

Physical, Chemical Properties Assessment and accumulation of Some Heavy Metals in Sediment of Edku Lake, Egypt

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ABSTRACT

To evaluate the physical, chemical properties and some heavy metals in sediment of Edku Lake the present study was carried out between January 2018 and December 2018 to identify the sediment pollution and assess its quality by calculating ecological indices, Sediment texture of the lake was classified as clay loam, organic matter (O.M) increased significantly as near to the source of the drainage canal while pH significantly increased as close to alkaline side of the Lake. Cations and anions are shown an increase at the end of the study than the beginning and the highest concentrations recorded nearest drainage water. The heavy metals ions concentrations in sediment varied widely and exhibit fluctuations among different metals during beginning and end of the present study, the order of abundance of these metals' $Fe^{2+} > Mn^{2+} > Zn^{2+} > Cd^{2+} > Pb^{2+}$. The highest concentrations of heavy metals were recorded at the sites nearest drainage water. Ecological indices showed that all studied sediment samples are classified as moderate contaminated ($1 \leq CF < 3$) for Fe^{2+} except Boughaz site which belongs to the low contaminated category mean while Mn^{2+} at all sites described as very high contaminated ($CF \geq 6$). Also, there is a considerable degree of contamination ($16 \leq C_d < 32$) for all sites except site 6 described as a very high degree of contamination indicating serious anthropogenic pollution ($C_d \geq 32$). All sites sediment samples classified as low potential ecological risk ($Er^i < 40$) for Zn^{2+} and Pb^{2+} values, while the contamination of Cd^{2+} was reached to very high ecological risk ($Er^i \geq 320$) at all sites. Where, the sites (1, 6 and 7) were recorded to very high ecological risk ($RI \geq 600$) while, other sites (2, 3, 4 and 5) were classified as considerable ecological risk.

INTRODUCTION

Sediments are ecologically important components of the aquatic habitat and are also a reservoir of contaminants, which play a significant role in maintaining the trophic status of any water body (Singh *et al.*, 1989).

Sediments in surface water are most vulnerable to various pollution including heavy metals due to their ease of access for the disposal of urban and industrial wastewater. Heavy metal contamination of the environmental media has attracted a great deal of worldwide attention due to their non-biodegradable nature, long-biological half-lives for elimination from the body, their accumulation in the food chain will have a significant effect on human health in the long term (Mayuri and

Nema, 2012). Sediment quality has been recognized as an important environmental indicator of water pollution because sediments are the main sink for various pollutants, including metals discharged into the environment (Mayuri and Nema, 2012).

Heavy metals are among the most persistent pollutants in the ecosystem such as water, sediments, and biota because of their resistance to decomposition in natural conditions. Toxicity appears after exceeding the level of indispensability. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Metals have low solubility in water, get adsorbed and accumulated on bottom sediments (Jain *et al.*, 2008). Thus, the sediment could be a potential source of heavy metals that will be released into the overlying water via natural and anthropogenic processes, where they could have an adverse effect on the drinking water quality and human health. Moreover, benthic biota or other organisms can ingest metal particles or contaminated water, which results in metals accumulating in their tissues and ultimately entering the food chain (Yin *et al.*, 2011).

The lake sediments are basic components of our environments as they provide nutrients for the living organism. Lake bottom sediments are sensitive indicators for monitoring contaminants as they can act as a sink and a carrier for pollutants in the aquatic environment (Bai *et al.*, 2011). Thus, lake sediment analysis plays an important role in evaluating the pollution status in the aquatic environment.

The shallow brackish water north delta lakes of Egypt are considered as important fishing grounds. Where Edku lake considered the smallest in the area comparing with Manzala lake or Borollus lake. The lake located within El-Beheira Governorate approximately 30 km east of Alexandria between longitudes $30^{\circ} 8' 30''$ and $30^{\circ} 23' 0''$ E and Latitudes $31^{\circ} 10' 30''$ and $31^{\circ} 18' N$. It has an average depth of about 1 meter, a surface area of about 85 km^2 and a water volume of about $85.0 \times 10^6 \text{ m}^3$ (Saeed, 2013).

Water exchange between the lake and the Mediterranean Sea through the opening lied at northwestern of the lake through Boughaz El-Maadia from Abu Qir Bay. Also, the lake receives huge amounts of drainage water from two main drains that discharge their water into the lake. The beginning drain namely Kom Belag receives its water from three sub drains; Bosily, Edku, and El-Khairy where they are connected at about 3 km to the east of the lake. The drainage water of kom Belag drain is discharged at the eastern part of the lake. The second main drain connected to Lake Edku is Bersik drain which outlets its water at the southern central part of this lake (Shekweer, 2006). the drainage water contains unspecified quantities of urban, industrial, agricultural and chemicals from Beheira Governorate and beyond (Abdel Halim *et al.*, 2013). This study attempts to shed light on the natural and chemical properties of soil in different locations in Edku Lake, especially the accumulation of pollutants from heavy elements by the result of different wastewater estuaries (agricultural, industrial and sewage wastewater) as a basis for assessing the quality of fish product from the lake.

