Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(4): 139 – 158 (2020)
www.ejabf.journals.ekb.eg

Environmental Studies on Water Quality, Plankton and Bacterial Community in Mariout Lake, Egypt

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ARTICLE INFO

Article History:
Received: May 31, 2020
Accepted: June 13, 2020
Online: June 16, 2020

Keywords:
Mariout Lake
Water quality
Plankton
Bacteria
Pollution

ABSTRACT

Mariout Lake is now one of the most heavily polluted ecosystems in Egypt and a major source of pollution to the Mediterranean Sea through El Mex Bay. This study was carried out from February 2018 till January 2019, nine sites distributed in the Lake different basins to assay water quality properties, planktons, and bacterial community in water, sediment, and *O. niloticus* organs. Water quality results revealed that salinity ranged from 2.77 to 5.80 g/l. Total alkalinity fluctuated in range 230.00- 480.00 mg/l and this not well for fish growth. Nitrite and Nitrate were ranged between 0.024-0.321 mg/l and 0.096-1.541 mg/l, respectively. Most of these values are within the safe limits for fish health. Ortho- Phosphateconcentration fluctuated between 0.054 to 0.405mg/l. Phytoplankton community results take the following order Cyanophyta> Bacillariophyceae> Chlorophyceae> Euglenophyta. On the other hand, Copepoda and Cladocera were the most remarkably abundant zooplankton group than Rotifer and Ostracoda groups. The bacteriological examination showed that the main basin (6000 feddan) showed the highest bacterial load (TBC, CF, *E. coli* & *Vibrio cholera*) in water, sediment, and *O. niloticus* organs than other Lake basins. Where, TBC, CF, *E. coli* & *Vibrio cholera* recorded higher values in sediment and water than *O. niloticus* organs. The results of bacterial load in water and *O. niloticus* organs exceed the permissible limits which can cause a health risk for fish and consumers.

INTRODUCTION

Water quality is a highly imperative component to understand the healthiness of a water body and it is a critical factor affecting human health and welfare **(Al- Gahwari, 2007)**. Studies showed that approximately 3.1% of deaths (1.7 million) and 3.7% of disability- adjusted-life-years (DALYs) (54.2 million) worldwide are attributable to unsafe water, poor sanitation and hygiene **(WHO, 2005)**.

Globally, the water quality of inland Lakes is of great importance, particularly in countries of the arid region. This makes the majority of these inland Lakes of great public interest for recreational activities, some industries as well as water supply and support to most of the local communities **(El-Sheekh *et al*., 2019)**. Where, Egypt is an arid country that faces challenges due to its limited water resources and disorders of water balance **(Nasr and Zahran, 2015)**.

Physicochemical and biological water quality indicators will be affected in various ways. The main causes of water quality deteriorations are anthropogenic and natural agents **(Chaterjee and Raziuddin, 2002)**. Some of nature and human-induced factors that affect the quality of water for various purposes are natural hazards, agricultural activities; industrial; fishing; sewage discharging/disposal and other commercial activities that aggravate the pollution of the water body and greatly influence the quality of water **(Tamiru, 2006)**.

Shallow Lakes are often associated with abundant phytoplankton biomass and increasing water turbidity **(Asaeda *et al*., 2001)**. Changes in phytoplankton communities in Lakes have been regarded as a good bioindicator of water quality, ecosystem health and trophic status of the system **(Zeng *et al*., 2017)**.

One of the most important factors of water pollution is microbial contamination **(Karaboze *et al*., 2003)**. Contamination of water is a serious environmental problem as it adversely affects human health and biodiversity in the aquatic ecosystem. **APHA (1995)** confirm the use of indicator bacteria, such as fecal coliform (FC) and fecal streptococci (FS) for assessment of fecal pollution and possible water quality deterioration. Bacterial contamination of fish is considered the main cause of signs of spoilage as off- flavor and unpalatable taste and it may constitute a public health hazard as well as many of economic losses **(Zaky and Salem, 2015)**. At the time of harvest, fish carries a high microbial load on the surface of their skins, in their intestinal tracts and their gills. The type and number of microorganisms that live in fish vary according to the season, the species and the natural habitat. Egyptian Environmental Affairs Agency (EEAA) used Physical, chemical and microbial characteristics of water to determine the health status of water **(Ismail and Hettiarachchi, 2017)**.

Mariout Lake has a very important economic activity in Egypt for fish production **(Afifi *et al*., 2016)**. It is an important resource of popular tilapia fish species in Egypt. It is considered one of the most heavily populated urban areas in Egypt and in the world and a major source of pollution to the Mediterranean Sea through El Mex Bay. Where, it receives both agricultural drainage water (from the agricultural lands of neighboring Bohaira and Alexandria Provinces) besides discharges of Alexandria sewage and industrial wastewaters, with respective rates 6 and 1×10^6 m^3/day (the Lake volume is 23×10^6 m^3) **(El-Rayis *et al*., 2019)**.

The current work aims to study the physicochemical properties, planktons and investigate the bacterial community in Lake Mariout water, soil and *O. niloticus* organs to evaluate the dangerous effect caused by wastewater discharged into this Lake.

