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ASSESSMENT OF SOME HEAVY METALS, MAJOR CATIONS AND ORGANIC MATTER IN THE RECENT SEDIMENTS OF BARDAWIL LAGOON, EGYPT

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Key words: Heavy metals, Major cations, organic matter, recent sediment, Bardawil lagoon

ABSTRACT

The aim of the present study is to gather detailed information on the distribution and concentration levels of some heavy metals (Fe, Mn, Zn, Cu, Pb & Cd), major cations (Ca, Mg, Na & K), in addition to organic matter in the Bardawil lagoon sediments during four successive seasons during (2001-2002). The different metals concentrations could be arranged in descending order as follows: - Ca> Na> Fe> Mg> K> Mn> Cu> Zn> Pb> Cd.

INTRODUCTION

The Bardawil lagoon is one of the largest salt water lagoons in the northern coast of Sinai province of Egypt. The Bardawil lagoon is situated between 32^{o} 40̀ and 33^{o} 30̀ E and between 31^{o} 3̀ and 31^{o} 14̀ N Fig (1). The lagoon covers an estimated area of 650 Km^2 with a maximum length of 90 Km^2 and a maximum width of 22 Km. The water depth ranges from 0.5 m to a rather rare 3 m., separated from the Mediterranean sea by a sedimentary bar with maximum width of 2 Km. It is connected to, the sea by two artificial opening in the west named Boghazes I and II and an eastern natural opening called Zarnik. (Yitzhak, 1971), (Siliem, 1989) and (El-Bawaab, 1995).

According to Fabbri *et al.,* (2001), Bordes & Bourg (2001); Singh *et al.,* (2000) and Celo *et al.,* (1999), the sediment acts as a carrier and a possible source of pollution, because heavy metals are not permanently fixed then and can be released back to the water column by changes in environmental conditions such as pH, redox potential or the presence of organic matter chelators.

Lotfy (2003), reported that, the distribution of trace metals in the sediments of Bardawil lagoon indicates that a common feature of increasing levels of Cu, Pb, and Cd was observed in the western sector of the lagoon which is affected by sea water through Boughaz I, while of Fe, Zn and Mn were observed in the eastern area, which is highly affected by sea water through Boughaz II.

Yacoub and Abdel-Satar, (2003) studied the effect of heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) and the macroelements (Na, K, Ca and Mg) on the liver tissues of the four fish species in the Bardawil lagoon.

The aim of the present study is to gather detailed information on the distribution and concentrations of Fe, Mn, Cu, Zn, Pb, Cd, Na, K, Ca, Mn and OM in the recent sediment of the lagoon.

MATERIALS AND METHODS

The sampling stations were chosen to cover the western and eastern areas of the lake (Fig. 1). Twelve stations are classified and named as follows:-

(a) The eastern arm including the following six stations:-

Name	Code number on the map
Karn Samda	St. 12
El-Kalss	St. 6
Matt Ebliss	St. 8
Messefek	St. 10
El-Telol	St. 11
Boghaz (II)	-