MATERIALS AND METHODS

Sampling locations; Sampling date and analytical methods

The lake has been divided into seven sites which were determined using Geographic Position System (GPS) as shown in (Table 1 and Fig. 1). The present study was carried during 2018.

Sediment samples were collected twice (January and December 2018) from the surface bottom sediment (from the upper 10 cm surface layer) was achieved using Peterson grab sampler as described by Boyd and Tucker (1992), After mixing well the gross sediment sample, about one kg is transferred into labeled clean plastic bag and kept in icebox until transferred to laboratory. In the laboratory, the collected sample is spread thinly on a plastic sheet or tray for air-drying. Then crushed, sieved and kept in polyethylene bags for analysis.

Table 1: Sampling sites.

Site	Latitude	Longitude
1	31° 15' 48.15" N	30° 13' 57.94" E
2	31° 15' 14.59" N	30° 13' 57.62" E
3	31° 15' 35.38" N	30° 12' 43.55" E
4	31° 14' 8.52" N	30° 13' 53.29" E
5	31° 15' 50.52" N	30° 12' 33.63" E
6	31° 15' 45.20" N	30° 12' 46.87" E
7	31° 16' 0.491" N	30° 10' 46.32" E

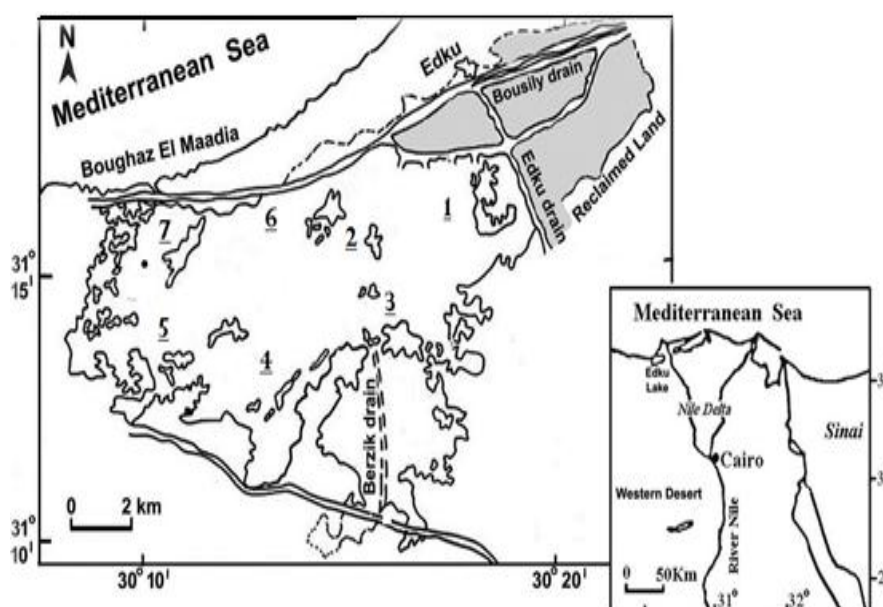


Fig. 1: Edku lake map shown studied sites.

Mechanical analysis: Particle size distribution was determined by the hydrometer method described by Weber (1977) using sodium hexametaphosphate as a dispersing agent.

Soil physical and chemical analyses: O. M. content was determined using the Walkley and Blacks method (Jackson, 1967). pH value was measured by pH meter (Thermo Orion pH Meter model 420) in 1: 2.5 soil-water suspension (Jackson, 1967). Soil water extract (1: 5) was prepared according to the method of (Jackson, 1967) and the following estimation was made as follows: Salinity was determined electrometrically in mS/cm by using a salinity-conductivity meter (Model YSI Environmental, EC 300) (Soil Conservation Service, 1984). Sodium, potassium, calcium, and magnesium were determined by atomic absorption spectrophotometer (Thermo Electron Corporation S Series AA Spectrometer). Carbonate and bicarbonate were determined by titration with 0.01 N sulfuric acid, using

phenolphthalein as an indicator for carbonate and methyl orange for bicarbonate (Richards, 1954). Chloride was determined by the titration of soil water extract with silver nitrate using potassium chromate as an indicator (Jackson, 1967). Soluble sulfate was calculated by subtracting the total soluble anions from the total soluble cations.

Heavy metals analysis: The sediment samples were dried at 105°C, grinded, sieved and the finest grains (1.0 gm) were digested with a mixture of H₂O₂ (30 ml) and 2 N HCl (10 ml) till evaporation, then with concentrated HCl (20 ml) and HNO₃ (10 ml). After dryness, the samples were dissolved in 6 N HCl then filtered and kept in 2 N HCl after filtration prior to elemental measurements according to the method of Nelson & Sommers (1982). The amounts of heavy metals (Fe, Pb, Zn, Cd, Mn) were determined by the atomic absorption (Thermo Electron Corporation S Series AAS) according to APHA (2000).

