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Assessment of Physico-chemical Characteristics of Sediment in Qarun Lake, Egypt

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Abstract: Qarun Lake is considered the oldest natural lakes in the world, the third-largest lake in Egypt and the rest of Lake Old Maurice. The aim of this study was to analyze the sediment quality of Qarun Lake, Egypt. Therefore, 12 geo-referenced sediment samples were collected from Qarun Lake for determined the physical and chemical parameters of the sediment. Cluster analyses (CA) based on Bray-Curtis similarity index and ordination of sites (DCA) was calculated. Results showed variability between the sites distributed in the lake. Calculated average sediment variables indicated that, the south part of lake is affected by anthropogenic activities than north part, due to drainage water from number of drains (such as El-Bats, El Mashroah and El-Wadi drains). Total nitrogen and phosphorus was varied from stand to the other, which varied from 15.85 to 30.05 ppm and 0.97 to 2.27 ppm with a mean value of 22.86 and 1.53 ppm, respectively. The soil pH value measured in all sites varied from slightly alkaline to alkaline in soil reaction (7.50 to 8.89, mean value = 8.55), the electrical conductivity, showed a very wide range (2.87 to 13.54µmhos/cm, mean value = 8.17µmhos/cm.) of variations between sampled stands. The order of different anions of sediments were; Cl^- (0.68-1.41%) > SO_4^{-2} (0.94-1.02%) > HCO_3^- (0.42-0.52%). For extractable cations (mg/100g dry soil), it had the sequence of Na^+ (285.77-421.47) > Ca^{+2} (71.84-103.24) > K^+ (45.77-61.76) > Mg^{+2} (32.99-48.83). Wetlands in Egypt should follow an organized plan from the various authorities in the country

keywords: Qarun Lake, hydrosoil, physical analysis, salinity, nitrogen, cluster analysis

1.Introduction

Wetlands are among the world's most productive environments and provide a wide variety of benefits. They are curdles of biological diversity, providing the water and primary productivity upon which countless species of plants and animals depend for survival. The interactions of physicals, biological chemical components of a wetland, such as soils, water, plants, and animals, enable the wetland to perform many vital functions [1].

According to Forbes [2], Lake (Lagoon) is a small world composed of environmental features and living organisms bound and organized by interdependences and interrelationships. According to international wetland [3] Lake is an area of permanent or semi-permanent water with little flow (e.g. ponds, salt Lakes, volcanic creator Lakes). Lagoons are commonly divided into coastal lagoons and internal lagoons. There is an overlap between bodies of water classified as coastal lagoons and bodies of water classified as estuaries. Lagoons are common coastal features around many parts of the world [4].

Inland saline lakes (e.g. El-Temsah, El-Mora Qarun, and Wadi El-Rayan lakes) have received increased attention in recent years due to their sensitivity to climatic change. Geochemical and hydrological features are largely responsible for controlling the concentration and composition of the resulting brine [5,6]. Changes in evaporation and precipitation can affect the physical and chemical conditions in such lakes [7-10]. Changes in water chemistry and lake depth in turn control the distribution and abundance of aquatic life. In this respect, inland saline lakes need to be considered in developing concepts concerning the geochemical and biological characteristics [6].

Qarun Lake is considered the oldest natural lakes in the world, the third-largest lake in Egypt and the rest of Lake Old Maurice. It is considered an interior lake which is not related to any sea. It persists today as a smaller saltwater lake called Birket Qarun [11]. Qarun Lake is exposed to huge amounts of drainage water containing organic and inorganic pollutants. Variations in nutrient concentrations are directly related to agricultural and industrial wastes which can be thrown directly or indirectly in the lake. Several studies have been conducted about the ecology and environmental status of Qarun Lake [12-17], species composition and distribution of phytoplankton [18,19], water quality [20,21], radioactivity [22,23] and fish [24,25]. The aim of this study was to analyze the sediment quality of Qarun Lake, Egypt.

the physical and chemical parameters of sediment were determined.

