bottom sediments of ML by a grab. Three groups of samples were collected from each station. Moreover, salinity, pH and water depth were measured as clarified in (Table 1). The first group of samples was prepared to carry out the grain size analysis. The second group was dried and reduced to a powder to calculate the levels of Mn, Cu, Cd, Pb, Zn and Ni using the digestion by HNO_3 hydrofluoric (HF) acids (Oregioni and Aston,1984). Atomic spectrophotometer was used to do this investigation.

Results

Water Depth

The recorded depths range between 53 cm and 250 cm (with an average of 162.9 cm (Table 1 and Figure 2). The high sedimentation rates that resulted from the discharge into the lagoon and the burial of dense vegetation may be the reasons for the shallowness of the lagoon.

Salinity

The measured salinities range between 1.23 g/l and 20.6 g/l with an average of 6.1 g/l (Table 1 and Figure 3). The salinity increases near the northeastern parts due to the intrusion of seawater, while it declines in the southern parts due to the entry of fresh water. Theses results are similar to those of El-Enany (2004), Elewa et al. (2007) El Baz (2017) and Elmorsi et al. (2017).

Hydrogen ion concentration (pH)

The values of pH range from 7.12 to 9.11 (at site 15) as seen in (Figure 4 and Table 2). The average is 8.09. Therefore, the water is alkaline. Generally, pH increases towards the northern stations, whereas it decreases at the southern stations. Theses results are comparable to that deduced by Elewa et al. (2007) El Baz (2017) and Elmorsi et al. (2017).

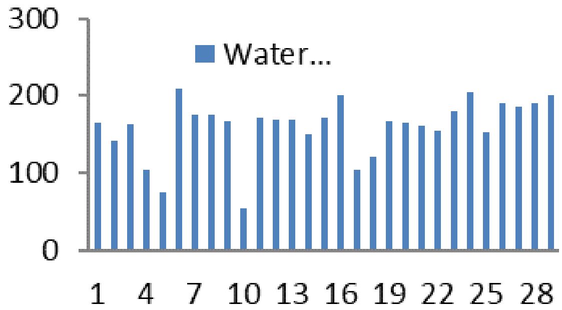

Fig. 2. Measured depths

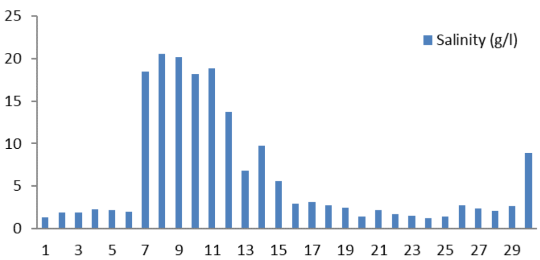

Fig. 3. Measured salinites

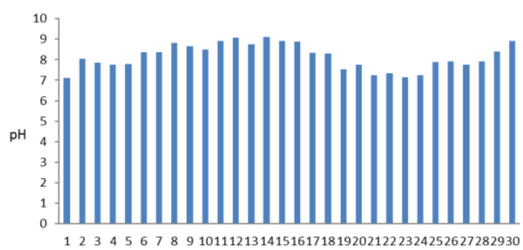

Fig. 4. Measured pH.

Table 1. Measured environmental parameters.

Site number	Salinity (g/l)	pH	Water depth (cm)
1	1.29	7.25	164
2	1.84	7.12	141
3	1.92	8.05	163
4	2.24	7.86	105
5	2.16	7.76	74
6	2.01	7.79	210
7	18.5	8.35	176
8	20.6	8.36	175
9	20.16	8.82	168
10	18.2	8.67	53
11	18.87	8.5	172
12	13.75	8.9	169
13	6.82	9.08	170
14	9.71	8.76	151
15	5.58	9.11	172
16	2.9	8.92	200
17	3.11	8.88	105
18	2.77	8.33	120
19	2.43	8.3	167
20	1.42	7.52	165
21	2.21	7.76	160
22	1.72	7.23	155
23	1.46	7.32	179
24	1.23	7.13	205
25	1.45	7.25	153
26	2.7	7.87	190
27	2.4	7.91	185
28	2.1	7.74	190
29	2.6	7.9	200
30	8.9	8.4	250
Average	6.1	8.09	162.9
Max	20.6	9.11	250
Min	1.23	7.12	53

