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The Current Status and the Long-Term Variations of Water Quality in Lake Manzala, Egypt

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ABSTRACT

This study aimed to shed light on the long-term current state and variations of Lake Manzala water quality by some chemical, physical, and biological parameters as: temperature, pH, total solids, hardness, sodium, chlorides, total nitrogen, total phosphorous, dissolved oxygen, biological oxygen demand, chemical oxygen demand, iron, manganese, total bacteria count, and faecal coliform count. Comparing results obtained with the limit of the Environmental Protection Agency for water body health showed the following: The mean of temperature and pH are within the permissible limits. Manganese is almost within the permissible limits, but in 2005, it was slightly above the permissible limit. The mean of total solids, hardness, BOD, COD, sodium, chloride, total nitrogen, total phosphorus, Iron are above the permissible limit. In some years, the dissolved oxygen is below the permissible limit. The study results will be effective in Manzala lake environmental management.

Key Words:

Lake Manzala, long-term, permissible limit, variations, water quality.

1. INTRODUCTION

Water quality degradation has significant impacts on lake ecosystems [1], and the need to improve water quality is widely recognized Depending on the prevailing opinions, shallow lakes are affected more rapidly by physical, chemical, and other factors [2].

Lake Manzala was selected as a case study due to its importance. Lake Manzala is considered as a national income project for local residents. It is the largest Egyptian lake and it produces about 30-50% of the total annual fish production of the Egyptian lakes, so it's consider one of the most important sources of fish wealth in Egypt. Approximately 2,785 fishing boats and 15,975 fishermen were licensed into the lake's waters. It represents an important path for migratory birds as one of the most important winter places and nests [3, 4, 5].Wastewater flows into Lake Manzala from nine main drains and canals. The Lake is experiencing environmental changes because of the human activities has changed the lake into a semi-enclosed basin [6]. Bahr al-Baqar drainage is considered to be one of the highly polluted drains. It has become as a source for epidemics and diseases to residents because of fertilizers, organic materials, and pesticides that are disposed of in the drain, which have a significant effect on the aquatic environment, resulting in ecological imbalance, reflected on the food chain, and reflected on health as well as public health. Diverting water drainage has a devastating effect on humans [7].

This study aimed to clarify the current situation and show the long-term variations for some pollution indicators (physical, chemical and biological) that illustrate the quality of the lake.

2. STUDY AREA

Site Description: The Lake is located in the northern part of the Nile Delta, inside the borders for four Egyptian governorates, (Fig. 1). The lake receives salty water from the Suez Canal from the eastern side through the Qabouti Canal, and from the Mediterranean Sea from the northern side through many outlets such as Al-Gamil and Al-Gamil Al-Jadeed. While, the lake is connected to the fresh water of the Nile River and Damietta Branch from the western and northwestern sides of the lake and reaches it a small flowing of water through the Al-Anania, Al-Soffra, and Al-Ratmah Canals. [3, 4, 8].