2. Materials and methods

1.Study area

Qarun Lake (Lake Moeris) is located in the western desert of Egypt, northwest of the Faiyum Oasis and lies 83 km southwest of Cairo. The third largest lake in Egypt, it is located between longitudes of 30° 24' and 30° 49' E and latitudes 29° 24' and 29° 33' N (Figures 1 and 2). It is bounded from the south and east by the urban and cultivated areas and from the north and west by the unoccupied desert areas [14,26]. The lake and surrounding area is a protected area and has been designated as a Ramsar site since 2012. Lake Qarun plays

san important part in the agriculture and ecology of Fayoum region as it receives the drainage water from the irrigation canals. The lake's main sources of water are a mixture of untreated agriculture drainage and domestic wastewater (about 450 million m3/year) from El-Fayoum province [12]. The drainage in El-Fayoum depression is mainly by gravity. The network of drainage consists of three main drains (El-Bats, El Mashroah and El-Wadi drains) and a number of small drains, which terminate into the lake.

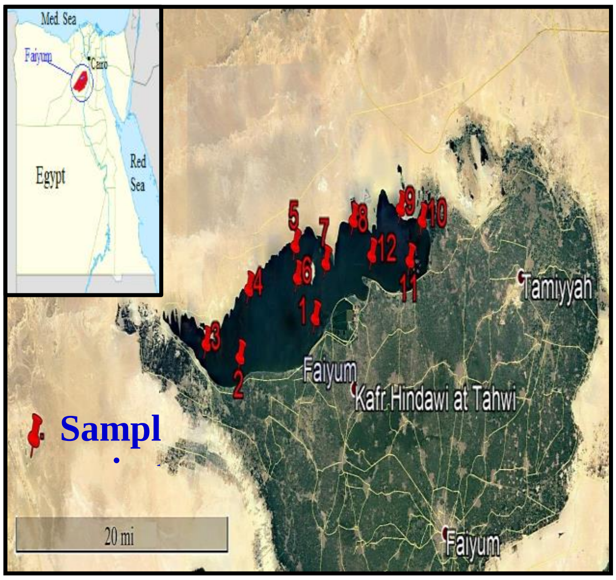

Figure 1. Map of Egypt showing the studied lake and sampling sites.Therefore

2. Sediment Analysis

Geo-referenced sediment samples were collected from 12 sites of Qarun Lake. All samples were carried to the laboratory in plastic bags shortly after collection. These samples were air-dried, thoroughly mixed, sieved using a 2 mm sieve to remove gravel and debris and stored in plastic bags for subsequent physical and chemical analyses. Texture of soil was determined according to the hydrometer method. Water-holding capacity (WHC), porosity, chlorides, sulphates and organic carbon were measured as described by Piper [27]. Soil pH is determined by using the pH-meter (Model Lutron YK-2001, pH meter) and electrical conductivity is determined using EC-meter (YSI Incorporated Model 33). Calcium carbonate is measured according to Jackson [28]. Carbonates and bicarbonates were determined by the titration method as described by Pierce *et al*. [29]. Total phosphorus was determined by direct stannous chloride method [30], while the total nitrogen was determined by the micro-Kjeldahl method according to Allen et al. [31]. Cations (Na^{+}, K^{+}, Ca^{+2}, and Mg^{+2}) were measured using the method of extraction of different elements was described by Allen *et al.* [32]. The sodium adsorption ratio (SAR) and potassium adsorption ratio (PAR) were calculated according to McKell and Goodin [33].

3. Statistical analyses of data

The hydrosoil variables were subjected to one-way ANOVA and the mean values were separated based on Duncan's test at 0.05 probability level, using COSTAT 6.3 program. Cluster analyses (CA) based on Bray-Curtis similarity index and ordination of sites (DCA) was calculated using the PAST program (multivariate statistical package, ver. 1.72).