Sediment:

The percentages of sand fractions range from 5% (at site 22) to 66% (site 8) with an average of 30.2 %. The percentages of silt fractions range from 30% (site 8) to 44% (at site 20) with an average of 37.13 %. The percentages of clay fractions fluctuate between 3% (at sites 9 and 10) and 59% (at site 25) with an average of 32.6 %. Near the northern sites, sand portions dominate, whereas the clay portions dominate the southern parts, that are close to drains (Table 2).

Concentration of trace metals :

For Cu, the levels range from 36 µg / g (site 9) to 163 µg / g (site 2 opposite to the drain of Bahr El Baqar) with an average of 94.2 µg/g. It is clear that the values increase in the southern sites near drains,while they decrease towards the northern sites (Fig. 6). This trend of distribution is similar to those recorded by El Baz (2017).

For Zn, the levels range from 23 µg / g (site 30) to 152 µg / g (at site 2 opposite to the drain of Bahr El Baqar) with an average of 69.43µg/g (Fig. 7).

For Pb, the levels range from 22 µg /g (site 30) to 166 µg /g (site 2) with an average of 83.53 µg /g (Fig. 8).

For Mn, the levels range from 240 µg /g (at site 29) to 832 µg /g (site 2) with an average of 448.73 µg/g (Fig. 9).

For Cd, the levels range from 12 µg /g (at site 17) to 22 µg /g (site 24) with an average of 16.6 µg/g (Fig. 10).

For Ni, the levels range from 142 µg /g (at site 9) to 271 µg/g (site 4) with an average of 218.9 µg/g (Fig. 10).

Generally, the maximum levels of trace metals were noted near southern drains and decrease in northen sites, owing to the invasion of the industrial disposal and agricultural drainage water.Generally, the maximum levels of trace metals were noted near the southern drains and decrease in the northen sites, owing to the entrance of the industrial disposal and agricultural drainage water into the lagoon for a long time without treatment.

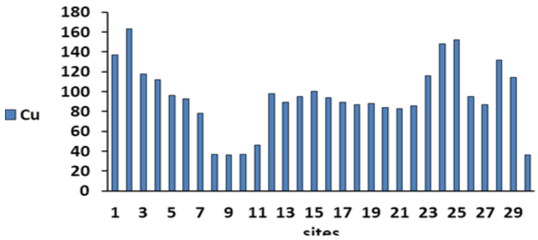

Fig 5. The concentraions of Cu (µg/g) .

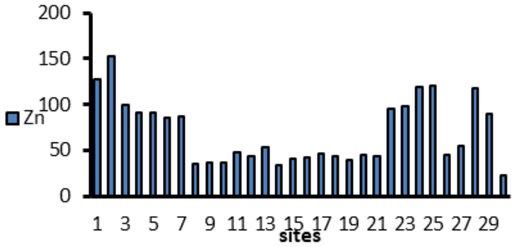

Fig. 6. The concentraions of Zn (µg/g) .

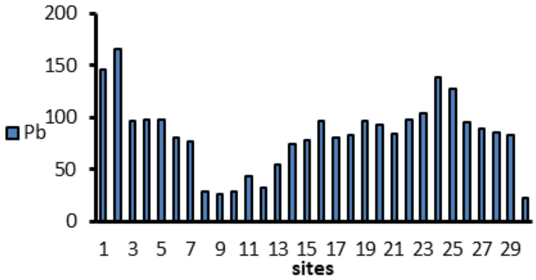

Fig. 7. The concentrations of Pb (µg/g).