MATERIALS AND METHODS

Study area

Mariout Lake is one of the northern Nile Delta Lakes situated along the Mediterranean coast of Egypt south Alexandria city and extends between longitudes 31° 01' 48" and 31° 10' 30" N and latitudes 29° 49' 48" and 29° 57' 00" S **(Mateo, 2009)**. Therefore, it differs from the other coastal Egyptian Lakes in being disconnected from the sea and freshwater. It is of depths ranging between 3.4 and 4.0 m below sea level and separated from the sea by a ridge called Abuser Hill.

The Lake has divided artificially into five Basins **(Fig. 1)** namely 6000, 5000, 3000, 2000 and 1000 feddans, which dissected by roads and embankments and receives their water from the drainage waters of El-Umoum drain, Noubaria Canal, settled sewage water from west treatment plant outfall, agricultural wastewater and sewage water from El Qalaa Drain Outfall which considered the major source of pollution in the Lake, raw sewage water from Gheit El Enab Outfall and Mogama industrial waste water into the Lake, which is discharged industrial effluents of eight factories were Salt and Soda, Extracted Oils, National Paper, Starch and Yeast, Nile Matches, South Alexandria Mills and Alexandria Foundry.

Sampling locations and study period

Sampling was done at nine sites distributed in the Lake basins, which were determined by Geographic Position System (GPS) during 2018 as shown in **(Table 1 and Fig. 1)**.

Table 1. The location and geographic position of sampling sites at different basins of the Lake.

Basins	Sites	Coordination	
		Latitude /	Longitude
6000 feddans	1	31° 9' 24.37" N	29° 55' 6.36" E
	2	31° 9' 18.89" N	29° 53' 44.95" E
	3	31° 8' 46.73" N	29° 52 '40.98" E
3000 feddans	4	31°7' 30.55" N	29°52' 37.88" E
	5	31°6' 39.36" N	29°51' 46.36" E
	6	31°7' 51.70" N	29°51' 40.40" E
1000 feddans	7	31°8' 28.92" N	29°51' 53.53" E
2000 feddans	8	31°6' 18.23" N	29°52' 56.26" E
	9	31°3' 50.00" N	29°52' 36.29" E

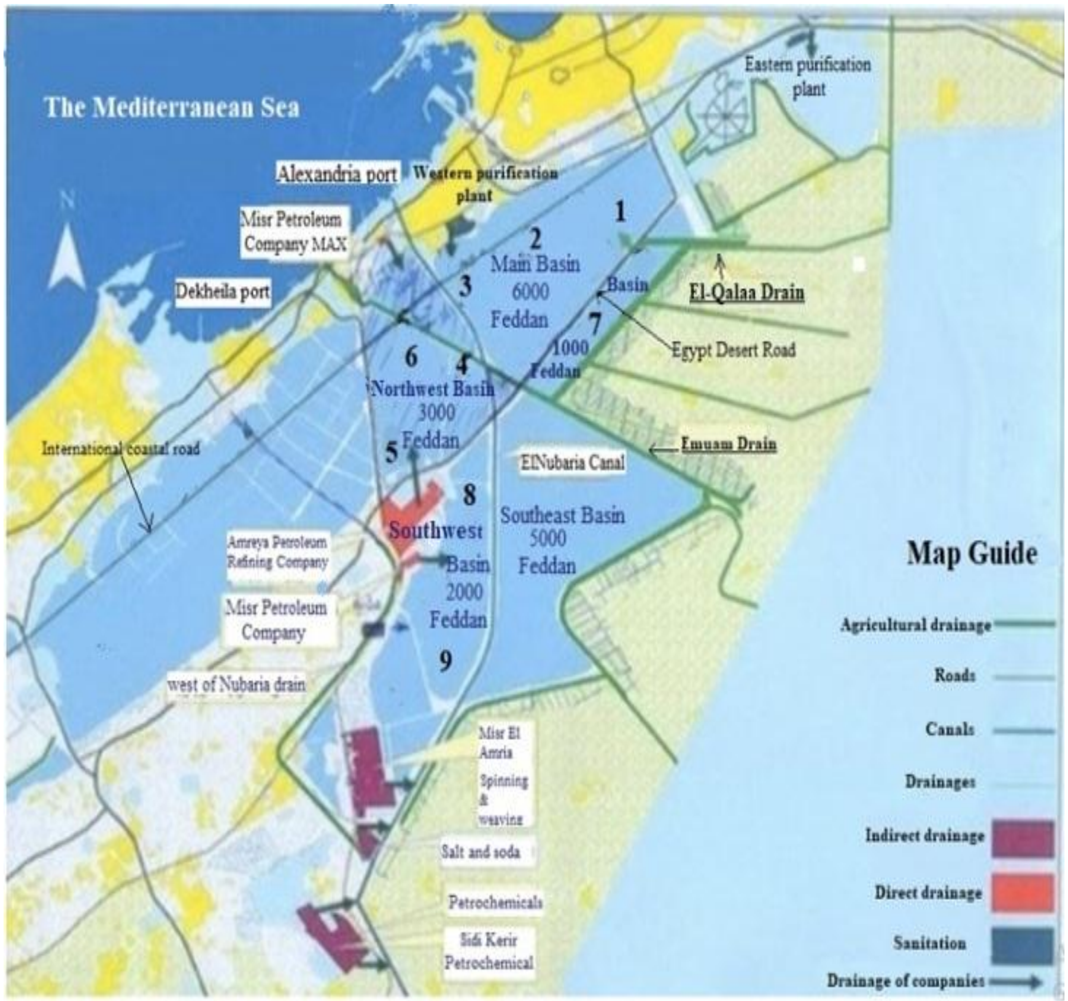

Fig. 1. Map of Mariout Lake location and different sampling sites at different basins.