Ecological indices: In order to evaluate the sediment quality, different ecological indices were calculated as the following:

Contamination Factor (CF): The contamination factor is developed by Hakanson (1980) to describe the contamination status of the sediments. The CF is calculated as following (CF = C metal/ C background).

Where, C metal: metal concentration in polluted sediments and C background is background value of that metal. The following terminologies are used to describe the contamination factor: (CF < 1) low contamination factor, (1 ≤ CF < 3) moderate contamination factor, (3 ≤ CF < 6) considerable contamination factor and (CF ≥ 6) very high contamination factor.

Degree of Contamination (C_d): The degree of contamination (C_d) was defined as the sum of all contamination factors. The C_d is calculated as follows

$$C_d = \sum_{i=1}^N CF_i$$

Where CF is the single contamination factor and N is the count of the elements present.

The following terminology was adopted by Hakanson (1980) to describe the degree of contamination (C_d values) for the selected metals. (C_d < 8) low degree of contamination, (8 ≤ C_d < 16) moderate degree of contamination, (16 ≤ C_d < 32), a considerable degree of contamination and (C_d ≥ 32) very high degree of contamination indicating serious anthropogenic pollution.

Potential Ecological Risk factor (Erⁱ): The potential ecological risk of given contamination was calculated according to (Hakanson, 1980). The Erⁱ is calculated as follows (Erⁱ = Trⁱ x CF).

Where, Trⁱ = the toxic-response factor for a given substance and CF = the contamination factor. Trⁱ for Zn, Pb, and Cd are 1, 5 and 30 respectively, (Hakanson, 1980). The following terminology are used to describe the risk factor: (Erⁱ < 40) low potential ecological risk, (40 ≤ Erⁱ < 80) moderate potential ecological risk, (80 ≤ Erⁱ < 160) considerable potential ecological risk, (160 ≤ Erⁱ < 320) high potential ecological risk and (Erⁱ ≥ 320) very high ecological risk. **Potential Ecological Risk index (RI):** The potential ecological risk index (RI) is defined as the sum of the risk factors (Hakanson, 1980). The RI is calculated as follows

$$RI = \sum_{i=1}^N Er^i$$

The following terminology is used for the RI value: ($Ri < 150$) low ecological risk, ($150 \leq Ri < 300$) moderate ecological risk, ($300 \leq Ri < 600$) considerable ecological risk and ($Ri \geq 600$) very high ecological risk.

The statistical analysis was applied according to Sendector and Cochran (1982). Differences between means were tested at 5 % probability level according to Duncan's new multiple range test (Duncan, 1955). All statistical evaluations were done using the SPSS computer program according to Dytham (1999).

RESULTS AND DISCUSSIONS

Mechanical analysis

The mechanical analysis was performed for all samples in order to calculate the sand-silt-clay ratio. The result is listed in Table 2 and the sediment texture is illustrated in Fig. 2, according to USDA (2006) ternary diagrams as the following

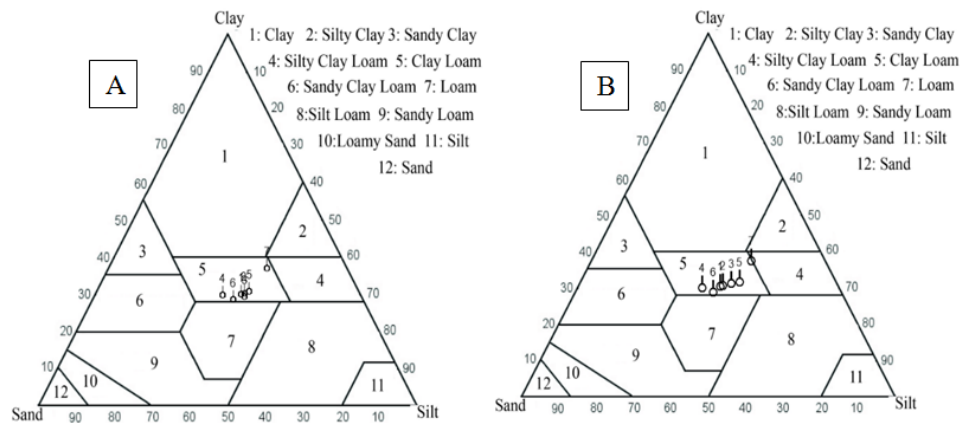


Fig. 2: Texture classification of Edku sediment samples (A: beginning study and B: end study) according to USDA (2006).

Table 2: Granulometric analysis of the site's sediment samples in Edku lake and their texture nomenclature according to USDA classification.