Table 2. Grain size analysis of the studied samples.

Site number	Sand %	Silt %	Clay %
1	8	41	51
2	9	38	53
3	12	37	51
4	17	37	46
5	16	34	50
6	18	32	50
7	47	43	10
8	66	30	4
9	65	32	3
10	64	33	3
11	62	34	4
12	61	35	4
13	57	38	5
14	53	40	7
15	52	42	6
16	36	38	26
17	21	41	38
18	18	40	42
19	19	40	41
20	10	44	46
21	7	37	56
22	5	38	57
23	6	38	56
24	7	42	51
25	5	36	59
26	33	36	31
27	31	37	32
28	26	32	42
29	33	35	32
30	42	34	24
Average	30.2	37.13	32.6
Max	66	44	59
Min	5	30	3

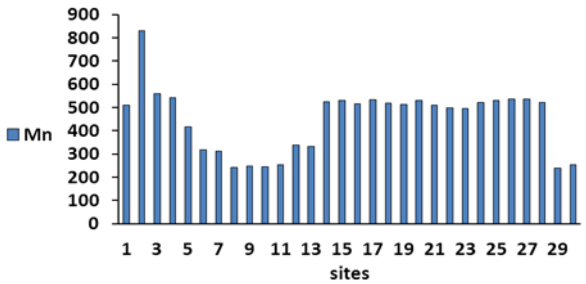

Fig. 8. The concentrations of Mn (μg/g) .

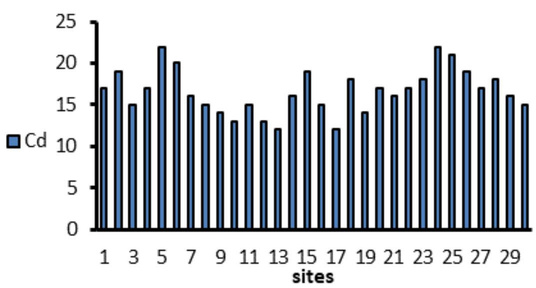

Fig. 9. The concentrations of Cd (μg/g).

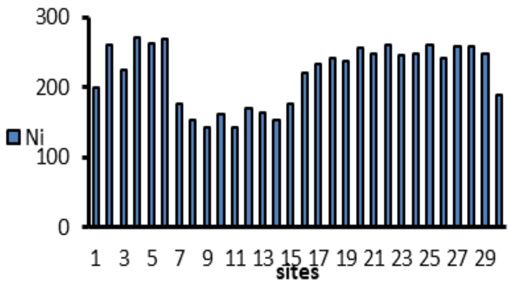

Fig. 10. The concentrations of Ni (μg/g) .

Table3. The concentrations of trace metals (μg /g).

	Cu	Zn	Pb	Mn	Cd	Ni
Min	36	23	22	240	12	142
Max	163	152	166	832	22	271
Average	94.2	69.43	83.53	448.73	16.6	218.9
Background shale	45	95	20	850	0.3	68
Toxic response factors	5	1	5	1	30	5

Contamination indices :

According to Turekian and Wedepohl (1961), the values of background shale are utilized here (Table 3). Also, toxic-response factors of Hökanson (1980) are followed here.

Contamination factor (Cf) :

The calculated values of Cf are displayed in Table 5. Regarding Cu, sediments at sites 1, 2, 24 and 25 are considerably contaminated, sites 8, 9, 10 and 30 are low contaminated, whereas the others are moderately contaminated. Concerning Zn, sites 1-3, 22-25 and 28 are moderately contaminated, while the others are low contaminated. For Pb, stations 1, 2, 24 and 25 are very highly contaminated, sites 8-13 and 30 moderately contaminated, whereas the others display considerable contamination. For Mn, all sites show low contamination. For Cd, all sites show very high contamination. For Ni, sites 1, 7-15, 30 are moderately contaminated, while the others are considerably contaminated.