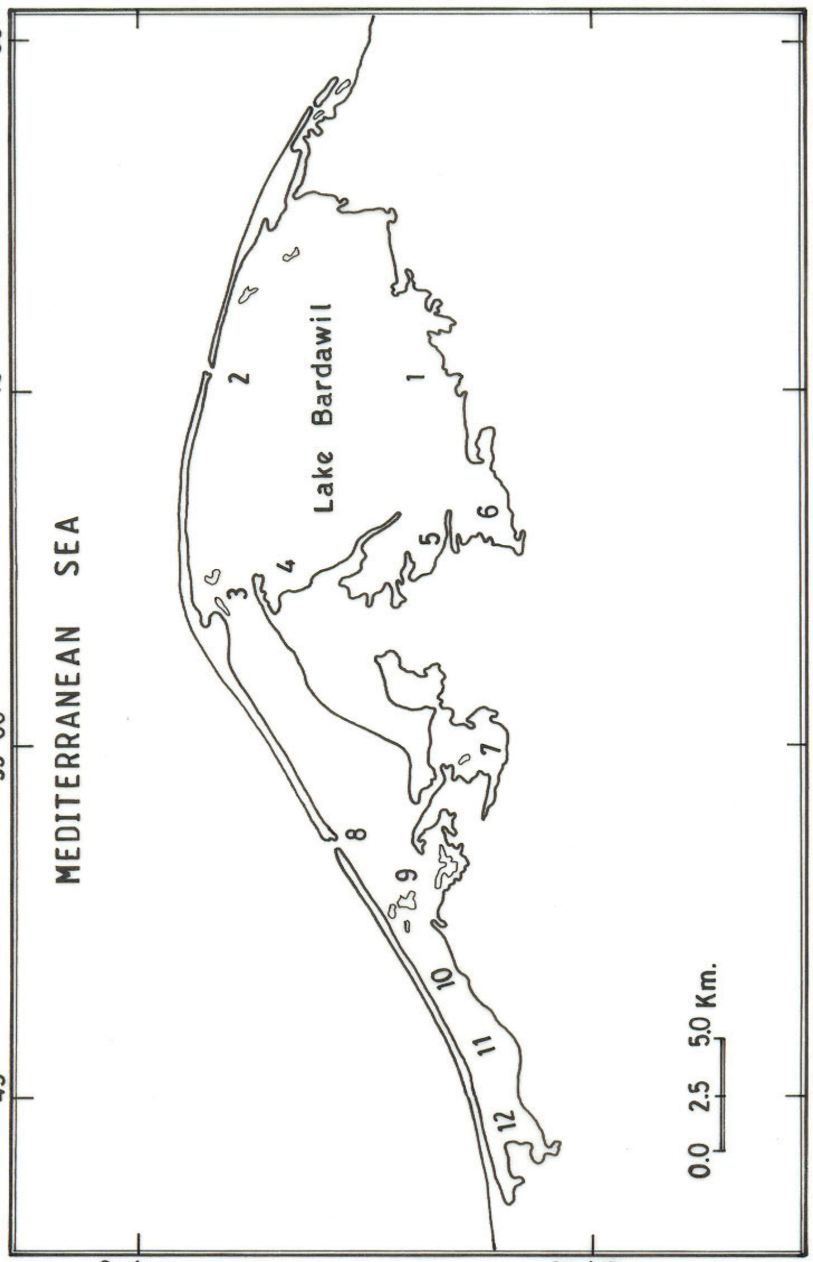

Fig. (1): Map showing the sampling sites in Lake Bardawil

(b) The western arm including the following six stations:-

Name	Code number on the map
El-Roak	St. 7
Al-Romih	St. 4
Al-Nasser	St. 3
Al-Negila	St. 2
Raba	St. 1
Boghaz (I)	-

The present study was extended from autumn 2001 to winter 2002.

Sediment analysis:-

The sediment samples were collected superficially by using Ekman Derdge and washed with deionized water and oven dried at 105^0, and grind in an agate mortar, then stored in polyethylene pags. The sediment samples were digested according to Kouadio and Trefry (1987). Totals metals (Fe, Mn, Cu, Zn, Pb, Cd, Ca and Mg) were measured using Inductive Coupled Plasma instrument (ICP-400 model perkin Elmer). Na^+ and K^+ were determined using the Flam-photometer Emission technique (model Jenway PFP U.K).

Organic matter in the sediment samples were determined by loss on ignition method according to Hanna (1965).

Statistical Analysis

Correlation coefficient (r) and standard deviation "S.D" between the studied elements in the sediment samples at different selection stations were tested using the computer programme EXCEL (Office XP).

RESULTS AND DISCUSSION

(A) Heavy metals in sediment:

Because of the very important role of heavy metals pollution, the determination and speciation of heavy metal is a primary target in environmental research (Warren and Zimmerman, 1994; Nowack *et al.,* 2001). Therefore, the analysis of heavy metals in sediments permit us to detect pollution that could liberated to water. Also, provides information about the critical sites of the water system under consideration (Fabbri *et al.,* 2001; Bordes & Bourg, 2001).