Sampling methods and analytical techniques

Physicochemical analyses of the Lake water

Water samples were collected seasonally from the mentioned sites along the study period (February 2018 to January 2019) by a Kemmerer water sampler at depth of half a meter from the water surface. Water samples at each site were mixed in plastic bucket and a sample of 1 liter was placed in a clean polyethylene plastic bottle and stored in an ice-box at 4 ºC until transported to the laboratory for further analysis according to APHA (2000). During sampling, temperature and pH were measured using a glass electrode Digital Mini-pH-meter (Thermo Orion, model 420A). Salinity, Electrical conductivity (EC) and total dissolved solids (TDS) measured by the salinity-conductivity meter (model YSI Environmental, EC 300). In the laboratory, Total alkalinity and total hardness were measured by titration according to **APHA (2000)**. Nitrite-nitrogen (mg/l) was measured by the Diazotizing method at 543nm, **(APHA, 2000)**. Nitrate-nitrogen (mg/l) was measured by phenol di-sulphonic acid method according to **Boyd (1984)**. Ortho-phosphorus (mg/l), total Nitrogen (TN), total phosphorus (TP) and Chlorophyll ″a″ (µg/l) were measured photometrically using spectrophotometer Thermo Electron Corporation (model Nicolet evolution 100) according to **APHA (2000)**.

Biological examinations of the Lake water

Planktons were quantitatively counted in water seasonality of each site according to methods reported in **APHA (2000)**.

Bacterial Examinations

The average bacterial load of the Lake during study year was measured in water, sediment and organs (skin, muscle and gills) of *O. niloticus* of basins (٦000; 3000; 1000 and 2000 feddans) according to **APHA (1992)**. Total bacterial count, coliform group, fecal coliform (*E. coli*) and *Vibrio cholera* were estimated on plate count agar, MacConkey agar (Oxoid) and thiosulfate citrate bile salts sucrose agar (TCBSA, Biolife), respectively according to **APHA (1995)**.

Statistical Analysis

The obtained data were subjected to two-way ANOVA to test the differences between basins and seasons for water quality parameters and plankton species. While, one-way ANOVA was applied to test the effect of basins for bacterial examinations. Tukey's Multiple Range's Test was used as a post-hoc test to compare means at $P < 0.05$. The software SPSS, version 17.0 (SPSS, Richmond, Virginia, USA) was used as described by **Dytham (1999)**.

RESULTS AND DISCUSION

Water quality is made up of physical, chemical and biological factors which influence the use of water for fish production purposes.

Physical parameters

The seasonal results of physical parameters at different Lake basins are tabulated in **Table (2)**. All recorded parameters significantly affected by basins ($P<0.05$), while only temperature and electric conductivity affected significantly by seasons ($P<0.05$). All recorded parameters not affected significantly by basins and seasons interaction ($P>0.05$).

The temperature of Mariout Lake water fluctuated between the four seasons in the lowest range of 16.0 °C during winter to the highest range of 30.0 °C during summer. This value falls within a desirable range for optimum yield in aquaculture recommended by **(Pooja Devi, 2013)**.

The pH is one of the most important environmental factors limiting the distribution of species in aquatic habitats. Hydrogen ion concentration exhibited slight seasonal variations in the Lake water. The pH values show alkaline affinity where ranging from 7.7 to 8.8 and these values were within the permissible range (6.5- 9) according to **(Pooja Devi, 2013)**. The lowest values of Lake Water pH recorded at sites of basins 3000 and 6000 feddans (near the drains inputs) may due to increase of the organic matter from effluent fresh water drains. This explanation comes in agreement with those obtained by **(Ismail and Hettiarachchi, 2017)**. While, basins water of 2000 and 1000 feddans exhibited the highest pH values during the summer and lower values during the winter reflecting the role of intensive aquatic plants mainly in the removal of CO_2 during photosynthetic activities, consequently raising pH values. This is in agreement with the results obtained by **El-Rayis *et al*. (2019)**. Photosynthesis increases during the summer season and the middle of the day where sunlight is at the maximum **(Long *et al*., 2006)**.

Table 2. Seasonality variation of physical parameters of Mariout lake water at different basins during 2018.