Sites	Sample date	Sand	Silt	Clay	Texture (USDA, 2006)
1	Beginning	39.74	29.65	30.61	Clay Loam
	End	40.26	31.66	28.08	Clay Loam
2	Beginning	33.66	30.14	36.2	Clay Loam
	End	32.88	30.55	36.57	Clay Loam
3	Beginning	40.22	31.15	28.63	Clay Loam
	End	42.22	32.04	25.74	Clay Loam
4	Beginning	39.14	30.55	30.31	Clay Loam
	End	38.22	31.12	30.66	Clay Loam
5	Beginning	38.55	30.33	31.12	Clay Loam
	End	37.68	30.88	31.44	Clay Loam
6	Beginning	37.12	28.88	34.00	Clay Loam
	End	36.55	29.35	34.10	Clay Loam
7	Beginning	41.78	37.31	20.91	Clay Loam
	End	42.55	38.05	19.71	Clay Loam

Results showed that the particle size distribution of sediment the average content of sand in sediment were ranged from 33.66 – 41.78 % at beginning study, where end the study were from 32.88 – 42.55 %; the average content of silt in soil were ranged from 28.88 – 37.31 % at first study, while end the study were from 29.35 – 38.05 %; and the average content of clay in soil were ranged from 20.91 – 36.2 % at beginning study, and end the study were from 19.71 – 36.57 %. These results cleared that sediment texture of Edku lake during the study year classified as clay loam according to USDA (2006).

Grain size is one of the most considerable factors controlling sediment capacity for concentrating and retaining metals (Förstner & Wittmann, 1981). It is well known that elements are heterogeneously distributed over the various grain-size fractions (Ducarourir & Lamy, 1995). There is a strong correlation between the increase of metal concentration and the decrease in grain size. Fine-grained particles are the main sites for the accumulation and transport of metals, because of their large specific surface area (Jenne *et al.*, 1980). Fine particles are more soluble than coarser ones due to the increased surface area (Lin *et al.*, 1998).

Physical properties

The results obtained in Table 3, show some physical properties (sediment pH and O.M. content percentage) of the lake sediment. Physical properties of the soil are the most important factors determining the quality of the soil, as well as the chemical properties of the soil and the soil's ability to retain chemical compounds and heavy metals. Soil O.M. plays an important role in deciding/maintaining soil physical conditions. It also influences soil chemical properties especially cation exchange capacity. O.M. supply the energy sources for soil micro-organisms in addition to that have a key role in determining soil pH (Farouk, 2014 & El Morshedy, 2017). In the present study, the O.M. ranged from 2.99 to 7.81 % at the beginning of the study while at the end of the study ranged from 3.35 to 8.94 %.

Table 3: pH data and O.M content in samples from the Edku lake site (at the beginning of the study, Jan. 2018 and at the end of the study, Dec. 2018).

Site	Sample date	pH	O.M
1	Beginning	7.94±0.06 a	7.81±0.03 c
	End	7.56±0.03 defg	8.94±0.02 b
2	Beginning	7.63±0.02 cde	6.84±0.03 de
	End	7.33±0.03 h	8.94±0.09 b
3	Beginning	7.89±0.02 ab	7.95±0.02 c
	End	7.41±0.02 gh	11.77±0.09 a
4	Beginning	7.77±0.02 bc	6.74±0.02 de
	End	7.35±0.03 h	8.94±0.02 b
5	Beginning	7.71±0.06 cd	6.66±0.03 e
	End	7.42±0.02 fgh	8.88±0.02 b
6	Beginning	7.67±0.02 cd	6.91±0.01 d
	End	7.47±0.02 fgh	8.74±0.03 b
7	Beginning	7.57±0.02 def	2.99±0.03 g
	End	7.51±0.03 efg	3.35±0.08 f
Two Way ANOVA		P value	
	Site	0.0001	0.0001
	Sample date	0.0001	0.0001
	Site × Sample date	0.0001	0.0001

Means having the same letter in the same column are not significantly different at (P < 0.05)

The lowest percent of O.M. was recorded in Site 7 which sited near of Boughaz El-Madiaa to the decrease of the amount of drainage and sewage water, and decrease of aquatic plant while the highest percentage recorded at sites (1& 3) which sited near

of the drainages (Barsik; Edku and El-Bosily) and this agrees with El Morshedy (2017) and Elnady *et al.* (2016) who were indicated that increasing O.M. in soil related to many factors as the amount of O.M. in the water source, the nearest from drainage sources, the amount of aquatic plant and algae decaying and fish faeces. These results clear that the accumulation of organic matter in surface sediment depending on accumulated of organic matter from water to soil, waste and die of aquatic. These finding are good in agreement with those data in Table 1. The organic matter percentages were significantly increased in station near drainage canals (Shaker *et al.*, 2016).

In the current study, sediment pH of the lake ranged from 7.57 to 7.94 at the beginning of the study, while the pH ranged between 7.96 to 7.24, at the end of the study. These results cleared that the pH of the soil in Lake lies in the alkaline side and this agrees with which found by (El-Dars *et al.*, 2014 & El Morshedy, 2017). The pH values weren't significantly ($P > 0.05$) differ between before and after investigation for the same site. The O.M. values and pH hadn't a significant difference ($P > 0.05$) among sites, sample date and their interaction Whether at the beginning or end of the study as shown in Table 3. These results are in agreement with Shaker (2006) who reported the change in the natural properties of the soil needs to be long periods, an occurrence of natural phenomena such as floods and earthquakes, a high-intensity activity and human intervention to bring about change, such as reclamation or deep cleansing.