Seasonal variations of the studied heavy metals were found to be in the ranges of (2.03-17.06 mg/g), (18.25-785.20 µg/g), (11.20-95.15 µg/g), (17.85-70.80 µg/g), (3.20-40.65 µg/g) and (0.70-20.80 µg/g) for Fe, Mn, Cu, Zn, Pb and Cd respectively during different seasons. The results obtained of these heavy metals (Tables 1-6) revealed that, the high concentration values of most of the heavy metals were observed during hot seasons (summer- spring), and the lower values were recorded during cold seasons (winter- autumn). This may be attributed to the increase in organic matter concentrations which facilitate settling of iron to the sediment during hot seasons (Abdel-Satar & Elewa, 2001) and the lower values during cold season, may be attributed to the mobilization of iron from sediment to water (Elewa & Goher, 1999). Mn precipitate as MnO_2 under reducing conditions and rise of air and water temperatures during this period (Abdo, 2002). Zinc is precipitated as zinc oxide and zinc carbonate, in addition to copper. These results agreed with that reported by (Abdo, 2004). However, the lower concentration values of these metals during cold seasons may be due to, the mobilization of these metals from sediment to overlying water due to the low pH values and microbial activity (Elewa and Goher, 1999). These results are in harmony with that reported by (Abdo, 2004). On the other side, the relative increase of Pb and Cd concentrations during winter may be related to, the decaying of plankton and precipitation of organic matter associated with Pb and Cd to the sediment. This agreed with that reported by (Goher, 1998).

The maximum values of the studied heavy metals were recorded at stations Boghazes I & II. Fe; 17.06 mg/g & 16.35 mg/g. Mn; 747.75 µg/g & 318 µg/g. Cu; 95.15 µg/g & 52.3 µg/g. Zn; 53.40 µg/g & 53.65 µg/g. Pb; 56.60 µg/g & 40.65 µg/g and Cd; 20.7 µg/g & 24.75 µg/g respectively.

This may be attributed to the effect of intrusion of water borne-iron, manganese, copper, zinc, lead and cadmium coming from Mediterranean sea to fine small grain size of the sediment at two stations which facilitate the adsorption of these metals from the overlying water to bottom sediments. The data are in agreement with that reported by Elewa *et al*., (1996), Abdel-Satar, (998) and Goher, (2002).

Comparing the present data with those obtained from other aquatic environment in Egypt revealed that the concentrations of Fe, Mn, Zn and Pb are lower than Qarun lake, where the ranges of those elements were found to be (8.08-44.72 mg/g), (86.76-835.70 µg/g), (17.56-742.34 µg/g) and (1.00-71.84 µg/g) respectively (Goher, 2002). Also, Ibrahim *et al.,* (1999) reported that, the ranges of Zn and Pb in El-Manzala lake sediments were found to be (65.70-137.50 µg/g) and (15.25-24.60 µg/g). In case of Cu and Cd elements, the concentrations of two elements in the Bardawil lagoon sediments were found to be higher than that reported by Goher, (2002) in Qarun lake and Ibrahim *et al.,* (1999) in Manzala lake. However, the ranges of two elements in these lakes were found to be in the ranges of (2.98-133.24 µg/g) & (21.4-35.90 µg/g) and Cd; (1.00-2.94 µg/g) & (0.00-0.82 µg/g) respectively. Also, the comparison of the heavy metals concentrations in the Bardawil lake sediments with other areas of the world, gave higher levels of Zn (225), Cu (125), Cd (1.00) and Pb (45) µg/g dry wt recorded in the Schrader lake sediments (USA) (Allen-Gil *et al.,* 1997).

Generally, the source of trace metals is mostly allochtonous and the absorbtion processes mainly control remobilization of metals from waters. Four types of chemical changes occur in water of Bardwil lake; 1) elevated salt content, 2) changes in the redox conditions, 3) lowering of pH and 4) presence of natural competing agents that mostly cause remobilization, in addition to biochemical processes (i.e. high accumulation of biogenic origin of carbonates) Lotfy, (2003).

(B) Major cations in sediment:-

Sodium, potassium, calcium and magnesium represent the major cations in the natural water and sediment (Wetzel, 1983), and are considered as necessary for the growth of phytoplankton and also for aquatic animals (Conley, 2000).

Seasonal variations of the concentrations of the studied cations (Ca, Mg, Na and K) were fluctuated in the ranges of (3-42.88 mg/g), (0.6-15.52 mg/g), (12.30-56.5 mg/g) and (2.1-15.27 mg/g) respectively during different seasons (Tables 7-10).

The results of Ca & Mg (Tables 7, 8) showed that, the high calcium and magnesium contents in the Bardawil lagoon sediment were recorded during hot seasons especially spring. This may be attributed to the ability of phytoplankton to extract carbon dioxide from water, which raise pH and calcium carbonate precipitates. But the lower values of calcium contents in sediment were recorded during cold period especially winter, mainly due to, the organic matter oxidation, where carbon dioxide is released under anoxic condition, and hence pH is decreased leading to the dissolution of calcium carbonate from sediment (Lerman, 1978 and Abdo, 2004).