Basins	Seasons	Temp. (°C)	pH	Salinity (g/l)	EC (mS/cm)	TDS (mg/l)
6000 feddans	winter	16.00±0.436 [e]	7.87±0.206 [ab]	3.50±0.361 [efg]	6.99±0.441 [def]	3.67±0.241 [cdef]
	springe	21.90±0.296 [cd]	7.96±0.233 [ab]	2.77±0.273 [g]	5.13±0.333 [f]	2.56±±0.168 [f]
	summer	30.00±0.289 [a]	8.34±0.131 [ab]	3.87±0.273 [defg]	7.77±0.667 [def]	3.83±0.338 [cdef]
	Autumn	26.60±0.555 [b]	7.85±0.105 [ab]	3.10±0.252 [fg]	5.49±0.571 [f]	2.91±0.346 [ef]
3000 feddans	winter	16.70±0.2 [e]	7.97±0.368 [ab]	4.03±0.433 [defg]	7.72±0.902 [def]	3.86±0.452 [bcdef]
	springe	21.70±0.2 [cd]	7.89±0.084 [ab]	3.43±0.033 [efg]	6.65±0.090 [def]	3.50±0.209 [def]
	summer	29.70±0.2 [a]	8.07±0.088 [ab]	3.60±0.058 [efg]	7.03±0.233 [def]	3.60±0.115 [def]
	Autumn	26.20±0.5 [b]	8.11±0.110 [ab]	3.53±0.617 [efg]	5.89±0.749 [ef]	3.56±0.658 [def]
1000 Feddans	winter	16.40±0.404 [e]	7.70±0.252 [b]	5.20±0.153 [abcd]	11.00±1.155 [abc]	5.10±0.091 [abc]
	springe	20.50±0.173 [d]	7.94±0.095 [ab]	5.60±0.173 [abc]	10.56±0.598 [abc]	5.33±0.015 [ab]
	summer	30.00±0.854 [a]	8.20±0.321 [ab]	5.80±0.208 [a]	11.50±0.210 [a]	5.60±0.153 [a]
	Autumn	25.00±0.306 [b]	8.00±0.252 [ab]	5.70±0.361 [ab]	11.2±0.182 [ab]	5.60±0.252 [a]
2000 feddans	winter	16.50±0.029 [e]	8.32±0.165 [ab]	4.20±0.058 [cdef]	8.35±0.087 [cde]	4.1±0.058 [bcde]
	springe	22.60±0.087 [c]	8.57±0.306 [ab]	4.35±0.029 [bcdef]	8.33±0.069 [cde]	4.83±0.416 [abcd]
	summer	29.50±0.289 [a]	8.80±0.115 [a]	4.60±0.000 [abcde]	8.74±0.136 [bcd]	4.55±0.029 [abcd]
	Autumn	16.40±0.029 [e]	8.32±0.165 [ab]	4.20±0.058 [cdef]	8.35±0.087 [cde]	4.10 ±0.058 [bcde]
Two-way ANOVA				***P* value**		
Basin		0.038	0.002	0.0001	0.0001	0.0001
Season		0.0001	0.078	0.105	0.004	0.340
Basin × Season		0.051	0.914	0.305	0.371	0.117

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

Salinity plays an important role in biological processes affecting algal blooms, fish movements, shellfish productivity, and aquaculture. During this study, water salinity of the Lake Basins ranged between 2.77 to 3.87 g/l in 6000 feddans basin, 3.43 to 4.03 g/l in 3000 feddans basin, 5.2 to 5.8 g/l in 1000 feddan basin and 4.2 to 4.6 g/l in 2000 feddans basin **(Table 2)**. The Main Basin of 6000 feddans was characterized by low salinity as it is the only one directly receiving highest amount of the Alexandria sewage and industrial wastewaters, this agrees with **El- Rayis *et al*. (2019)**. Besides that, the highest salinity of the Lake water was recorded during the summer season than other seasons due to increase water evaporation rate with a raise water temperature degree **(Farouk, 2018)**.

Electric conductivity reflects the quantities of dissolved salts and salinity **(Thompson *et al*., 2012)**. Total Dissolved Solids (TDS) is a water quality parameter defining the concentration of dissolved organic and inorganic chemicals in the water. It is used to evaluate the quality of freshwater systems **(DRI, 2010)**. Electric conductivity (EC) and Total Dissolved Solids (TDS) of Mariout Lake were recorded the same trend of salinity where EC ranged between 5.13- 11.5 mS/cm and TDS ranged between 2.56-5.60 mg/l, these values are far greater than the standard value of 0.13 mg/l recommended by **Davis (1993)**. The highest values of salinity, EC and TDS in 1000 feddans basin may be related to low of drainage water discharge entered it comparing with the others basins.

Chemical parameters

Chemical parameters were tabulated in **Table 3.** Total Nitrogen affected significantly by basin and season and their interaction, while total hardness, nitrates, and total phosphorus significantly affected by basin ($P<0.05$). Furthermore, total alkalinity and total hardness significantly affected by season ($P<0.05$). Finally, the other parameters have not affected significantly by basins, seasons, or their interaction ($P>0.05$).