3. Results and Discussion

1.Characteristics of sediment samples

Lake sediments are comprised mainly of clastic material (clay, silt, and sand sizes), organic debris, chemical precipitates, or combinations of these. The relative abundance of each depends upon the nature of waters draining into a lake, the prevailing climate, and the relative age of a lake [34,35]. The soil texture determined by the sieve method revealed generally that, the soil samples in Qarun Lake is sandy with very low content of silt and clay fractions. The percentages of sand, silt and clay varied from 63.21- 88.12%, 7.94-23.72% and 3.93-13.06% with mean values of 75.53%, 16.73% and 7.74%, respectively. The percentage of porosity was obviously comparable in the different sites, the percentage of soil porosity varied from 33.15-41.95%, with a mean value of 37.33%. On the other hand, water-holding capacity of the soil samples collected from Qarun Lake varied from 34.96% to 52.26% with a mean value of 44.62%, these results agreed with El-Amier et al. [36], Elnaggar and El-Alfy [37].

Sediments are a major sink for chemical components of water bodies, therefore, the biological availability of sediment components is an important issue, especially in water management [34]. Calcium carbonate content was markedly varied from stand to the other in the different habitats. The percentage of calcium carbonate varied from 3.24% - 5.45% with a mean value of 4.60% in Qarun Lake. It can be explained as sediments with high carbonate content deposited in warm water, while the cold water attenuate the precipitation of $CaCO_3$ [38,39]**.** The $CaCO_3$ is widely distributed in the northern parts parallel to the coastal line (i.e. sites 3-9). Organic carbon content showed a slight variation in the different stands. The percentage of organic carbon ranged from 0.69% to 3.15% with a mean value of 1.36%. The accumulation pattern of organic carbon contents in the uppermost layers were associated the grain size of the sediments. The stations with higher percent of silt and clay had higher organic carbon [40].

Total nitrogen and phosphorus was varied from stand to the other, which varied from 15.85 to 30.05 ppm and 0.97 to 2.27 ppm with a mean value of 22.86 and 1.53 ppm, respectively. The highest values of TN and TP recorded in southern part of Qarun Lake (sites 1-3, 11, 12). The highest values of phosphorus and nitrogen in lake sediments were mainly associated with agricultural runoff in the form of fertilizers and detergents etc. [41,35]. The soil pH value measured in all sites varied from slightly alkaline to alkaline in soil reaction, with a narrow range (7.50 to 8.89, mean value = 8.55) of variation from stand to the other. The electrical conductivity, which indicates the salinity of soil samples, showed very wide range (2.87 to 13.54µmhos/cm, mean value = 8.17µmhos/cm.) of variations between sampled stands.

The order of different anions of sediments were; Cl^- (0.68-1.41%) > SO_4^{-2} (0.94-1.02%) > HCO_3^- (0.42-0.52%). The soluble carbonate content was absent in all soil samples. Chloride is abundant between other anions; it may as a result of closed lake or from anthropogenic sources in sites nearby drains in south side. For extractable cations (mg/100g dry soil), it had the sequence of Na^+ (285.77-421.47) > Ca^{+2} (71.84-103.24) > K^+ (45.77-61.76) > Mg^{+2} (32.99-48.83). These results are higher than those identified by other studies of Arain et al. [42], El-Amier et al. [36] and El-Alfy et al. [35]. The increase of cations in hot periods than cold as for Ca^{+2}, may be attributed to the ability of phytoplankton to extract carbon dioxide from water, which increases pH and precipitation of calcium carbonate, for, Mg^{+2} due to the biogenic precipitation of aragonite and calcite by aquatic organisms. Na^+ deposits in shape of carbonate and adsorption of potassium onto clay particulates [43,44].

The SAR, which expresses the combined effect of the different ions on sodium availability in the soil, was calculated for the soil from each stand of the study area. In Qarun

Lake, it varied from 39.47 to 49.44 with mean value of 44.43. Similarly the PAR expresses the combined effect of the different ions on potassium availability in the soil. The obtained data indicated that, the PAR showed a moderately range of variation in the most sampled stand, it ranged between 6.32 and 7.11 with a mean value of 6.71.

Generally, the chemical composition of lakes varies greatly throughout the world and within the same country, due to the different chemistry of erosion products for different lake basins. The impacts of human activities have also contributed significantly to the chemical composition of lakes [45].