In the same manner, the higher contents of magnesium during hot season especially spring, could be due the biogenic precipitation of aragonite and calcite by aquatic organisms, which build their shells from calcium and magnesium carbonates at high temperature and pH values. On the other side, the noticed low values during cold period especially autumn season, may be related to the effect of winds and overturne of water which facilitate the dissolution of magnesium element from sediment to overlying water (Latif *et al.,* 1989). Again, these results are in agreement with that reported by (Abdo, 2002) and (Abdo, 2004).

Also, the high contents of Na & K during hot seasons (Tables 9, 10), may be attributed to the deposition of sodium as carbonate and phosphate. Also, the precipitation and the adsorption of potassium onto clay particles as K_2CO_3 and/ or $KHCO_3$ could be related to the increase of air and water temperatures during this period, (Elewa *et al.,* 1990 and Elewa *et al.,* 1997). These results agreed with that documented by Goher, (2002) and Abdo, (2004).

The maximum values of Ca & Mg reached 46.84, 47.60 mg/g and 49.44 mg/g at stations Matt Ebliss, Messfek and Karn Samada, respectively may be attributed to the abundance of mollusca shell fragments at these stations.

However, the maximal values of Na & K reached to 46.65 mg/g, 56.50 mg/g and 10.55 mg/g, 10.27 mg/g at Bogahzes I, II respectively, can be explained to be due to the effect of Mediterranean sea water-sediment exchanges with Bardawil lagoon water-sediment.

Generally, the increase or decrease of the major cations (Ca, Mg, Na and K) may depend on the nature of the sediment sample, collection season and climatic conditions of the Bardawil lake.

Comparing the present results of the major cations with those obtained from other Egyptian Lakes e.g Quarun lake, Ca (13.49-121.40 mg/g), Mg, (6.57-40.39 mg/g), Na, (31.15-43.45 mg/g) and K, (6.44-11.49 mg/g) determined by Goher, (2002) shows that their values are higher than the present data. This is related to the different agricultural effluents discharged into Quarun lake from El-Wadi and El-Bats drains (Goher, 2002).

(C) Organic Matter (OM %):-

The total organic matter in sediments plays an important role in the accumulation and release of pollutants in lagoon water, and it is a source of nutrient for the living fauna in the lagoon. For these reasons, it is important to have a clear picture about the distribution of the organic matter on bottom sediments (Ahmed and Elaa, 2003).

Seasonal variations of OM % in the Bardawil lagoon sediments were found to be in the ranges of (1.00-7.80 %), (0.70-7.10 %), (2.15-11.66 %) and (0.80-10.14 %) during autumn, winter, spring and summer seasons respectively, (Table 11).

The values of OM in the investigated sediments, revealed that, there was a high OM % during hot seasons which may be attributed to the flourishing of phyto and zooplankton leading to high organic productivity during this period especially spring (Boyd and Tucker, 1979). On the other side, the low values of OM % during cold seasons especially autumn, may be due to high decomposition rates of organic matter in the presence of high dissolved oxygen content (Wahby *et al.,* 1972). These, results agree also, with the reported by Abdo, (2004).

The values of OM % were increased at the stations affected by fishermen activities e.g El-Telol (11) and Messfek (10), but the decrease of OM % is noticed at stations affected by Mediterranean sea water entering the lagoon from the north e.g Boghazes I & II. However, the seawater is considered as a source of nutrients for the aquatic resources in the seawater, as reported by (Ahamed and Elaa, 2003).

Comparing the ranges of OM % in the Bardawil lagoon sediments with other Egyptian lakes; e.g. Quarun lake (2.59-9.09 %) Goher, (2002) and Manzala lake (3.69-31.86 %) (Ahamed and Elaa, 2003). However, OM % in the Bardawil lagoon sediments are approximately in the same ranges of Quarun and considerably less than Manzala lake sediments.

(D) Statistical Analysis:-

(1) Standard Deviation "SD"

In view of the standard deviation results presented in Tables (1-11) they indicate that; the increase in the variations at all stations for the same chemical parameter they leading to the increase of "SD" values and vice versa. The maximum values of "SD" recorded in the manganese concentrations, Table (2), were found to be (24.25-215.78). However, the lower values of "SD" recorded for the potassium concentrations Table (10), were (0.49-2.64), in harmony with that reported by Abdo (2002).