Degree of contamination (Dc) :

Dc was calculated for Cu, Zn, Pb, Mn, Cd and Ni. According to Hökanson (1980), all sites display very high Dc, where the values are more than 28 (Table 4). The average value of Dc is 66.08.

Geoaccumulation index (I_{geo}) :

For Cu, sites 8-11 and 30 are unpolluted, but the others are unpolluted to moderately polluted (Table 5). All the sites are unpolluted with Zn and Mn. For Pb, sites 8-10 and 30 are unpolluted, but the others are unpolluted to moderately polluted. For Cd, all sites are moderately polluted. For Ni, all sites are unpolluted to moderately polluted.

Ecological risk factor (Er):

Er of Hökanson (1980) is applied here. For Cu, Zn, Mn and Ni all sites showed low values of Er. For Pb all sites show low values of Er, with the exception of site 2 that show moderate value of Er (Table 6). On the contrary, Cd displays very high Er values.

Table 4. Values of Cf and Dc.

Site	Cf						Dc
	Cu	Zn	**Pb**	**Mn**	**Cd**	**Ni**	
1	3.04	1.34	7.3	0.59	56.67	2.94	71.89
2	3.62	1.6	8.3	0.97	63.33	3.83	81.67
3	2.62	1.04	4.85	0.66	50	3.29	62.46
4	2.48	0.95	4.9	0.63	56.67	3.98	69.63
5	2.13	0.95	4.9	0.48	73.33	3.86	85.68
6	2.06	0.89	4.05	0.37	66.67	3.94	77.99
7	1.73	0.91	3.85	0.36	53.33	2.58	62.78
8	0.82	0.36	1.45	0.28	50	2.25	55.17
9	0.8	0.38	1.3	0.29	46.67	2.08	51.53
10	0.82	0.37	1.45	0.28	43.33	2.38	48.65
11	1.02	0.50	2.15	0.29	50	2.10	56.07
12	2.17	0.45	1.6	0.39	43.33	2.48	50.44
13	1.97	0.55	2.75	0.39	40	2.41	48.08
14	2.11	0.35	3.7	0.61	53.33	2.23	62.35
15	2.22	0.43	3.9	0.62	63.33	2.58	73.10
16	2.08	0.44	4.85	0.60	50	3.25	61.23
17	1.977	0.48	4.05	0.62	40	3.42	50.56
18	1.93	0.45	4.15	0.61	60	3.55	70.70
19	1.95	0.41	4.8	0.60	46.67	3.47	57.90
20	1.86	0.47	4.65	0.62	56.67	3.75	68.03
21	1.84	0.46	4.2	0.59	53.33	3.64	64.08
22	1.91	1.01	4.9	0.58	56.65	3.83	68.91
23	2.57	1.03	5.2	0.58	60	3.60	72.99
24	3.28	1.25	6.95	0.61	73.33	3.63	89.07
25	3.37	1.27	6.35	0.62	70	3.83	85.46
26	2.11	0.47	4.75	0.62	63.33	3.55	74.85
27	1.93	0.57	4.45	0.63	56.64	3.77	68.04
28	2.93	1.23	4.3	0.61	60	3.80	72.88
29	2.53	0.94	4.15	0.28	53.33	3.63	64.87
30	0.8	0.24	1.1	0.29	50	2.77	55.21
average	2.09	0.73	4.17	0.52	55.59	3.21	66.08

Discussion :

The results of trace metal show that Mn has the highest concentrations in Manzala lagoon followed by Ni, Cu, Pb, Zn, while Cd has the lowest concentrations. The invasion of wastewater discharge and fertilizers may be the chief reasons for the increase of Mn in the study area. The drainage water that come in the lagoon may be the main source for Cu. The possible sources of Zn may be due the fertilizers and heavy industries. Moreover, the chief causes of Cd are textile, wastewater, fertilizers and petroleum (El Nemr et al. 2007).

Table 5. Values of I_{geo} and PLI.