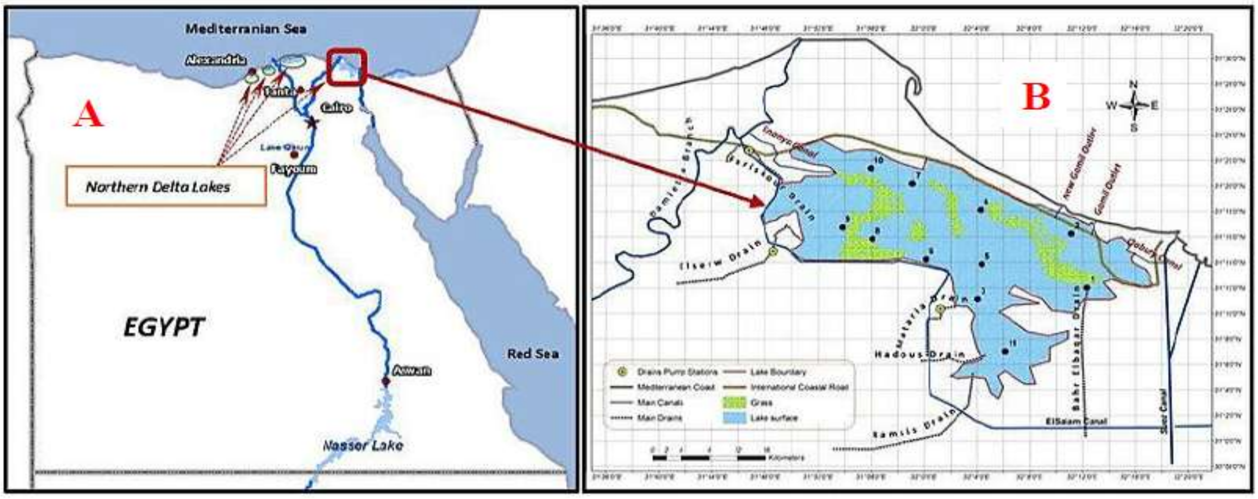

Fig (1) [8]: A. Lake Manzala geographical location,
B. Lake Manzala and the major five drains.

3. MATERIALS AND METHODS

3.1 Samples collection and analysis: The present study was conducted on 9 different sites, (Fig. 2) [9]. Samples were collected seasonally in 2018 from the surface water of the lake by means of a boat. Sample preservation methods were limited to refrigeration and pH control. physical and chemical analysis was conducted by using the standard methods APHA [10, 11]. Water Temperature and pH was measured in the field by using thermometer and Electrical-pH meter. Total Solids was measured by using the evaporation method. Hardness was carried out using EDTA titrimetric method. Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) was measured by the modified Winkler method. Chemical Oxygen Demand (COD) was estimated by titration method with standard ferrous ammonium sulfate. Sodium was conducted by Flame Photometer method. Chloride was measured by Mohr’s method. Total Nitrogen was carried out by kjeldahl method. Total Phosphorus was measured by using colorimetric method by spectrophotometer. Heavy metals (Mn and Fe) was measured by atomic absorption spectrophotometer. Total Viable Bacterial Count was conducted by using the pouring technique. Faecal coliform Count was measured with using MacConky agar medium [12].

3.2 Data Source: Long-term changes over a period of about twenty years in Lake Manzala were studied by comparing data from previous studies based on sampling dates not on the dates of publishing. In addition to results of the present study, that were collected seasonally in 2018, and on which some physical, chemical, and biological analysis were conducted. The study results was expressed as mean SE.

Fig (2) [9]: Sampling map for the present study

4. RESULTS AND DISCUSSION

Physico-chemical parameters

4.1 Water temperature: Temperatures was found that it affect the solubility of oxygen, which decreases in summer, and on phosphorous release, which increases in summer. In addition, fish are known to be sensitive to temperature changes [13, 14]. The mean values of water temperature in the lake correlated with different locations as well as seasonal changes for samples collection. Results in Table (1) and (Fig. 2, (A)) represent long-term changes in the mean of the surface water temperature for from 1995 to 2018. Statistical data analysis showed no significant variations ($P>0.01$) in surface water temperature degree between different years. Results showed close levels, whereas, the minimum value (20.7±8.2 °C) was recorded in 1995 when it ranged between 12.5 and 29 °C. The maximum value was (26.6±3.7 °C) in 2015 was ranged between 22.8 and 30.2 °C.

4.2 Hydrogen Ion Concentration: Most lakes are basic alkaline at the beginning of their formation and because of the accumulation of organic matter, they become more acidic over the time. Where a weak acid is formed from the union of carbon dioxide, which is produced from the decomposition of organic matter, with water. This acid lowers the pH of lakes water. Almost fish can withstand a water pH of 7 to 9 [15, 16]. Results in Table (1) and (Fig. 2, (B)) represent long-term changes in the mean of pH for Lake Manzala from 1995 to 2018. Statistical data analysis showed no significant variations ($P>0.01$) in water pH between different years. Whereas, minimum value of hydrogen ion concentration was (7.91± 0.7) in 2000 when it ranged between 7.2 and 8.6. While, the maximum value was (8.55±1.6) in 2010 ranged from 7 to 10.2. This may be because industrial activities, especially mining and energy production from fossil fuels, which may cause local acidification for freshwater systems [17].

4.3 Total Solids: Obviously, the contents of the total solids in the lake water are affected by different factors, the most important factors of which are the continuous discharge of wastewater and the accelerated evaporation of the summer heat [18]. Results in Table (1) and (Fig. 2, (C)) represent long-term changes in the mean of TS for Lake Manzala from 2005 to 2018. Statistical data analysis showed significant variations ($P<0.01$) in water total solid between different years. Whereas, minimum TS value was (11.6 ±10.5 gL^{-1}) in 2010 when it ranged between 1.2 and 22.1 gL^{-1}. While, the maximum was (15.7 ±14.2 gL^{-1}) in 2018 ranged between 1.5 and 29.9 gL^{-1}.