2. Principle Component Analysis (PCA)

PCA was performed to analyze the compositional pattern of the variables in the entire dataset and bring out strong patterns in a dataset [46]. The correlation between sites and soil characteristics is indicated on the ordination diagram produced by PCA, it is clear that, the electrical conductivity, soil texture, porosity, Mg, K, Cl^-, and organic carbon are the most effective soil variables which have high significant correlations with the first and second axes (Figure 2).

3. Cluster analysis (CA) and Ordination of sites (DCA)

The cluster analysis of the sampling sites according to the chemical properties in the sediments maintained somewhat similar trends, showing three distinct clusters (A-C), each consisting of similar sampling sites distributed within the study area. The clustering pattern based on sediment analysis indicated that the similarity index ofsamplingsites in groups as following: A-B which occupying the western and middle part of lake and B-C representing the middle and eastern part of lake (Figure 3a). On the other hand, according to ordination of sites in the study area, given by Detrended Correspondence Analysis (DCA) is shown in Figure 3b. It is clear that, the collection sites are distinguishable and have a clear pattern of segregation on the ordination plane. It’s obvious that group B segregated at the uppermost middle side of the DCA diagram.

4. Conclusion

Qarun Lake is exposed to huge amounts of drainage water containing organic and inorganic pollutants. Variations in nutrient concentrations are directly related to agricultural and industrial wastes which can be thrown directly or indirectly in the lake. The soil texture determined by sieve method revealed generally that, the soil samples in Qarun Lake is sandy with very low content of silt and clay fractions. Total nitrogen and phosphorus was varied from stand to the other. The highest values of TN and TP recorded in southern part of Qarun Lake (sites 1-3, 11, 12). The soil pH value measured in all sites varied from slightly alkaline to alkaline in soil reaction, the salinity of soil samples, showed a very wide range of variations between sampled stands. The order of different anions of sediments were; Cl^- (0.68-1.41%) > SO_4^{-2} (0.94-1.02%) > HCO_3^- (0.42-0.52%). For extractable cations (mg/100g dry soil), it had the sequence of Na^+ (285.77-421.47) > Ca^{+2} (71.84-103.24) > K^+ (45.77-61.76) > Mg^{+2} (32.99-48.83)

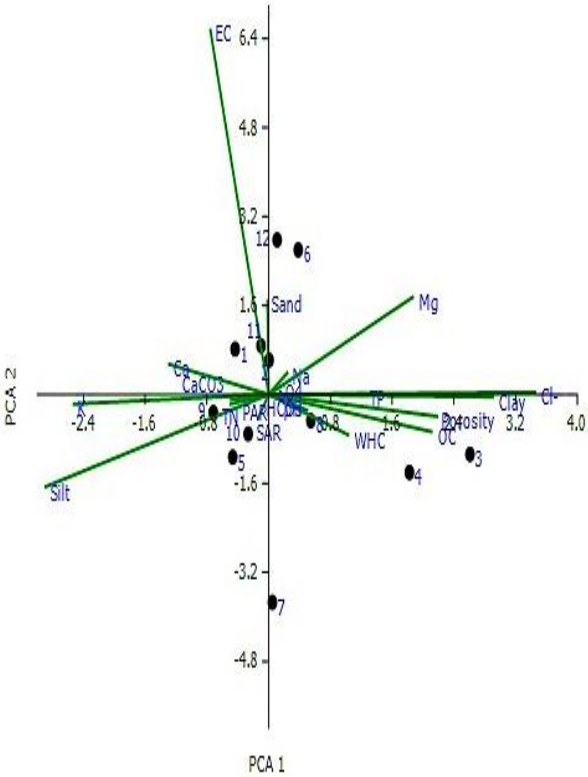

Figure 2. Principle component analysis (PCA) of soil variables with different sampling sites distributed in the study area.

Table 1. The physical and chemical parameters of the sediment samples at different sites in Qarun Lake, Egypt.