Total alkalinity of the Lake basins ranged between 266.60-351.60 mg/l in 6000 feddans, 208.30- 480.00 mg/l in 3000 feddans basin, 237.50-385.00 mg/l in 2000 feddans basin and 278.00- 400.00 mg/l in 1000 feddans basin. The results of the Lake alkalinity >300 mg/l are undesirable for fish growth and cause stress as previously mentioned by **Pooja Devi (2013)**. The highest value of total alkalinity in Mariout Lake might be attributed to the presence of the high amount of organic matter accessible to bacterial decomposition by increasing sewage, domestic, agricultural and industrial effluents discharged into the Lake, where bicarbonate is the final product of the decomposition **(Abdo and El-Nasharty, 2010)**.

Total hardness of the Lake during the study fluctuated between 1511.0-2534.4 mg/l, 1616.0-2193.3 mg/l, 1665.0-2985.0 mg/l and 1675.0-3100.0 mg/l in basins of 6000, 3000, 1000 and 2000 feddans, respectively. The lowest TH averages recorded in basins of 6000 and 3000 feddans than other basins may be related to lower of its water salinity due causing the decrease of carbonate and bicarbonate salts **(Darwish, 2016)**. Overall, all TH results of Mariout Lake falls in the harmful range which is lethal to fish life according to **(WHO, 2003)** and these results agree with **Alnagaawy *et al*. (2018)** in the same Lake.

Water nitrite (NO_2) values obtained in the investigated basins of Mariout Lake were ranged between 0.024 and 0.124, 0.046 and 0.321, 0.033 and 0.073, 0.028 and 0.121 mg/l, respectively in basins of 6000; 3000; 1000 and 2000 feddans as revealed in **Table 3**. Water nitrate (NO_3) values ranged between 0.200 and 0.274, 0.416 and 1.541, 0.115 and 0.228, 0.096 and 0.260 mg/l, respectively for the same basins. The increased values of water NO_2-N and NO_3-N in the Lake may be due to sewage effluents **(Alnagaawy *et al*., 2018)**. Also, it could be observed that the nitrate concentrations were found to be higher than nitrites at different basins of the Lake, this is consistent with the fact that nitrite is relatively short-lived in water, because it is quickly converted to nitrate by bacteria. Because of its short lifetime, pollution with NO_2 mainly is relevant for aquatic organisms **(Ismail and Hettiarachchi, 2017)**.

Results of nitrite and nitrate for Mariout Lake basins are within the standard safe limit as indicated by **OATA (2008)** who recommended that nitrite should not exceed 0.20 mg/l in the freshwater. **Pooja Devi (2013)** suggested that the acceptable range of nitrite is 0.02 to 2.00 mg/l. For nitrate, the standard safe limit of range 0.10 to 4.00 mg/l NO_3 recommended by **Santhosh and Singh (2007)**.

Total nitrogen in water is comprised of dissolved inorganic (nitrites, nitrates and ammonia) and organic nitrogen. High organic nitrogen levels are due to decomposition of aquatic life **(Mohammed, 2018)**. During the study period, total nitrogen results were ranged from 1.14 to 3.21, 1.62 to 4.46, 0.421 to 0.669, and 0.897 to 3.77 mg/l in the basins of 6000; 3000; 1000 and 2000 feddans, respectively. It noted that the highest TN values were recorded in basins of 3000 and 6000 feddans during autumn and winter. This is attributed to the increase in the estuaries of drains, whether agricultural drainage, sanitation, or mixed drainage, which is loaded with large quantities of nutrients. This agrees with **El Zokm *et al*. (2018)** who indicated the high agricultural discharge during

Table 3. Seasonal variation of Chemical parameters of Mariout Lake water at different Basins from February 2018 to January 2019.