4.4 Hardness: Results in Table (1) and (Fig. 2, (D)) represent long-term changes in the mean of hardness for Lake Manzala from 2005 to 2018. Statistical data analysis showed no significant variations ($P>0.01$) water hardness between different years. Whereas, minimum value of hardness was (1.7±1.5 gL^{-1}) was recorded in 2018 when it ranged between 0.2 and 3.1 gL^{-1}. While, the maximum value of water hardness was (4.6±3.5 gL^{-1}) in 2005 ranged between 1.08 and 8.08 gL^{-1}.

4.5 Dissolved Oxygen: Results in Table (1) and (Fig. 2, (E)) represent long-term changes in the mean dissolved oxygen (DO) of Lake Manzala from 1995 to 2018.The values of DO in the lake are related to the temperature, the amount of plants, salinity, and wind [4, 19]. Results showed that DO increased until it reached its maximum value in 2005 where it was (8.3 ± 5.1 mg O_2L^{-1}) , This may be due to biological activity, organic loading, and nutrient introduction [4, 20], and then it decreased again. Statistical data analysis showed no significant variations (P>0.01) in water dissolved oxygen between different years. Whereas, the minimum value of DO was (6.5 ± 3.5 mg O_2L^{-1}) recorded in 2000 when it ranged between 3 and 10 mg O_2L^{-1}.

4.6 Biological Oxygen Demand: Results in Table (1) and (Fig. 2, (F)) represent long-term changes in the mean biological oxygen demand (BOD) of Lake Manzala from 1995 to 2018. Results showed that BOD increased until it reached its maximum value in 2015 where it was (16.5 ± 6.8 mg O_2 L^{-1}), this due to the organic matter that decomposing anaerobically in industrial and municipal wastewater. Whereas, the minimum value of BOD was (3.66 ± 3.2 mg O_2 L^{-1}) recorded in 1995 when it ranged between 0.4 and 6.89 mg O_2 L^{-1}.

4.7 Chemical Oxygen Demand: COD values increases with increasing concentration of organic matter [22]. Results in Table (1) and (Fig. 2, (G)) represent long-term changes in the mean COD of Lake Manzala from 1995 to 2018. Statistical data analysis showed significant variations (P<0.01) in water COD between different years. Whereas, minimum mean value of COD was (12.2±7.2 mg O_2 L^{-1}) was recorded in 2000 when it ranged between 5 and 19.4 mg O_2L^{-1}. While, the maximum value was (41.5±28.3 mg O_2 L^{-1}) in 2015 ranged from 13.2 and 69.8 mg O_2 L^{-1}, this may because of an increase in industrial wastewater [9].

4.8 Sodium: Results in Table (1) and (Fig. 3, (A)) represent long-term changes in the mean of sodium for Lake Manzala from 1995 to 2018. The mean values of sodium concentrations in the lake are relate to the different sites and their closeness to the Mediterranean Sea. Results showed that sodium concentrations increased until it reached its maximum value in 2010 where it was (4.24 ± 3.9 gL^{-1}) and then decreased again. Whereas, the minimum value of sodium concentrations was (1.5 ± 0.5 gL^{-1}) recorded in 2018 when it ranged between 0.96 and 2.04 gL^{-1}.

4.9 Chloride: Results in Table (1) and (Fig. 3, (B)) represent long-term changes in the mean of chloride concentrations for Lake Manzala from 2005 to 2018. The values of chloride concentrations in the lake are related to the different sites and their closeness to the Mediterranean Sea. Results noted significant differences over the years. Whereas, minimum value of chloride concentrations was (3.9±2.6 gL^{-1}) was recorded in 2010 when it ranged between 1.3 and 6.5 gL^{-1}. While, the maximum value of chloride concentrations was (7.02±6.5 gL^{-1}) in 2005 ranged between 0.5 and 13.5 gL^{-1}.