Site	**I_{geo}**						**PLI**
	Cu	**Zn**	**Pb**	**Mn**	**Cd**	**Ni**	
1	0.30	-0.04	0.68	-0.39	1.57	0.29	3.79
2	0.38	0.02	0.74	-0.18	1.62	0.40	4.74
3	0.24	-0.15	0.50	-0.35	1.52	0.34	3.36
4	0.21	-0.19	0.51	-0.37	1.57	0.42	3.44
5	0.15	-0.19	0.51	-0.48	1.68	0.41	3.34
6	0.13	-0.22	0.43	-0.60	1.64	0.419	3.00
7	0.06	-0.21	0.40	-0.61	1.55	0.23	2.60
8	-0.26	-0.60	-0.01	-0.72	1.52	0.17	1.55
9	-0.27	-0.58	-0.06	-0.71	1.49	0.14	1.50
10	-0.26	-0.59	-0.01	-0.71	1.46	0.20	1.54
11	-0.16	-0.47	0.15	-0.70	1.52	0.14	1.80
12	0.16	-0.52	0.02	-0.57	1.46	0.21	2.01
13	0.12	-0.42	0.26	-0.58	1.42	0.20	2.20
14	0.14	-0.62	0.39	-0.38	1.55	0.17	2.42
15	0.17	-0.54	0.41	-0.38	1.62	0.23	2.69
16	0.14	-0.53	0.50	-0.39	1.52	0.33	2.75
17	0.12	-0.49	0.43	-0.37	1.42	0.35	2.63
18	0.11	-0.52	0.44	-0.39	1.60	0.37	2.79
19	0.11	-0.56	0.50	-0.39	1.49	0.36	2.68
20	0.09	-0.50	0.49	-0.38	1.57	0.39	2.85
21	0.08	-0.51	0.44	-0.39	1.55	0.38	2.73
22	0.10	-0.17	0.51	-0.40	1.57	0.40	3.26
23	0.23	-0.16	0.53	-0.40	1.60	0.38	3.47
24	0.34	-0.07	0.66	-0.38	1.68	0.38	4.09
25	0.35	-0.07	0.62	-0.38	1.66	0.40	4.07
26	0.14	-0.50	0.50	-0.37	1.62	0.37	2.96
27	0.11	-0.41	0.47	-0.37	1.57	0.40	2.96
28	0.29	-0.08	0.45	-0.38	1.60	0.40	3.60
29	0.22	-0.19	0.44	-0.72	1.55	0.38	2.85
30	-0.27	-0.79	-0.13	-0.70	1.52	0.26	1.43
Average	0.11	-0.36	0.39	-0.47	1.56	0.32	2.83

From Table 10, it is observed that, the measured concentrations of Mn are higher than those registered by El-Sorogy et al., (2016) from the Rosetta coast, Egypt, by Abdel Ghani et al., (2013) from Abu-Qir Bay, Egypt, by Soliman et al., (2015) from the Mediterranean coast of Egypt by Nasr et al., (2015) from Libya and by Omar et al., (2015) from Morocco, but they are lower than that documented by Shalaby et al. (2017) from Manzala and Edku.

Concerning Cu, the recorded levels are the greatest, with the exception of the Safax coast, Tunisia, which have higher values (Dias de Alba et al. (2011). For Zn, the levels are the greatest, with the exception of Edku (Shalaby et al. 2017) and Rosetta El-Sorogy et al., (2016). For Cd, the recorded levels are the greatest, with the exception of Rosetta (El-Sorogy et al., 2016). For Pb, the recorded levels are the greatest, with the exception of the Safax coast, Tunisia (Dias de Alba et al. (2011), and

Rossetta (El-Sorogy et al., 2016). Based on the average values of the contamination factor, the measured trace metals are in the order Cd > Pb > Ni > Cu > Zn > Mn. Also, based on the average values of I_{geo}, all sites are moderately polluted with Cd and the metals are arranged as follows Cd > Pb > Ni > Cu > Zn > Mn. According to the pollution load index, all sites are considered polluted, where the values are greater than one (Tomlinson et al. 1980).