No. of sites	Physical Characteristics					Chemical Characteristics															
	Soil texture %			WHC (%)	Porosity (%)	pH	EC $mS.cm^{-1}$	$CaCO_3$ %	OC %	TN ppm	TP ppm	Anions %				Cations mg/100g dry soil				SAR	PAR
	Sand	Silt	Clay									CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Na^+	K^+	Ca^{++}	Mg^{++}		
1	65.35	23.30	11.34	50.86	41.15	7.80	7.38	3.68	1.30	28.95	2.11	0	0.52	0.89	1.02	412.99	61.76	102.04	48.83	47.55	7.11
2	80.26	14.12	5.61	34.96	38.80	7.60	3.54	3.24	3.15	23.55	2.18	0	0.47	1.26	0.99	364.00	54.74	96.04	42.95	43.66	6.57
3	88.12	7.94	3.93	38.36	33.15	8.89	13.54	5.45	0.69	30.05	2.27	0	0.42	1.23	0.94	285.77	45.77	71.84	32.99	39.47	6.32
4	76.08	17.11	6.80	43.76	37.25	8.65	2.87	4.79	1.33	26.35	1.9	0	0.46	1.30	0.97	335.91	51.62	83.24	38.75	43.01	6.61
5	81.13	13.98	4.88	40.96	34.85	8.78	8.07	5.19	1.44	17.15	1.08	0	0.45	0.79	0.95	311.53	49.28	78.64	35.27	41.28	6.53
6	74.46	17.34	8.19	45.06	37.75	8.62	11.08	4.57	1.03	19.45	1.65	0	0.47	1.31	1.01	351.55	52.79	88.04	40.91	43.78	6.57
7	69.82	19.92	10.25	47.96	39.65	8.52	4.47	4.09	2.74	16.75	0.98	0	0.50	1.37	0.99	383.75	57.47	95.64	40.19	46.57	6.97
8	72.17	18.71	9.11	46.56	38.45	8.59	6.76	4.26	2.09	15.85	0.97	0	0.49	1.35	0.98	391.37	56.30	92.84	38.99	48.21	6.93
9	78.32	15.58	6.09	42.36	35.95	8.73	8.23	4.98	0.91	14.55	1.36	0	0.46	0.89	0.96	345.60	50.84	82.64	35.63	44.94	6.61
10	85.10	10.43	4.46	39.66	33.95	8.85	7.90	5.33	0.75	22.35	1.48	0	0.44	0.68	0.94	298.88	48.11	76.04	33.35	40.41	6.50
11	63.21	23.72	13.06	52.26	41.95	8.41	9.41	3.51	1.37	21.15	1.91	0	0.52	1.41	1.02	421.47	60.20	103.24	42.11	49.44	7.06
12	66.90	22.50	10.59	49.26	40.35	7.50	9.33	3.87	1.22	29.95	1.88	0	0.51	1.37	1.02	405.63	59.81	99.84	47.75	47.22	6.96
Mean	75.53	16.73	7.74	44.62	37.33	8.55	8.17	4.60	1.36	22.18	1.65	0	0.47	1.17	0.98	353.15	53.22	87.20	38.59	44.43	6.71
±SD	7.89	4.97	3.00	5.30	2.84	0.49	3.07	0.75	0.77	0.47	0.04	0	0.03	0.26	0.03	45.40	5.15	10.63	5.13	3.23	0.26
F-value	0.25 ns	0.23ns	0.27 ns	0.56ns	0.03ns	0.61 ns	3.34*	0.08ns	3.05*	5.85*	12.92**	0	0.19 ns	3.18 *	0.2ns	0.14 ns	0.05ns	0.04 ns	0.13 ns	0.40ns	0.23 ns

Abbreviation: WHC: water holding capacity; EC: electrical conductivity; OC: organic carbon; TN: total nitrogen; TP: total phosphorus; SAR: Sodium Adsorption Ratio, PAR: Potassium Adsorption Ratio