4.10 Total Nitrogen: Results in Table (1) and (Fig. 3, (C)) represent long-term changes in the mean total nitrogen of Lake Manzala, which show the increasing in nitrogen values from 1995 to 2018.The values of total nitrogen in the lake are related to the different sites and the agricultural waste disposal therein. Results noted significant differences over the years. Whereas, minimum value of total nitrogen was (1.8±1.05 mgL^{-1}) was recorded in 2005 when it ranged between 0.8 and 2.9 mgL^{-1}. While, the maximum value of total nitrogen was (9.7±7.7 mgL^{-1}) in 2010 ranged between 2.05 and 17.4 $mgL^{-1,}$ and this may be due to increased agricultural drainage [9].

4.11 Total Phosphorus: Results in Table (1) and (Fig. 3, (D)) represent long-term changes in the mean of TP for Lake Manzala from 1995 to 2018. Results showed that the value of phosphorus decreased until it reached its minimum value in 2010 where it was (1.2 ± 0.86 mgL^{-1}) and then increased again. Whereas, maximum value was (2.3±0.97 mgL^{-1}) in 1995 when it ranged between 1.3 and 3.25 mgL^{-1}. This may be due to the contamination of sewage and agricultural waste [23].

Concentration of heavy metals in Manzala Lake

Heavy metals have a long persistence and toxicity to humans and other organisms, especially in presence with high concentrations, therefore they are considered as one of the most important pollution indicators in the aquatic environment [24].

4.12 Iron: Iron concentration in water is affected by the change in water temperature that decreases the rate of iron absorption by aquatic organisms [25]. The human activities, resulting in different harmful environmental impact as industrial, wastewater, sewage and mining wastes [26, 27]. Results in Table (1) and (Fig. 3, (E)) represent long-term changes in the mean Fe from 2000 to 2018. It noted significant differences over the years. Minimum value of Fe was (0.79±0.66 mgL^{-1}) n 2015. While, the maximum was (3.06±2.9 mgL^{-1}) in 2000.

4.13 Manganese: Manganese concentrations in water is affected by the changes in water temperature, which is mainly attributed to the mobilization of manganese from sediment to overlapping water due to the decomposition of organic debris by microbial activity [28]. Results in Table (1) and (Fig. 3 (F)) represent long-term changes in the mean Mn in Lake Manzala from 2000 to 2018. It noted significant differences over the years. Whereas, minimum value was (0.15±0.2 mgL^{-1}) was recorded in 2015 when it ranged between 0.001 and 0.3 mgL^{-1}. While, the maximum was (0.6±0.3 mgL^{-1}) in 2005, this may be due to agricultural drainage containing fertilizers. Moreover, fish farms use poultry farm remains that manganese-rich as fish food [9].

Biological quality standards for the lake water

4.14 Total Bacteria Count: Total Bacteria Count in water is affected by the changes in water temperature and organic matter [29, 30, 31].Results in Table (1) and (Fig. 4, (A)) represent long-term changes in the mean of TBC in Lake Manzala from 2005 to 2018. Results showed that the mean TBC increased until it reached its maximum value in 2010 where it was (93.5 ± 83.5 cfu×10^3 mL^{-1}) and then decreased again. While, the minimum value of TBC was (22±13 cfu×10^3 mL^{-1}) recorded in 2005 when it ranged between 9 and 35 cfu×10^3 mL^{-1}.TBC increases with the increase of organic matter [9].

4.15 Faecal Coliform Count: Faecal Coliform Count in water is affected by the changes in water temperature, agricultural drainage, and human sanitation [32]. Results in Table (1) and (Fig. 4, (B)) represent long-term changes in the mean of FCC in Lake Manzala from 2006 to 2019. It indicated significant differences over the years. FCC gradually increased until it reached its maximum value in 2018 (485.05±485 cfu×10^3 mL^{-1}), this may indicate an increase in organic matter [9].

5. CONCLUSION

Comparing Results obtained with the limit of the Environmental Protection Agency [33] for water body health showed the following:

- The mean of temperature and pH are within the permissible limits. Manganese is almost within the permissible limits, but in 2005, it was slightly above the permissible limit.
- The mean of total solids, hardness, BOD, COD, sodium, chloride, total nitrogen, total phosphorus, Iron are above the permissible limit.
- In some years, the dissolved oxygen is below the permissible limit.
- Efforts were done to improve the water quality of Lake Manzala.