Basins	Seasons	T. Alk. (mg/l)	T. hardness (mg/l)	NO_2^- (mg/l)	NO_3^- (mg/l)	TN (mg/l)	PO_4^{3-} (mg/l)	TP (mg/l)
6000 feddans	winter	281.6±11.7 ^{ab}	2050.0±132.3 ^{cde}	0.042±0.025 ^{b}	0.366±0.165 ^{ab}	3.210±1.03 ^{ab}	0.189±0.11 ^{ab}	0.564±0.19 ^{ab}
	springe	485.0±100.4 ^{a}	1511.0±269.9 ^{e}	0.124±0.055 ^{ab}	0.225±0.060 ^{ab}	2.790±1.22 ^{b}	0.165±0.13 ^{ab}	0.598±0.27 ^{ab}
	summer	266.6±10.2 ^{b}	2534.0±134.4 ^{abc}	0.024±0.003 ^{b}	0.20±0.025 ^{ab}	1.330±0.04 ^{b}	0.405±0.26 ^{a}	0.414±0.27 ^{ab}
	Autumn	351.6±18.6 ^{ab}	1543.0±87.4 ^{de}	0.044±0.026 ^{b}	0.274±0.079 ^{ab}	1.140±0.07 ^{b}	0.147±0.03 ^{ab}	0.438±0.11 ^{ab}
3000 feddans	winter	208.3±25.9 ^{b}	2193.0±232.2 ^{bcde}	0.046±0.021 ^{b}	0.437±0.219 ^{ab}	3.590±3.45 ^{ab}	0.431±0.205 ^{a}	0.465±0.09 ^{ab}
	springe	480.0±70.0 ^{a}	1866.0±72.6 ^{cde}	0.109±0.028 ^{ab}	0.732±0.302 ^{ab}	2.510±1.42 ^{b}	0.056±0.005 ^{b}	0.708±0.19 ^{a}
	summer	230±27.8 ^{b}	2866.0±133.3 ^{ab}	0.078±0.043 ^{b}	0.416±0.204 ^{ab}	1.620±0.19 ^{b}	0.161±0.075 ^{ab}	0.181±0.07 ^{b}
	Autumn	317.7±18.6 ^{ab}	1616.0±158.9 ^{de}	0.321±0.248 ^{a}	1.541±1.186 ^{a}	4.460±7.7 ^{a}	0.084±0.007 ^{b}	0.356±0.06 ^{ab}
1000 feddans	winter	290.0±10.4 ^{ab}	1665.0±3.786 ^{de}	0.052±0.004 ^{b}	0.115±0.001 ^{ab}	0.421±0.002 ^{b}	0.040±0.001 ^{b}	0.117±0.003 ^{b}
	springe	400.0±4.4 ^{ab}	2150.0±2.0 bcde	0.033±0.003 ^{b}	0.131±0.002 ^{ab}	0.637±0.001 ^{b}	0.061±0.002 ^{b}	0.132±0.002 ^{b}
	summer	278.0±4.16 ^{ab}	2985.0±6.5 ^{a}	0.073±0.002 ^{b}	0.228±0.002 ^{ab}	0.669±0.002 ^{b}	0.085±0.001^{b}	0.179±0.001 ^{b}
	Autumn	355.0±14.6 ^{ab}	1770.0±6.1 ^{cde}	0.042±0.006 ^{b}	0.173±0.002 ^{ab}	0.501±0.001 ^{b}	0.054±0.000 ^{b}	0.125±0.002 ^{b}
2000 feddans	winter	255.0±14.4 ^{b}	2150.0±230.9 ^{bcde}	0.058±0.010 ^{b}	0.139±0.010 ^{ab}	0.925±0.080 ^{b}	0.120±0.037 ^{ab}	0.308±0.031 ^{ab}
	springe	385.0±89.3 ^{ab}	2325.0±274.2 ^{abcd}	0.028±0.002 ^{b}	0.171±0.020 ^{ab}	0.897±0.12 ^{b}	0.060±0.001^{b}	0.302±0.009 ^{ab}
	summer	237.5±7.3 ^{b}	3100.0±57.7 ^{a}	0.109±0.051^{ab}	0.096±0.012 ^{ab}	1.390±0.09 ^{b}	0.073±0.00 ^{b}	0.163±0.043 ^{b}
	Autumn	277.5±7.3 ^{ab}	1675.0±72.7 ^{de}	0.047±0.006 ^{b}	0.260±0.004 ^{ab}	3.770±0.12 ^{ab}	0.194±0.07 ^{ab}	0.350±0.011 ^{ab}
Two-way ANOVA					***P* value**			
Basin		0.229	0.008	0.240	0.034	0.002	0.119	0.002
Season		0.0001	0.0001	0.651	0.515	0.033	0.374	0.166
Basin x Season		0.722	0.064	0.364	0.770	0.029	0.299	0.646

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

autumn in Mariout Lake.

Phosphorus is an essential element in aquatic ecosystems. It can be the limiting nutrient controlling primary production. Almost all of the phosphorus (P) present in water is in the form of phosphate (PO_4^{3-}) and in surface water mainly present as bound to living or dead particulate matter. It is an essential plant nutrient as it is often in limited supply and stimulates plant (algae) growth and its role for increasing the aquatic productivity is well recognized. High concentrations of phosphorus can contribute to excessive algal and associated water quality issues **(Baldwin, 2013; Pooja Devi, 2013)**.

Water ortho-phosphorus concentration fluctuated between 0.147 to 0.405, 0.056 to 0.431, 0.040 to 0.085 and 0.060 to 0.194 mg/l in the Lake basins of 6000, 3000, 1000 and 2000 feddans, respectively. Total phosphorus is fluctuated in the present study between 0.414 to 0.598, 0.181 to 0.708, 0.117 to 0.179 and 0.163 to 0.350 mg/l in the Lake basins of 6000, 3000, 1000 and 2000 feddans, respectively. The maximum phosphorus values were recorded in the Lake basins of 3000 and 6000 feddans, where they were accompanied by the highest nitrate, nitrite, total nitrogen, and oxidizable organic matter concentrations **(El Zokm *et al*., 2018)**. The increased value of PO_4^{3-} and TP in some investigated basins reflects the effect of drainage waters, either sewage or agriculture which considered a major contributor of phosphorus to receiving waters **(Dougherty *et al*., 2004)**. Phosphorus values of Mariout Lake in the present study are in the desirable range (0.01-3.00 mg/l) as mentioned by **Pooja Devi (2013)**.