Chemical properties

Soil is one of the most important and fundamental resources for human survival and development. The results obtained in Table 4 shows the chemical properties. Chemical properties of the soil in the lakes are a reflection of the water properties where the soil properties are strongly influenced by the water properties that vary from soil to another by textures. Where light soils are less in ion retention capacity for heavy soil, which increases the surface area qualitative (Farouk, 2014). Soil salinity results were cleared hadn't significantly different ($P > 0.05$) among sites and sample date while it had significantly different ($P < 0.05$) among their interaction.

In the current study, the average values of salinity in soil ranged from 4.38 to 9.75 mS/cm at beginning of the study, while at end of study ranged from 4.75 to 10.05 mS/cm, where the highest values of salinity at Boughaz site. These results indicated that the soil salinity affected with water salinity and this agreement with those obtained by Shaker *et al.*, 2015 a,b; Elnady *et al.*, 2016 and Shaker *et al.* 2017. Also, the results indicated that the soil salinity was increased with time, especially in far sites radial corridors channels. Shaimaa *et al.*, (2012) and Bui (2013) concluded that any change in soil salinity mainly due to the change in salinity of the water. Soil salinity depends on a number of factors, inlet water salinity of the lake, groundwater salinity, groundwater level, evaporation rate and the distance between the site and Boughaz.

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). In the current study, cations and anions values didn't have a significant difference ($P > 0.05$) between sites, sample date and their interaction except Ca^{2+} had significant difference ($p < 0.05$) for interaction among sites and sample date (Table 4).

Table 4: Soil chemical properties of Edku Lake in different sites at the beginning (Jan. 2018) and end (Dec. 2018) of the study.

Sites	Sample date	Salinity (mS/cm)	Cations (meq/l)				Anions (meq/l)			
			Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ²⁻	Cl ²⁻	SO ₄ ²⁻
1	Beginning	5.15±0.05 bcde	54.15±0.47 cde	44.65±0.36 de	56.64±0.46 bc	6.34±0.17 ab	1.60±0.03 c	72.79±0.53 bc	82.73±0.16 d	4.65±0.04 i
	End	5.51±0.17 bc	58.47±0.51 abc	49.03±0.62 b	56.16±0.19 bcd	5.91±0.12 bc	1.90±0.02 b	74.20±0.16 ab	87.23±0.12 c	6.95±0.08 cd
2	Beginning	4.74±0.04 cde	51.33±0.28 def	42.10±0.84 fgh	53.14±0.47 fg	5.75±0.04 bc	1.10±0.03 e	69.40±0.38 e	75.62±0.37 g	6.22±0.11 ef
	End	5.05±0.22 bcde	54.14±0.59 cde	45.11±0.41 cde	55.04±0.23 cdef	5.89±0.09 bc	1.30±0.05 de	71.10±0.31 d	79.36±0.32 e	8.44±0.13 a
3	Beginning	5.35±0.04 bcd	58.78±2.78 ab	45.77±0.37 cd	57.54±0.52 ab	6.66±0.08 a	1.90±0.07 b	75.50±0.31 a	89.54±0.10 b	4.79±0.10 hi
	End	5.66±0.14 b	61.34±0.26 a	52.05±0.44 a	59.22±0.32 a	6.94±0.09 a	2.20±0.10 a	75.80±0.16 a	95.00±0.16 a	6.56±0.07 de
4	Beginning	4.38±0.04 e	45.88±0.11 gh	38.77±0.25 i	49.83±0.54 h	5.81±0.21 bc	1.27±0.04 de	65.30±0.26 f	68.49±0.07 j	5.22±0.11 ghi
	End	4.75±0.03 cde	49.06±0.23 fg	40.05±0.52 hi	53.33±0.43 fg	6.66±0.08 a	1.50±0.06 cd	68.80±0.15 e	70.76±0.22 i	7.33±0.22 bc
5	Beginning	4.65±0.07 de	49.66±0.34 efg	41.02±0.37 fghi	52.12±0.27 g	5.74±0.21 bc	1.10±0.06 e	68.50±0.30 e	73.10±0.12 h	5.65±0.15 fg
	End	4.89±0.12 bcde	52.58±1.07 def	42.87±0.11 efg	54.35±0.34 def	5.87±0.07 bc	1.10±0.001 e	71.40±0.20 cd	76.72±0.12 f	7.12±0.03 cd
6	Beginning	4.77±0.04 cde	52.04±0.34 def	43.04±0.53 ef	54.02±0.55 efg	5.30±0.16 c	0.80±0.04 f	69.10±0.31 e	79.15±0.14 e	5.46±0.17 g
	End	5.21±0.11 bcd	55.62±0.32 bcd	47.14±0.35 bc	55.36±0.21 cde	5.52±0.10 c	1.10±0.001 e	72.30±0.25 cd	82.40±0.11 d	7.84±0.05 ab
7	Beginning	9.75±0.23 a	41.14±0.66 i	40.01±0.52 hi	40.12±0.36 i	1.40±0.10 d	1.20±0.10 e	49.17±0.50 h	66.12±0.31 k	6.28±0.04 e
	End	10.05±0.38 a	42.21±0.52 hi	40.52±0.37 ghi	41.74±0.16 i	1.40±0.03 d	1.20±0.06 e	51.05±0.23 g	68.22±0.05 j	5.40±0.18 gh
Two Way ANOVA			<i>P</i> value							
	Site	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	Sample date	0.0001	0.0001	0.0001	0.0001	0.018	0.0001	0.0001	0.0001	0.0001
	Site × Sample date	0.978	0.705	0.0001	0.002	0.002	0.028	0.0001	0.0001	0.0001