(2) Correlation Coefficient "r"

The correlation coefficient "r" results are presented in Tables (12-15). They demonstrated that, there are positive correlations between Fe and Mn (r = 0.8, 0.8, 0.8 and 0.9), Fe and Zn (r = 0.8, 0.7, 0.8 and 0.6), Fe and Cu (r = 0.9, 0.9 and 0.7) at $P \leq 0.05$ during autumn, winter, spring and summer seasons respectively. These positive correlations among the four elements indicated that, iron and manganese oxides can play a role in the retention of trace metals. These metals in solution can be adsorbed by hydroxides of these two elements or co-precipitate with them when physico-chemical conditions change (Buffle, 1990). Under anoxic conditions, zinc, co-precipitates with iron sulphide rather than from discrete sulphide (Jenne, 1976), as Zn shows higher solubility product than ferrous sulphide and also zinc concentration occurs in less amount than iron (Salomons and Forstner, 1984).

The positive correlation between Mn and Cu (r = 0.7, 0.7, 0.8 and 0.8) during the same seasons shows that Mn is probably one of the geochemical support phases, when Cu is associated with Mn, it may co-precipitate or adsorbed on manganese oxide or hydroxide (Lin & Benjamin, 1992; Bertin & Bourg, 1995).

The significant positive correlation between Zn and Cu (r = 0.6, 0.8, 0.6 and 0.8) during the same seasons, revealed the association of metals with clay minerals or adsorption of both Cu and Zn on hydrated iron and manganese oxides. Similar situation was reported by Bertin and Bourg, (1995) and Abdel-Satar & Elewa, (2001) and Abdo, (2004).

The positive correlation between Cd with Fe, Mn, Zn and Pb (r = 0.6, 0.5, 0.7 and 0.8), respectively, during different seasons, Tables (12-15) suggest that, cadmium has been an environmental behaviour similar to that of Fe, Mn, Zn and Pb as mentioned by Abdo, (2002) and Abdo, (2004).

The positive correlation between Mg with Fe, Mn, Zn, Cu and Pb and the negative correlation between Ca and these elements Tables (12-15), explained that magnesium hardness only may inhibit trace metals sorption to the solid phase (Stum and Morgan, 1981) in the Bardawil ecosystem.

Also, a positive correlation was found between K with most chemical elements in the present study especially Na (r = 0.9), Fe(r = 0.7 and 0.6) and Zn (r = 0.6, 0.6 and 0.5) during different seasons Tables (12-15), agree with that reported by Abdo, (2002) and (2004).

CONCLUSION

From the previous mentioned discussion we can to the conclusion that the main factors which affect the distribution and concentrations of the studied elements and OM in the sediment of Bardawil lagoon are:- 1- Climatic conditions. 2- Nature of the sediment 3- Activities of fishermens in lake.

Table (1): Seasonal variations of iron (mg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	12.22	16.56	9.96	10.55	2.98
Boghaz (II)	9.96	7.12	16.35	10.45	3.88
El-Kalss (6)	8.68	8.34	16.37	16.35	4.53
Matt Ebliss (8)	4.94	5.64	16.37	16.33	6.39
Messfek (10)	2.03	13.60	11.38	8.02	5.04
El-Telol (11)	2.48	3.21	9.70	10.1	4.09
El-Roak (7)	5.54	3.78	10.43	2.19	3.57
Boghaz (I)	17.06	12.3	16.70	16.45	2.23
El-Romih (4)	14.16	4.53	11.66	11.50	4.14
Al-Nasser (3)	7.23	11.48	16.41	8.25	4.13
Al-Negila (2)	2.87	4.64	10.70	11.10	4.19
Raba (1)	10.31	4.20	16.05	7.81	4.98

Table (2): Seasonal variations of manganese (µg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	396.2	785.20	341.25	345.26	213.62
Boghaz (II)	318.00	179.20	198.95	201.80	63.15
El-Kalss (6)	168.55	135.55	233.75	425.85	129.86
Matt Ebliss (8)	109.10	111.20	288.75	290.10	103.51
Messfek (10)	132.10	286.10	194.55	155.40	67.80
El-Telol (11)	148.30	149.75	215.05	221.30	40.01
El-Roak (7)	231.90	104.0	272.15	79.00	94.68
Boghaz (I)	332.35	264.30	747.75	392.45	215.48
El-Romih (4)	265.0	18.25	204.55	224.2	109.44
Al-Nasser (3)	141.80	262.0	258.5	214.55	55.94
Al-Negila (2)	138.70	180.50	198.35	201.20	28.82