Based on these indices, the lagoon may be subdivided into three parts: highest contaminated part (southern), the middle part with considerable contamination and the northern less contaminated part. Therefore, the southern drains are the major causes for the pollution in the study area. Also, it is observed that, the lowest levels of trace metals are recorded in that sites with high percentages of sand, while the highest values noted in those dominated by a high percentages of clay. This conclusion is confirmed by Martins et al. (2015a, 2015b) from the Aveiro Lagoon (Portugal), where a high pollution load index was observed in sites dominated by fine fractions.

Table 6. Values of Er and Ri.

Site	Er						Ri
	Cu	Zn	Pb	Mn	Cd	Ni	
1	15.22	1.34	36.5	0.59	1700	14.70	1768.35
2	18.11	1.6	41.5	0.97	1900	19.19	1981.37
3	13.11	1.04	24.25	0.66	1500	16.47	1555.53
4	12.44	0.95	24.5	0.63	1700	19.92	1758.45
5	10.66	0.95	24.5	0.48	2200	19.33	2255.93
6	10.33	0.89	20.25	0.37	2000	19.70	2051.54
7	8.66	0.91	19.25	0.36	1600	12.94	1642.12
8	4.11	0.36	7.25	0.28	1500	11.25	1523.25
9	4	0.38	6.5	0.29	1400	10.44	1421.61
10	4.11	0.37	7.25	0.28	1300	11.91	1323.92
11	5.11	0.50	10.75	0.29	1500	10.51	1527.16
12	10.88	0.45	8	0.39	1300	12.42	1332.15
13	9.88	0.55	13.75	0.39	1200	12.05	1236.63
14	10.55	0.35	18.5	0.61	1600	11.17	1641.19
15	11.11	0.43	19.5	0.62	1900	12.94	1944.60
16	10.44	0.44	24.25	0.60	1500	16.25	1551.98
17	9.88	0.48	20.25	0.62	1200	17.13	1248.37
18	9.66	0.45	20.75	0.61	1800	17.79	1849.271
19	9.77	0.41	24	0.60	1400	17.35	1452.14
20	9.33	0.47	23.25	0.62	1700	18.75	1752.42
21	9.22	0.46	21	0.59	1600	18.23	1649.50
22	9.55	1.01	24.5	0.58	1700	19.19	1754.83
23	12.88	1.03	26	0.58	1800	18.01	1858.51
24	16.44	1.25	34.75	0.61	2200	18.16	2271.21
25	16.88	1.27	31.75	0.62	2100	19.19	2169.72
26	10.55	0.47	23.75	0.62	1900	17.79	1953.19
27	9.66	0.57	22.25	0.63	1700	18.89	1752.01
28	14.66	1.23	21.5	0.61	1800	19.04	1857.05
29	12.66	0.94	20.75	0.28	1600	18.16	1652.81
30	4	0.24	5.5	0.29	1500	13.89	1523.94

The results of risk factors point out that all the examined sites have low Er values . For Cd, all sites are at a very high risk level. Moreover, all sites have high values of potential ecological risk index. It is obvious that Cd is the main reason to the ecological risk factor in the study area. Also, this conclusion is detected by El Baz and Khalil (2018) from the Burullus Lagoon.

Conclusions

The sediments of ML are examined to assess the degree of pollution. These sediments contain of a combination of clay, sand and silt. Salinity decreases southward opposite to drains. The results declare that the levels of contamination decrease in northern parts which dominated by sand, however the southern part, that dominated by clay, shows the greatest levels of pollution. In addition, all sites are considered polluted, based on the pollution load index. According to the average values of the Cf and I_{geo}, the measured trace metals are arranged as follows Cd > Pb > Ni > Cu > Zn > Mn. Therefore, Cd is the most hamful toxic metal in this investigat

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