Means having the same letter in the same column are not significantly different at ($P < 0.05$)

Variations of the concentrations of cations (Ca^{2+} , Mg^{2+} , Na^+ and K^+) at beginning study were fluctuated in the ranges (41.14- 58.78 meq/l, 40.01- 45.77 meq/l, 40.12- 57.54 meq/l and 1.40- 6.66 meq/l) respectively, while at ending study it were fluctuated in the ranges (42.21-61.34 meq/l, 40.52- 52.05 meq/l, 41.74- 59.22 meq/l and 1.40- 6.94 meq/l) respectively.

For anions concentrations (CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-}) at beginning were fluctuated in the ranges of (1.20- 1.90 meq/l, 49.17- 75.50 meq/l, 66.12- 89.54 meq/l and 4.65- 6.28 meq/l) respectively, and at ending study it were fluctuated in the ranges (1.20- 1.90 meq/l, 51.05- 75.80 meq/l, 68.22- 95.00 meq/l, 5.40- 7.84 meq/l, at end) respectively. Where the highest concentrations were recorded at sites nearest from water drains while the lowest concentrations were recorded at Boughaz site. The higher value of carbonate is attributed to the aquatic plants and phytoplankton applied to extract CO_2 and thus promotes precipitation of carbonate with the increase of pH (Serruya, 1971 and Lerman, 1978). Generally, most of the cations and anions in the soil are a reflection of the state exchange, absorption, and adsorption between the soil and water and that this is due to the cationic exchange capacity of the soil (Farouk, 2014).

Heavy metals in soil

Environmental contamination and pollution by heavy metals is a threat to the environment and is of serious concern (Ali and Sajad, 2013& Hashem *et al.*, 2017). According to statistics, more than 99 % of heavy metals entering the aquatic system can be stored in the sediment in different ways (Salomons and Stigliani, 1995). increasing levels of heavy metals in rivers, lakes, oceans, and ponds are considered to be disastrous because they are the only sources for aquatic organisms such as fishes and other invertebrates especially in developing countries (Ochieng *et al.*, 2008). Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Metals have low solubility in water, get adsorbed and accumulated on bottom sediments (Jain *et al.*, 2008). The lake sediments are basic components of our environments as they provide nutrients for a living organism. Lake Bottom sediments are sensitive indicators for monitoring contaminants as they can act as a sink and a carrier for pollutants in the aquatic environment (Bai *et al.*, 2011). Thus, the lake sediment analysis plays an important role in evaluating the pollution status in an aquatic environment. In the present study, the heavy metals concentration of Edku lake sediment at the beginning and the end of the study had no significant difference ($P > 0.05$) among site, Sample date and their interaction except Zn^{2+} was significantly different ($P < 0.05$) among the site and Sample date interaction (Table 5). At the beginning of this study (Jan. 2018), concentration of heavy metals ions fluctuated in range of 214.20- 407.50; 7.36- 23.70; 8.20- 13.35; 2.10- 2.68 and 2.85- 3.85 mg/100g for Fe^{2+} ; Mn^{2+} ; Zn^{2+} ; Pb^{2+} and Cd^{2+} , respectively. While, at the end of study (Dec. 2018), concentration of its fluctuated in range of 221.50- 396.70; 8.51- 25.40; 8.30- 16.22; 3.01-2.64 and 3.45- 4.22 mg/100g, for Fe^{2+} ; Mn^{2+} ; Zn^{2+} ; Pb^{2+} and Cd^{2+} , respectively. These results cleared that the highest concentrations of heavy metals recorded at sediment of sites 1 and 3 followed by 6 which sited near drain water (Barsik, El khairy, El Bosily, and Edku drains) while the lowest concentrations of its recorded at Boughaz site 7 followed by sites of 4 and 5 which far from drain water, these results due to high concentration of heavy metals in drainage water led to uptake by phytoplankton and fixed on surface soil and adsorption by soil particles and this agreement with those obtained by Shaker (1998).