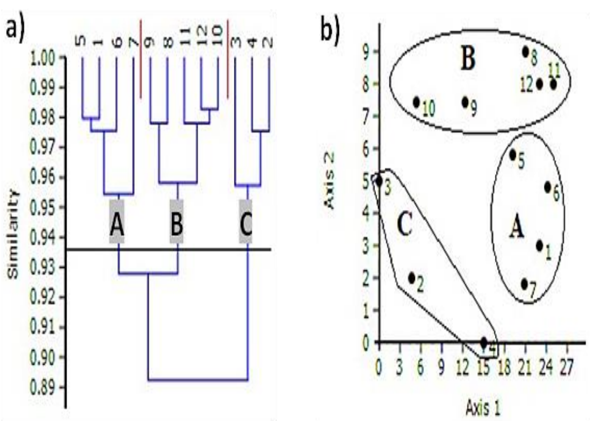

Figure 3.

a) Cluster analysis or similarity, and

b) Detrended Correspondence Analysis (DCA) ordination diagram for the different sampling sites based on the results of soil variable**.**

References

1. Ramsar, (2007)., Wetlands International Ramsar Sites Database (2007) www.wetlands.org/rsbd (accessed **15**.02.07).
2. Forbes, S.A.,(1887).The Lakes as a Microcosm, Peoria, Historical Society, Illinois.
3. Wetland International, Wetlands and Water, Sanitation and Hygiene (WASH)-(2010). understanding the linkages. Wetlands International, Printed by Boom & van Ketel Grafimedia, The Netherlands,
4. Pérez-Ruzafa, A., C. Marcos, I.M. Pérez-Ruzafa, and M. (2011).Pérez-Marcos, Coastal lagoons:“transitional ecosystems” between transitional and coastal waters.

Journal of Coastal Conservation, **15(3)**: pp. 369-392.

5. Lent, R.M., W.B. Lyons, W.J. Showers and K.H. Johannesson, (1995) Late Holocene paleoclimatic and paleobiologic records from sediments of Devils Lake, North Dakota. *Journal of Paleolimnology*,. **13(3)**: pp.193-207.
6. Taher, A.G., (1999). Inland saline lakes of Wadi el Natrun depression, Egypt. International *Journal of Salt Lake Research*, **8(2)**: pp.149-169.
7. Williams, W.D., (1981).The limnology of saline lakes in western Victoria. In Salt Lakes (pp. 233-259). Springer, Dordrecht.
8. Melack, J.M., (1988). Primary producer dynamics associated with evaporative concentration in a shallow, equatorial soda lake (Lake Elmenteita, Kenya). Hydrobiologia, **158**: pp. 1–14.
9. Comin, EA. and T.G. (1990). Northcote, Proceedings of the Fourth International Symposium on A Thalassic (Inland) Saline lakes, Banyoles, Spain, May (1988). Hydrobiologia, 197.
10. Pienitz, R., I.R. Walker, B.A. Zeeb, J.P. Smol and P.R. Leavitt, (1992) Biomonitoring past salinity changes in an athalassic subarctic lake. International *Journal of Salt Lake Research*,. **1(2)**, pp. 91-123.
11. Rasmy, M. and S.F. Estefan, (1983) Geochemistry of saline minerals separated from Lake Qarun brine. Chemical Geology,. **40(3-4)**: pp.269-277.
12. Gohar, M., O.A. Økstad, N. Gilois, V. Sanchis, A.B. Kolst∅ and D. Lereclus, (2002) Two-dimensional electrophoresis analysis of the extracellular proteome of Bacillus cereus reveals the importance of the PlcR regulon. Proteomics,. **2(6)**, pp.784-791.