Biological parameters

Many human activities affect chlorophyll "a" in water, such as sewage inputs and destruction of Lake. Chlorophyll "a" reflected the water quality in the Nile tilapia aquaculture ecosystem **(Ahmed, 2015)**. Seasonal variation of chlorophyll "a" value in the Lake ranged between 150.70 - 176.30, 95.28 - 247.20, 95.40 - 235.30 and 86.60 - 114.45 µg/l in the Lake basins of 6000, 3000, 1000 and 2000 feddans, respectively. The maximum values of chlorophyll "a" were recorded during spring season of the study which may be related to increase phytoplankton with increase nutrients of TN and TP **(Farouk, 2009)**. Chlorophyll "a" value in the Lake hadn't significant difference ($P>0.05$) among the Lake basins, the study seasons, and their interaction **(Table 5)**.

Chlorophyll "a" is essential to the existence of phytoplankton. Phytoplankton can be used as an indicator organism for the health of a particular body of water. Monitoring chlorophyll "a" level is a direct way of tracking algal growth. Surface waters that have high chlorophyll "a" condition is typically high in nutrients, generally phosphorus and nitrogen.

Planktons community (Phytoplankton & Zooplankton) of the Lake water

The amount and diversity of phytoplankton in a water body reflect the average ecological condition and therefore may be used as an indicator of water quality **(El-Sheekh *et al*., 2019)**. The existence of zooplankton production primarily depends on primary production. Zooplankton is a link in the food chain between the primary producers and nektonic and benthonic animals in higher trophic levels **(Siddika *et al*., 2012)**. Seasonal variation of plankton abundance (phytoplankton and zooplankton) in Mariout lake basins during the present study was revealed in **Tables 4** and **5**.

Phytoplankton community

The phytoplankton community **(Table 4)** was presented by four main orders (Chlorophyceae, Bacillariophyta, Cyanophyta, Euglenophyta), which had significantly difference (P<0.05) among basins and seasons. While, interaction among them hadn't shown significant difference (P>0.05) in the phytoplankton community except for Chlorophyceae.

Chlorophyceae abundance ranged between 39.00-47.71, 34.07-40.88, 22.16-26.22 and 27.32-31.33 x10^5 org./l in the lake basins of 6000, 3000, 1000, 2000 feddans, respectively. Bacillariophyta abundance ranged between 37.48-50.62, 35.26-42.13, 23.13-33.15 and 30.93-36.43 x10^5 org./l. Cyanophyta abundance ranged between 47.27-87.84, 49.04-58.00, 23.13-33.15 and 34.73-38.46 x10^5 org./l. Euglenophyta abundance ranged between 32.8-38.7, 29.05-34.85, 30.14-33.36, and 9.95-10.58 x10^5 org./l for the same Lake basins, respectively.

Table 4. Seasonal variation of chlorophyll "a" and phytoplankton abundance in Mariout Lake water at different Basins from February 2018 to January 2019.

Basins	Seasons	Chlorophyll "a" ug/l	Phytoplankton (org. x 10^5 /l)			
			Chlorophyceae	Bacillariophyta	Cyanophyta	Euglenophyta
6000 Feddans	Winter	167.07±57.9 ab	39.00±0.73 d	37.48±0.705 bcdef	47.27±2.13 cd	32.80±0.88 bcde
	Springe	176.30±59.9 ab	42.64±0.87 bc	44.19±3.53 abc	51.30±2.98 abc	35.11±1.74 abc
	Summer	150.70±62.3 b	47.71±0.18 a	50.62±3.68 a	57.84±3.51 a	38.70±1.10 a
	Autumn	175.17±120.8 ab	44.30±0.10 b	46.61±4.41 ab	56.02±3.01 ab	36.64±1.61 ab
3000 feddans	Winter	221.6±102.4 ab	34.07±0.55 e	35.26±0.39 cdefg	49.04±1.00 bc	29.05±0.61 e
	Springe	247.20±120.9 a	35.85±0.67 e	36.86±0.148 cdef	52.69±0.83 abc	31.26±0.65 cde
	Summer	95.28±9.6 b	40.88±0.21 cd	42.13±0.468 abcd	58.00±1.06 a	34.85±1.01 abc
	Autumn	197.40±90.7 ab	39.80±0.29 d	40.11±0.575 bcde	54.63±1.45 abc	33.21±0.54 bcde
1000 feddans	Winter	115.60±3.03 b	22.16±0.04 k	23.13±0.104 h	33.67±0.15 e	30.14±0.18 de
	Springe	235.30±2.0 ab	23.91±0.05 jk	26.19±0.111 gh	35.77±0.87 e	31.55±0.19 cde
	Summer	95.40±0.86 b	26.22±0.04 hi	33.15±0.05 defg	40.24±0.14 de	33.36±0.04 bcd
	Autumn	100.90±1.68 b	24.12±0.07 jk	30.22±0.218 fgh	40.06±0.13 de	31.75±0.15 cde
2000 feddans	Winter	91.14±4.9 b	27.32±0.39 gh	30.93±0.124 efgh	34.73±0.22 e	9.95±0.35 f
	Springe	114.45±8.6 b	29.13±0.58 fg	33.96±.04619 defg	35.99±0.16 e	10.45±0.38 f
	Summer	86.60±1.9 b	31.33±0.70 f	36.43±0.171 cdef	38.46±0.42 e	10.85±0.42 f
	Autumn	107.85±1.1 b	30.12±0.59 f	35.15±0.078 cdefg	37.10±0.57 e	10.60±0.35 f
Two-way ANOVA			***P* value**			
Basin		0.209	0.0001	0.0001	0.0001	0.0001
Season		0.289	0.0001	0.0001	0.0001	0.0001
Basin × Season		0.950	0.0001	0.710	0.353	0.185