Table 5: Some heavy metals concentrations (mg/100g) in the soil surface layer at the beginning (Jan. 2018) and end (Dec. 2018) of the study period in different sites of Edku Lake.

Site	Sample date	Fe ²⁺	Mn ²⁺	Zn ²⁺	Pb ²⁺	Cd ²⁺
1	Beginning	379.50±0.81 d	23.49±0.15 b	13.35±0.13 bc	2.10±0.07 d	3.85±0.03 bc
	End	396.70±3.40 b	25.40±0.55 a	16.22±0.07a	2.64±0.03 c	4.10±0.15 ab
2	Beginning	355.10±0.75 efg	19.60±0.16 d	12.20±0.12 ef	1.82±0.03 ef	3.20±0.06 ef
	End	360.70±0.15 e	21.20±0.15 c	15.70±0.12 a	1.95±0.02 de	3.86±0.07 abc
3	Beginning	407.50±1.01 a	23.70±0.26 b	12.96±0.05 cd	1.89±0.01 de	3.91±0.04 ab
	End	389.80±0.96 c	26.30±0.12 a	15.81±0.08 a	1.98±0.05 de	4.22±0.06 a
4	Beginning	348.50±0.35 g	16.50±0.15 fg	11.30±0.09 gh	1.46±0.03 g	2.67±0.11 g
	End	355.50±0.82 ef	18.30±0.25 e	13.80±0.17 b	1.90±0.03 de	2.91±0.03 fg
5	Beginning	349.30±0.44 fg	17.20±0.31 ef	10.85±0.23 h	1.58±0.02 fg	2.85±0.03 fg
	End	358.80±0.97 e	19.50±0.06 d	12.50±0.16 de	1.85±0.04 def	3.05±0.07 f
6	Beginning	283.80±0.15 i	13.70±0.18 h	11.80±0.10 fg	3.27±0.03 b	3.53±0.04 cde
	End	301.20±1.20 h	15.90±0.17 g	12.76±0.07 cde	3.75±0.12 a	3.75±0.11 bcd
7	Beginning	214.20±2.41 k	7.36±0.05 i	8.20±0.06 i	2.68±0.12 c	2.85±0.03 fg
	End	221.50±0.85 j	8.51±0.11 i	8.30±0.04 i	3.01±0.02 b	3.45±0.04 de
Two Way ANOVA				<i>P value</i>		
Site		0.0001	0.0001	0.0001	0.0001	0.0001
Sample date		0.0001	0.0001	0.0001	0.0001	0.0001
Site × Sample date		0.0001	0.0001	0.086	0.002	0.025

Means having the same letter in the same column are not significantly different at ($P < 0.05$)

Also, Abdallah *et al.*, 2000 stated that the agriculture drainage water, industrial and sewage effluent supply the water bodies with huge quantities of inorganic anions and heavy metals.

The heavy metals ions concentrations in sediment varied widely and exhibit fluctuations among different metals during the beginning and end of the present study. The order of abundance of these metals' $\text{Fe}^{2+} > \text{Mn}^{2+} > \text{Zn}^{2+} > \text{Cd}^{2+} > \text{Pb}^{2+}$ (Table 5). Where, that concentration of heavy elements in the soil at the end of the study period slowly increased from a concentration at the beginning of this study, but this increase in most cases not significantly ($P > 0.05$) increased and this related to the change in the natural properties of the soil needs to be long periods as indicated by Shaker, 2006. The heavy metals accumulations in soil depending on practical size distributions and clay percentage, these results are good in agreement with those obtained by Shaker and Mousaa (2007) and Shaker *et al.* (2015a, b & 2016b and 2017), which the texture of soil in this lagoon is clay loam, Table 2. Metals concentrations in sediment are generally much higher than in water. Sediments may act as a source of chemicals in the water column and also adversely affect sediment-dwelling organisms through direct toxicity (Dummeea *et al.*, 2012). Sediment quality has been recognized as an important environmental indicator of water pollution because sediments are the main sink for various pollutants, including metals discharged into the environment (Singh, and Kalamdhad, 2013).

The leachability of metals from sediments depends on several factors (Sahuquillo *et al.*, 2003). 1. The sediment-characteristics, including pH, CaCO_3 content, O. M. content, cationic exchange capacity (CEC) and texture. 2. The nature of contamination in terms of origin and characteristics of deposition and composition (Rulkens *et al.*, 1995 and Shetaia, 2016).

Ecological indices

There are several ways to assess heavy metal pollution in sediments were established such as contamination factor (CF), degree of contamination (C_d), ecological risk factor (Er^i) and potential ecological risk index (RI). These indices are commonly used to identify and quantify the anthropogenic inputs of various elements in relation to a natural (geogenic and pedogenic) background (Reimann & De Caritat, 2000). In such circumstances, background values are required to distinguish between natural and input concentration. the indices were calculated based on the 7 sediment samples while the international background values of the studied heavy metals were listed in (Table 6) based (Wedepohl, 1995). The different factor was discus below and the result was listed in (Table 7).