13. Abdel-Satar, A.M., A.A. Elewa, A.K.T. Mekki and M.E. Gohar,. (2003). Some aspects on trace elements and major cations of Lake Qarun sediment, Egypt. Bulletin Faculty of Science, Zagazig University, **25(2)**: p. 77-97.
14. Abdel-Satar, A.M., M.E. Goher and M.F. (2010). Sayed, Recent environmental changes in water and sediment quality of Lake Qarun, Egypt. *Journal of Fisheries and Aquatic Science*, **5(2)**: p. 56-69.
15. Hassan, R.M., (2015) Ecosystem restoration using maintenance dredging in Lake Qarun, Egypt. *Journal of American Science*,. **11(12)**: pp. 55-65.
16. Mosad, A. and El-Sayed, M., (2017). Studying of Physico-chemical and Biological characters of Qarun Lake, El-Fayoum-Egypt. Egyptian Academic *Journal of Biological Sciences.* **9(2)**: pp. 11-20.
17. El-Kady, A.A., T.L. Wade, S.T. Sweet and A.G. Klein, (2019). Spatial distribution and ecological risk assessment of trace metals in surface sediments of Lake Qaroun, Egypt. Environmental monitoring and assessment, **191(7):** pp.413.
18. Abd El-Monem, A.M., (2001) Radiophotosynthesis and Assimilation Rate of 14C Uptake By Phytoplankton In Closed, Turbid, Saline Lake (Lake Qarun-Egypt). Arab *Journal of Nuclear Sciences and Applications*,. **34(2)**: p. 243-250.
19. Abd El-Karim, M.S., (2015). Survey to compare phytoplankton functional approaches: How can these approaches assess River Nile water quality in Egypt? The Egyptian *Journal of Aquatic Research*, **41(3)**, p. 247-255.
20. Abdel-Malek, S.A. and M.M. Ishak, (1980) Some ecological aspects of Lake Qarun, Fayoum, Egypt. Part II. Production of plankton and benthic organisms. Hydrobiologia,. **75(3)**, p. 201-208.
21. Mansour, S.A. and M.M. Sidky, (2003). Ecotoxicological Studies. 6. The first comparative study between Lake Qarun and Wadi El-Rayan wetland (Egypt), with respect to contamination of their major components. Food Chemistry, **82(2)**: pp.181-189.
22. El-Zakla T., A.M. Basha, N.A. Kotb, S.A. Abu Khadra and M.S. Sayed, (2013). Environmental studies involving determination of some radionuclides at qaroun lake, al- Fayoum, Egypt. Arab *Journal of Nuclear Sciences and Applications*, **46(4)**: pp. 122-131.
23. Amin, R.M., (2013). Radioactivity levels in some sediments and water samples