Raba (1)	239.40	190.40	211.8	186.60	24.25

Table (3): Seasonal variations of copper (µg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	37.60	48.10	27.00	29.00	9.62
Boghaz (II)	23.90	20.00	52.30	26.90	14.63
El-Kalss (6)	34.15	32.10	46.70	83.15	23.65
Matt Ebliss (8)	16.80	24.75	62.85	37.50	20.14
Messfek (10)	15.90	51.05	35.70	27.75	14.75
El-Telol (11)	17.65	20.20	27.10	31.20	6.22
El-Roak (7)	24.55	23.40	39.00	17.25	9.21
Boghaz (I)	36.95	43.80	95.15	38.85	27.79
El-Romih (4)	39.75	11.20	31.70	32.30	12.25
Al-Nasser (3)	28.50	42.65	52.10	24.70	12.69
Al-Negila (2)	19.65	34.75	30.55	32.10	6.64
Raba (1)	36.15	19.05	55.00	30.35	15.03

Table (4): Seasonal variations of zinc (µg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	36.55	43.05	24.55	26.20	8.77
Boghaz (II)	41.50	29.80	53.65	22.75	13.57
El-Kalss (6)	29.40	24.90	36.20	70.80	20.84
Matt Ebliss (8)	21.40	22.85	49.55	51.10	16.30
Messfek (10)	17.85	47.40	30.45	23.75	12.77
El-Telol (11)	21.90	40.20	25.25	27.10	8.02
El-Roak (7)	30.45	21.75	33.30	37.70	6.73
Boghaz (I)	38.25	53.40	36.20	42.10	7.68
El-Romih (4)	32.05	6.150	30.25	32.50	12.76
Al-Nasser (3)	19.55	37.75	42.55	26.25	10.51
Al-Negila (2)	24.45	30.85	26.55	27.00	2.67
Raba (1)	32.55	29.80	40.65	31.60	4.80

Table (5): Seasonal variations of lead (µg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	22.45	11.20	7.80	8.10	6.88
Boghaz (II)	7.90	40.65	4.40	7.45	17.10
El-Kalss (6)	38.60	27.00	8.90	8.60	14.67
Matt Ebliss (8)	10.70	33.05	12.35	12.00	10.71
Messfek (10)	9.45	21.45	8.40	11.45	5.98
El-Telol (11)	7.55	13.95	13.40	13.60	3.06
El-Roak (7)	7.10	36.05	13.60	13.50	12.69
Boghaz (I)	3.20	56.60	16.45	21.55	22.79
El-Romih (4)	5.35	12.20	21.20	13.80	6.51
Al-Nasser (3)	12.30	6.60	21.65	14.30	6.22
Al-Negila (2)	8.25	13.05	17.25	17.70	4.40
Raba (1)	7.95	11.55	21.50	9.05	6.18

Table (6): Seasonal variations of cadmium (µg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	4.70	7.90	4.00	3.50	1.98
Boghaz (II)	3.15	24.75	19.55	3.70	11.02
El-Kalss (6)	20.30	19.10	5.90	6.25	7.88
Matt Ebliss (8)	1.70	20.80	7.90	7.10	8.10
Messfek (10)	1.55	9.10	4.25	5.15	3.13
El-Telol (11)	0.70	16.60	3.45	3.50	7.15
El-Roak (7)	2.60	16.60	4.05	1.70	6.98
Boghaz (I)	6.70	20.70	15.65	4.15	7.72
El-Romih (4)	5.95	2.35	4.00	4.10	1.47
Al-Nasser (3)	2.30	4.45	5.90	3.10	1.58
Al-Negila (2)	1.65	5.80	3.90	6.10	2.05
Raba (1)	2.90	4.15	5.65	10.5	3.33