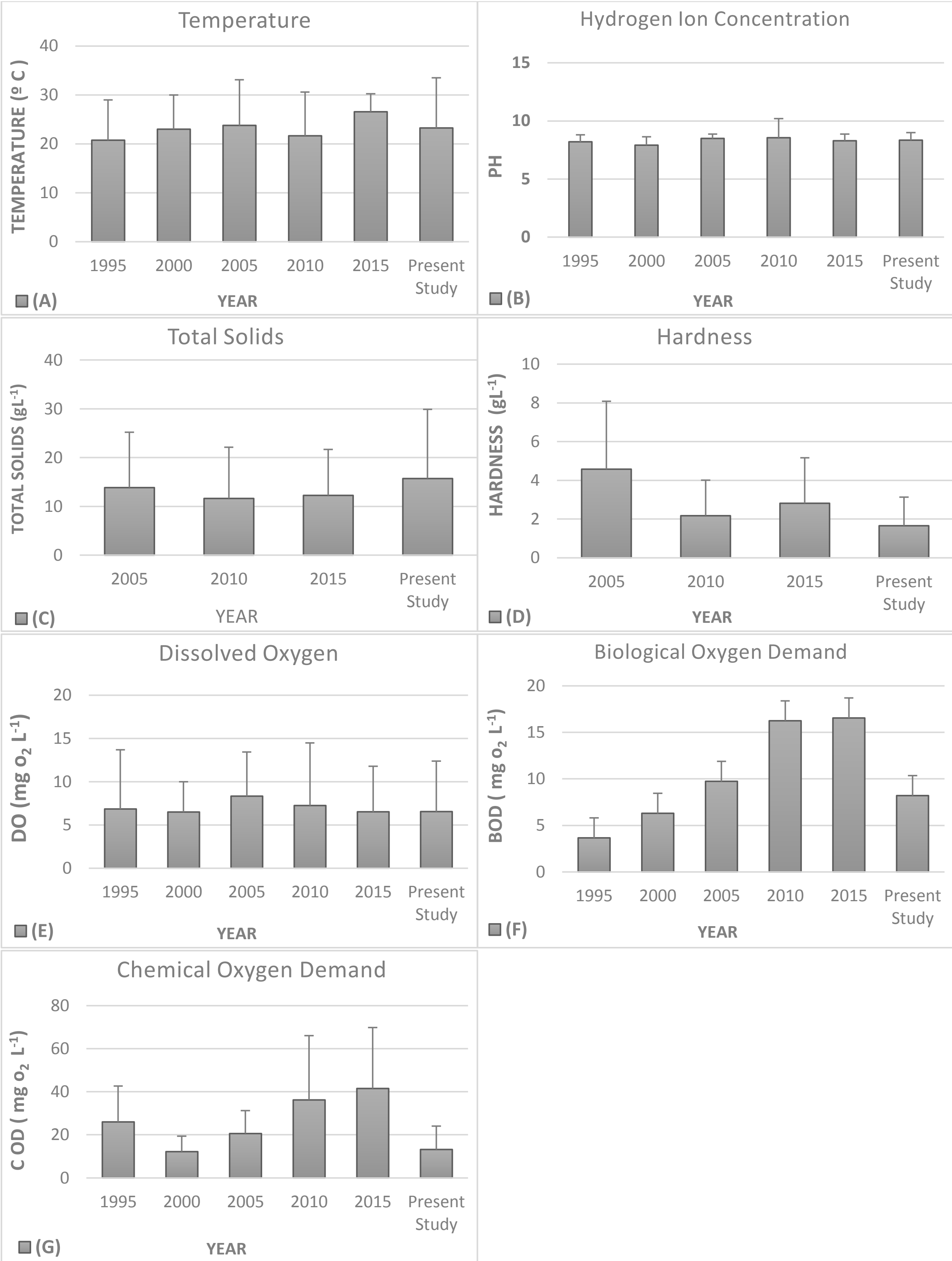

Fig (2): long-term changes of physico-chemical parameters for Manzala Lake water: (A) Water temperature (T), **(B)** pH, **(C)** Total Solids(TS), **(D)** Hardness, **(E)** Dissolved Oxygen(DO), **(F)** Biological Oxygen Demand(BOD), and **(G)** Chemical Oxygen Demand. Data expressed as mean ±SE.