from Qarun Lake by low–level gamma spectrometry. International *Journal of Science and Research*, p. 2319-7064.
24. Alrouby, T.H.E. and E.Y. Abdul-Tawab, (2019) Analytical Study of the Current and the Future Situation of Fishery Resources in Qaroun and Al-Rayyan Lakes in Fayoum Governorate, Egypt. Egyptian *Journal of Aquatic Biology and Fisheries*, **23(3):** pp.303-320.
25. Mehanna F.S., , (2020). Isopod parasites in the Egyptian fisheries and its impact on fish production: Lake Qarun as a case study. Egyptian *Journal of Aquatic Biology and Fisheries***24(3)**: pp.181-191.
26. Al-Afify, ADG, U.M. Tahoun and M.H. Abdo, (2019). Water Quality Index and Microbial Assessment of Lake Qarun, El-Batts and El-Wadi Drains, Fayoum Province, Egypt. Egyptian *Journal of Aquatic Biology and Fisheries*, **23(1):** p. 341-357.
27. Piper, C.S., (1947) Soil and plant analysis. Inter science Publishers, Inc. New York,
28. Jackson, M.L., (1962) Soil chemical analysis constable and Co. LTD. London..
29. Pierce, W.C., E.L. Haenisch and D.T. Sawyer, (1958) Quantitative Analysis. Wiley Toppen, Tokyo..
30. APHA, (1998).Standard methods for the examination of water and waste water, 19th Edition. American Public Health Association, American Water Work Association, Water Pollution Control Federation, Washington, D.C
31. Allen, S.E., H.M. Grimshaw and A.P. Rowland, (1986) Chemical Analysis. In: Methods of Plant Ecology (Eds. Moore, P.D. and Chapman, S.B.), Blackwell, Oxford,. Pp. 285- 344.
32. Allen, S.E., H.M. Grimshaw, J.A. Parkinson, C. Quarmby and J.D. Roberts, (1974) Chemical Analysis of Ecological Materials. Blackwell Scientific Publications. Osney, Oxford, London..
33. McKell, C.M. and J.K. Goodin, A Brief (1984) Overview of the Saline Lands of the United States. Research and Development Seminar on Forage and Fuel Production from Salt Affected Waste Land Western Australia. Dept. Agric..
34. Rosich, R.S. and P. Cullen, (1980) Lake Sediments: chemical composition and some aspects of their formation and diagenesis. In Biogeochemistry of Ancient and Modern Environments (pp. 105-115). Springer, Berlin, Heidelberg.
35. El-Alfy, M.A., Y.A. El-Amier and T.E. El-Eraky, (2020). Land use/cover and eco-toxicity indices for identifying metal contamination in sediments of drains, Manzala Lake, Egypt. Heliyon, **6(1)**, pp.e03177.
36. El-Amier, Y.A., H. Abd El-Azim and M.A. El-Alfy, (2016) Spatial assessment of water and sediment quality in Burullus Lake using GIS technique. *Journal of Geography, Environment and Earth Science International*,. **6(1):** pp. 1-16.
37. Elnaggar, A.A. and M.A. El-Alfy, (2016) .Physiochemical Properties of Water and Sediments in Manzala Lake, Egypt. *Journal of Environmental Sciences*, **45(2)**: pp. 157-174.
38. Mudroch, A., A.J. Zeman and L.L. Kalas, (1982) Calcium Carbonate in Postglacial Lake Erie Sediment. *Journal of Great Lakes Research*,. **8(4):** pp. 711-718.
39. Matter, M., F. S. Anselmetti, B. Jordanoska, B. Wagner, M. Wessels and A. Wuest, (2010) Carbonate sedimentation and effects of eutrophication observed at the Kalista subaquatic springs in Lake Ohrid (Macedonia). Biogeosciences,. **7**: pp. 3755–3767.
40. Baran, A., M. Mierzwa-Hersztek, K. Gondek, M. Tarnawski, M. Szara, O. Gorczyca and T. Koniarz, (2019) The influence of the quantity and quality of sediment organic matter on the potential mobility and toxicity of trace elements in bottom sediment. Environmental Geochemistry and Health,. **41(6):** p. 2893-2910.
41. Chandrakiran, S.K., (2013). Assessment of Physico-Chemical Characteristics of Sediments of a Lower Himalayan Lake, Mansar, INDIA. International Research *Journal of Environmental Sciences*, **2(9):** 16-22.
42. Arain, M.B., T.G. Kazi, M.K. Jamali, H.I. Afridi, J.A. Baig, N. Jalbani and A. Shah,

(2008) Evaluation of Physico-chemical Parameters of Manchar Lake Water and Their Comparison with Other Global Published Values. *Pakistan Journal of Analytical and Environmental Chemistry*,. **9(2)**: p. 101-109.

43. Elewa, A.A., M.B. Shehata, Y.M. Issa and A.M. Abdel-Satar, (1997). Accumulation of chemical elements in the recent sediments of River Nile at Greater Cairo from Helwan to El-Kanater El-Khyria. Egypt. *Journal of Analytical Chemistry*, **6**: pp. 84-96.
44. Abdo, M. H., (2005) Assessment of some heavy metals, major cations and organic matter in the recent sediments of Bardawil lagoon, Egypt. Egyptian *Journal of Aquatic Research*,. **31(1):** p. 214-228.
45. Cooke, G.D., E.B. Welch, S. Peterson and S.A. Nichols, (2016). Restoration and management of lakes and reservoirs. CRC press.
46. Wang, J., G. Liu, H. Liu, and P.K. Lam, (2017) Multivariate statistical evaluation of dissolved trace elements and a water quality assessment in the middle reaches of Huaihe River, Anhui, China. Science of the Total Environment,. **583:** pp.421-431.