Table (7): Seasonal variations of calcium (mg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Seasons / Stations	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	14.42	4.85	19.91	15.50	6.34
Boghaz (II)	5.50	8.81	4.70	8.85	2.18
El-Kalss (6)	12.42	4.86	15.47	6.90	4.89
Matt Ebliss (8)	14.90	4.03	46.84	16.60	18.36
Messfek (10)	3.00	2.70	47.60	28.14	21.72
El-Telol (11)	6.52	4.40	24.75	13.10	9.15
El-Roak (7)	14.03	5.63	32.48	12.91	11.44
Boghaz (I)	14.62	7.03	9.66	6.37	3.75
El-Romih (4)	16.82	12.35	17.50	12.20	2.83
Al-Nasser (3)	27.20	16.76	31.57	17.85	7.21
Al-Negila (2)	6.35	6.03	42.88	16.10	17.34
Raba (1)	9.37	8.34	36.17	20.51	12.95

Table (8): Seasonal variations of magnesium (mg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Seasons / Stations	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	30.60	10.92	49.44	31.00	15.73
Boghaz (II)	1.87	3.82	2.31	3.95	1.05
El-Kalss (6)	4.82	2.27	14.67	4.40	5.53
Matt Ebliss (8)	3.60	1.93	15.47	4.60	6.15
Messfek (10)	0.60	1.85	9.74	6.60	4.24
El-Telol (11)	2.10	4.33	15.52	6.10	5.90
El-Roak (7)	2.50	1.93	4.87	1.70	1.45
Boghaz (I)	5.63	4.50	9.61	2.53	2.98
EL-Romith (4)	5.53	4.45	5.73	3.75	0.93
Al-Nasser (3)	4.90	6.11	8.42	4.09	1.89
Al-Negila (2)	1.77	2.35	6.85	7.10	2.85
Raba (1)	3.86	3.31	7.13	4.00	1.73

Table (9): Seasonal variations of sodium (mg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Seasons / Stations	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	44.20	19.70	36.83	35.50	10.31
Boghaz (II)	29.50	46.65	32.00	29.50	8.24
El-Kalss (6)	39.30	24.55	27.00	29.50	6.47
Matt Ebliss (8)	22.10	25.50	39.30	35.50	8.12
Messfek (10)	41.75	29.50	32.00	27.00	6.46
El-Telol (11)	24.55	24.55	29.50	30.20	3.07
El-Roak (7)	27.70	27.00	27.00	39.30	6.04
Boghaz (I)	34.55	56.50	32.00	29.50	12.41
El-Romih (4)	24.55	12.30	19.70	23.50	5.55
Al-Nasser (3)	24.55	27.00	41.75	22.10	8.83
Al-Negila (2)	19.70	21.00	32.00	30.00	6.23
Raba (1)	22.10	27.00	27.00	32.00	4.04

Table (10): Seasonal variations of potassium (mg/g) at different selection stations of Bardawil lake sediment during 2001-2002.

Seasons / Stations	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	5.36	6.66	6.28	6.30	0.55
Boghaz (II)	4.55	6.55	8.18	5.24	1.60
El-Kalss (6)	7.03	5.42	5.53	6.45	0.77
Matt Ebliss (8)	5.01	5.30	6.11	5.20	0.49
Messfek (10)	2.42	4.22	4.55	6.74	1.77
El-Telol (11)	4.26	5.80	2.77	4.30	1.24
El-Roak (7)	4.20	4.80	5.30	4.03	0.58
Boghaz (I)	8.24	10.27	5.20	4.67	2.64
El-Romih (4)	5.65	4.00	3.52	4.20	0.92
Al-Nasser (3)	2.68	4.86	3.70	5.07	1.11
Al-Negila (2)	2.10	3.50	5.70	5.50	1.72
Raba (1)	4.15	5.76	3.70	6.28	1.24

Table (11): Seasonal variations of organic matter (%) at different selection stations of Bardawil lake sediment during 2001-2002.

Stations \ Seasons	Autumn	Winter	Spring	Summer	Standard Deviation
Karn Samda (12)	7.06	3.36	7.50	10.30	2.85
Boghaz (II)	1.00	1.36	2.42	1.60	0.60
El-Kalss (6)	2.00	7.10	5.17	9.31	3.10
Matt Ebliss (8)	3.45	4.40	9.40	9.60	3.24
Messfek (10)	4.10	7.60	4.04	8.00	2.16
El-Telol (11)	7.60	5.14	5.80	9.30	1.87
El-Roak (7)	3.60	2.10	11.66	9.84	4.66
Boghaz (I)	2.20	0.70	4.62	1.87	1.65
El-Romih (4)	2.82	2.16	2.15	0.80	0.85
Al-Nasser (3)	2.94	4.70	7.84	5.00	2.03
Al-Negila (2)	7.80	6.50	9.00	10.14	1.57
Raba (1)	2.00	5.10	8.40	5.80	2.63