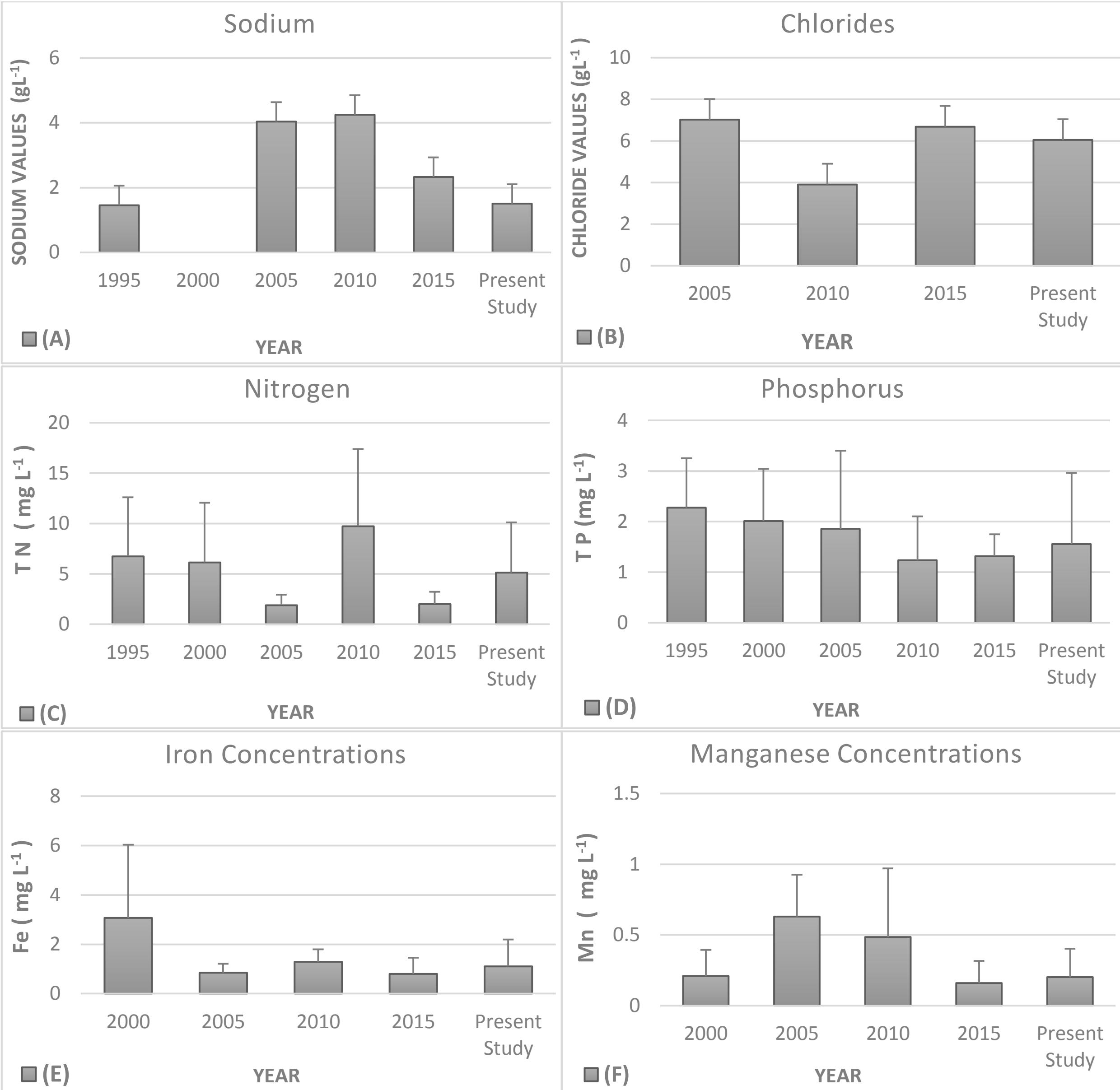

Fig (3): long-term changes of main ions and some heavy metals for Manzala Lake water: (A) Sodium, **(B)** Chlorides, **(C)** Total Nitrogen(TN), **(D)** Total Phosphorus(TP)**, (E)** Iron concentrations(Fe) and **(F)** Manganese concentrations(Mn). Data expressed as mean ±SE.