Table 6: Data average of heavy metals ions (Fe^{2+} , Mn^{2+} , Zn^{2+} , Pb^{2+} , and Cd^{2+} ppm) in surficial sediment samples of Edku lake comparing with an international background of heavy metals values (Wedepohl, 1995).

Sites	Fe^{2+}	Mn^{2+}	Zn^{2+}	Pb^{2+}	Cd^{2+}
1	38960	24.45	14.785	3.975	2.37
2	35790	20.4	13.95	3.53	1.885
3	39835	25	14.385	4.065	1.935
4	35200	17.4	12.55	2.79	1.68
5	35405	18.35	11.675	2.95	1.715
6	29250	14.8	12.28	3.63	3.51
7	21785	7.935	8.25	3.17	2.855
I.B.	30890	527	52	17	0.102

I. B.: international background of heavy metals according to **Wedepohl, 1995**.

Table 7: Calculated ecological indices; Contamination Factor (CF), Degree of Contamination (C_d), Potential Ecological Risk factor (Er^i), Potential Ecological Risk index (RI) and Potential ecological risk index (RI) of different sites sediments samples of Edku lake.

Sites	CF					C_d	Er_i			RI
	Fe ²⁺	Mn ²⁺	Zn ²⁺	Pb ²⁺	Cd ²⁺		Zn ²⁺	Pb ²⁺	Cd ²⁺	
1	1.623	0.049	0.070	0.303	23.235	25.281	0.070	1.515	697.059	698.644
2	1.491	0.041	0.066	0.269	18.480	20.348	0.066	1.346	554.412	555.823
3	1.659	0.051	0.069	0.309	18.971	21.059	0.069	1.549	569.118	570.735
4	1.466	0.035	0.059	0.213	16.471	18.245	0.059	1.063	494.118	495.241
5	1.475	0.0371	0.056	0.225	16.814	18.606	0.056	1.124	504.412	505.592
6	1.219	0.029	0.058	0.277	34.412	35.995	0.058	1.383	1032.353	1033.795
7	0.908	0.016	0.039	0.242	27.990	29.195	0.039	1.208	839.706	840.953

Contamination factor (CF)

The contamination factor was calculated for Fe²⁺, Mn²⁺, Zn²⁺, Pb²⁺, and Cd²⁺ listed in Table (7). The values of contamination Factor are variable from one element to another in addition to the site. For Fe²⁺, the highest and the lowest values (1.659 and 0.908) of contamination factor were observed at sites 3 and 7, all studied sediment samples are classified as moderate contaminated ($1 \leq CF < 3$) for Fe²⁺, except Boughaz site 7 which is belong to low contaminated category ($CF < 1$). For Mn²⁺, Zn²⁺, and Pb²⁺, the contamination factor for all sites are described as a low contaminated category ($CF < 1$). While the calculated contamination factors for Cd²⁺ are ranged between 16.471 and 34.412 for sites 4 and 6 respectively where that all sites described as very high contaminated ($CF \geq 6$).

Degree of contamination (C_d)

The degree of contamination was performed for Fe²⁺, Mn²⁺, Zn²⁺, Pb²⁺, and Cd²⁺. The highest value of C_d was 18.245 at site 4 and the lowest value was 34.412 at site 6. The values of C_d documented that there is a considerable degree of contamination ($16 \leq C_d < 32$) for all sites except site 6 described as a very high degree of contamination indicating serious anthropogenic pollution ($C_d \geq 32$).

Potential ecological risk factor (Er^i)

According to the potential ecological risk factor of selected heavy metals (Zn²⁺, Pb²⁺, and Cd²⁺), all sites sediment samples classified as low potential ecological risk ($Er^i < 40$) for Zn²⁺ and Pb²⁺ values, while the contamination of Cd²⁺ was reached to very high ecological risk ($Er^i \geq 320$) at all sites.

Potential ecological risk index (RI)

The values of Potential Ecological Risk index for selected heavy metals (Fe²⁺, Mn²⁺, Zn²⁺, Pb²⁺, and Cd²⁺) showed that, the highest values (698.644, 840.953 and 1033.795) were observed at sites (1, 6 and 7) respectively which refer to very high ecological risk ($RI \geq 600$). On the other hand, other sites (2, 3, 4 and 5) were classified as considerable ecological risk ($300 \leq RI < 600$).

Sediment quality has been recognized as an important environmental indicator of water pollution because sediments are the main sink for various pollutants, including metals discharged into the environment (Singh and Kalamdhad, 2013). Metals enter the environment through atmospheric deposition, erosion of the geological matrix, or from anthropogenic sources, such as sewage outfalls and industrial and agricultural runoff. They can decline water and sediment quality and may adversely affect fish health and other biological attributes due to their toxicity, persistence, and bioaccumulation in the

food chains. An aquatic ecosystem is one of the most closely monitored areas, and fish as the final link of the food chain in particular (Alhashemi, *et al.*, 2012).

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