Table (12): Correlation coefficient matrix of studied parameters in sediment during autumn 2001

	Fe	Mn	Zn	Cu	Pb	Cd	Ca	Mg	Na	K	OM
Fe	1.0										
Mn	0.8	1.0									
Zn	0.8	0.9	1.0								
Cu	0.9	0.7	0.6	1.0							
Pb	0.0	0.0	0.0	0.2	1.0						
Cd	0.4	0.1	0.3	0.5	0.8	1.0					
Ca	0.4	0.1	-0.1	0.5	0.1	0.1	1.0				
Mg	0.4	0.6	0.4	0.5	0.4	0.1	0.3	1.0			
Na	0.2	0.4	0.2	0.2	0.5	0.4	-0.1	0.5	1.0		
K	0.7	0.5	0.6	0.6	0.3	0.6	0.2	0.3	0.3	1.0	
OM	-0.5	-0.2	-0.4	-0.3	0.0	-0.4	-0.2	0.3	0.0	-0.4	1.0

Table (13): Correlation coefficient matrix of studied parameters in sediment during winter 2002

	Fe	Mn	Zn	Cu	Pb	Cd	Ca	Mg	Na	K	OM
Fe	1.0										
Mn	0.8	1.0									
Zn	0.7	0.6	1.0								
Cu	0.9	0.7	0.8	1.0							
Pb	0.1	-0.2	0.2	0.0	1.0						
Cd	-0.1	-0.2	0.1	-0.1	0.8	1.0					
Ca	0.0	-0.2	-0.3	-0.2	-0.3	-0.4	1.0				
Mg	0.6	0.8	0.3	0.3	-0.3	-0.3	0.3	1.0			
Na	0.3	0.0	0.6	0.2	0.8	0.6	0.0	-0.1	1.0		
K	0.4	0.3	0.6	0.2	0.7	0.5	-0.1	0.3	0.8	1.0	
OM	0.0	0.0	0.1	0.3	-0.5	-0.3	-0.3	-0.3	-0.5	-0.6	1.0

Table (14): Correlation coefficient matrix of studied parameters in sediment during spring 2002

	Fe	Mn	Zn	Cu	Pb	Cd	Ca	Mg	Na	K	OM
Fe	1.0										
Mn	0.3	1.0									
Zn	0.8	0.0	1.0								
Cu	0.8	0.8	0.6	1.0							
Pb	0.1	0.1	-0.1	0.1	1.0						
Cd	0.6	0.5	0.7	0.7	-0.3	1.0					
Ca	-0.2	-0.4	-0.1	-0.2	0.2	-0.6	1.0				
Mg	-0.3	0.2	-0.4	-0.3	-0.3	-0.3	-0.1	1.0			
Na	0.3	0.2	0.3	0.2	-0.2	0.2	0.3	0.4	1.0		
K	0.2	0.1	0.5	0.2	-0.7	0.6	-0.3	0.1	0.3	1.0	
OM	-0.2	0.0	-0.1	-0.1	0.2	-0.4	0.6	0.1	0.3	0.0	1.0

Table (15): Correlation coefficient matrix of studied parameters in sediment during summer 2002

	Fe	Mn	Zn	Cu	Pb	Cd	Ca	Mg	Na	K	OM
Fe	1.0										
Mn	0.9	1.0									
Zn	0.6	0.6	1.0								
Cu	0.7	0.7	0.8	1.0							
Pb	0.2	0.0	0.0	-0.2	1.0						
Cd	0.3	0.1	0.3	0.3	-0.2	1.0					
Ca	-0.4	-0.5	-0.5	-0.4	-0.2	0.3	1.0				
Mg	0.0	0.3	-0.2	-0.1	-0.3	-0.1	0.1	1.0			
Na	-0.2	-0.1	0.2	-0.1	-0.2	0.0	-0.1	0.3	1.0		
K	0.2	0.3	0.1	0.4	-0.5	0.6	0.5	0.4	0.0	1.0	
OM	-0.1	0.0	0.2	0.1	-0.2	0.1	0.3	0.4	0.6	0.3	1.0

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