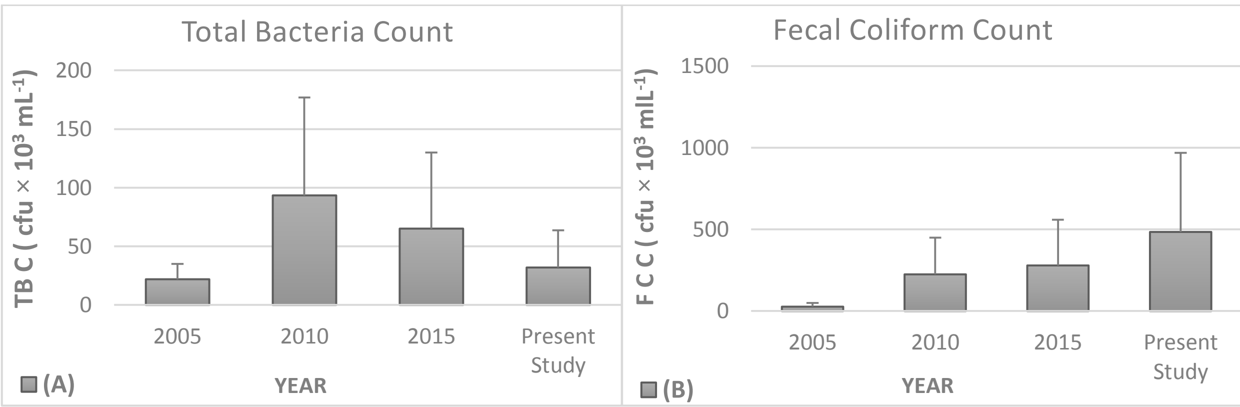

Fig (4): long-term changes of biological parameters for Manzala Lake water: (A) Total Bacteria Count, and **(B)** Fecal Coliform Count. Data expressed as mean ±SE.

Table 1: Annual average variations for some physical, chemical, and biological parameters in water samples collected from Lake Manzala since 1995 to 2018 and permissible limits.

Year	T (º C)	PH	TS (gL^{-1})	Hardness (gL^{-1})	DO ($mgO_2 L^{-1}$)	BOD ($mgO_2 L^{-1}$)	COD ($mgO_2 L^{-1}$)	Na (gL^{-1})	Cl (gL^{-1})	TN (mgL^{-1})	TP (mgL^{-1})	Fe (mgL^{-1})	Mn (mgL^{-1})	TBC cfu×10^3 mL^{-1}	FCC cfu×10^3 mL^{-1}	References
1995	20.7	8.2	—	—	6.85	3.66	26.01	1.45	—	6.73	2.28	—				[34, 35, 36]
	±8.3	±0.6			±6.8	±3.2	±16.6	±1.2		±5.9	±0.97					
2000	23	7.91	—	—	6.5	6.3	12.2	—	—	6.13	2.01	3.07	0.21			[37, 38]
	±7	±0.7			±3.5	±2.7	±7.2			±5.9	±1.03	±2.9	±0.2			
2005	23.7	8.5	13.86	4.58	8.34	9.74	20.6	4.04	7.02	1.88	1.86	0.84	0.63	22	27.5	[39, 40, 41]
	±9.3	±0.3	±11.4	±3.5	±5.1	±5.09	±10.6	±3.7	±6.5	±1.05	±1.5	±0.36	±0.3	±13		
2010	21.6	8.55	11.64	2.18	7.25	16.24	36.22	4.25	3.9	9.72	1.24	1.29	0.49	93.5	225.5	[42, 43, 8, 44, 45]
	±8.9	±1.6	±10.5	±1.8	±7.2	±7.6	±29.8	±3.9	±2.6	±7.7	±0.8	±0.5	±0.5	±83.5		
2015	26.6	8.29	12.26	2.82	6.53	16.54	41.54	2.33	6.67	2	1.32	0.79	0.16	65.18	280	[46, 47, 48, 49, 50]
	±3.7	±0.5	±9.4	±2.3	±5.2	±6.75	±28.3	±2.0	±6.3	±1.2	±0.4	±0.66	±0.2	±64.8		
Present Study	23.3	8.34	15.72	1.66	6.55	8.2	13.21	1.51	6.04	5.11	1.55	1.1	0.2	32.02	485.05	[9]
	±10.2	±0.6	±14.2	±1.5	±5.8	±1.4	±10.8	±0.5	±5.6	±4.9	±1.4	±1.09	±0.2	±31.5		
Limits*	<35	6-9	<2	0.3	> 6.5-8	4	30	0.2	2	0.3	0.1	1	<0.5			[33]

Data expressed as mean ±SE, SE= standard error of mean, Permissible limits according to EPA (2002).

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