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

Phytoplanktons community results clarified that Cyanophyta abundance had the highest contribution in the Lake basins followed by Bacillariophyceae and Chlorophyceae then Euglenophyta and this agrees with **Kousaa (2000)** who identified Cyanophyta species constituted about 80% of the total density of Mariout Lake, Bacillariophyta formed 17% and Euglenophyta about 2%. Cyanophyta and Chlorophyceae species abundance in the Lake has attributed to the high concentration of nitrate and phosphate in the lakes basins water as a result of the high nutrients through sewage and agriculture wastewater entered the lake and this agrees with **(El-Sheekh, 2009)**. Also, genus Euglena tops considered as a biological indicator of organic pollution **(Palmer, 1969)**.

Also, the results showed that increasing the Phytoplanktons abundance in the Lake basins of 6000 and 3000 feddans than others basins could be attributed to nutrients abundance in these basins and this agrees with **Breitburg *et al*. (1999)** who indicated that any increase in nutrient loading can cause an increase in phytoplankton productivity. On the other hand, the basin of 2000 feddan showed a lack of phytoplankton abundance and this attributed to increasing industrial drainage water **(El-Sheekh *et al.*, 2000)**. Summer season recorded the highest Phytoplankton abundance in all basins and this may be attributed to eutrophication of the Lake which is responsible for increasing phytoplankton density during summer as indicated in Edku Lake by **(Ali and Khairy, 2016)**.

Zooplankton community

Zooplankton community was tabulated in **Table, 5** and presented by four main orders (Cladocera, Copepoda, Rotifer and Ostracoda). Where, all orders had a significant difference ($P<0.05$) among basins and seasons except Rotifera species hadn't shown significantly difference ($P>0.05$) in basins and seasons. The interaction between basins and seasons had a significant difference ($P<0.05$) in Ostracoda species only.

Table 5. Seasonal variation of Zooplanktons abundance in Mariout Lake water at different basins from February 2018 to January 2019.

Basins	Seasons	Zooplankton (org. x 10^4 /l)			
		Cladocera	**Copepoda**	**Rotifera**	**Ostracoda**
6000 feddans	**winter**	11.80±0.34 ghi	12.7±0.35 ef	1.80±0.06 ab	0.95±0.15 g
	springe	11.97±0.42 ghi	13.04±0.34 de	1.85±0.14 ab	1.13±0.09 fg
	summer	12.69±0.66 efg	13.65±0.30 de	2.05±0.13 ab	1.32±0.10 fg
	Autumn	12.38±0.54 fgh	13.38±0.34 de	1.93±0.09 ab	1.24±0.08 fg
3000 feddans	**winter**	12.83±0.12 defg	12.86±0.13 ef	2.0±0.10 ab	1.23±0.18 fg
	springe	13.46±0.35 cdefg	13.97±0.09 cde	2.20±0.15 ab	1.37±0.12 fg
	summer	14.58±0.29 abcd	15.06±0.29 bc	2.43±0.07 ab	1.63±0.19 ef
	Autumn	13.99±0.15 cdef	14.31±0.10 cd	2.10±0.12 ab	1.47±0.17 efg
1000 Feddans	**winter**	14.26±0.03 bcde	15.11±0.09 bc	2.10±0.09 ab	2.80±0.07 ab
	springe	15.12±0.04 abc	16.71±0.14 a	2.41±0.03 ab	2.00±0.04 de
	summer	16.06±0.06 a	17.02±0.07 a	2.60±0.02 ab	2.40±0.04 bcd
	Autumn	15.93±0.05 ab	16.08±0.04 ab	2.30±0.03 ab	2.20±0.03 cd
2000 feddans	**winter**	9.95±0.35 j	9.95±0.29 h	0.97±0.01 b	2.35±0.03 bcd
	springe	10.45±0.38 ij	10.77±0.24 gh	1.04±0.01 ab	2.55±0.03 bc
	summer	10.85±0.42 hij	11.63±0.30 fg	1.23±0.01 ab	3.20±0.06 a
	Autumn	10.62±0.35 hij	10.93±0.41 gh	4.09±3.00 a	2.75±±0.03 ab
Two-way ANOVA					
Basin		0.0001	0.0001	0.765	0.0001
Season		0.0001	0.0001	0.418	0.0001
Basin × Season		0.640	0.077	0.458	0.0001

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

Copepoda and Cladocera were the most remarkably abundant zooplankton group than Rotifer and Ostracoda, where, Cladocera species were ranged between 9.95-16.06 (ind.x10^4) and Copepoda species were ranged between 9.95-17.02 (ind.x10^4), while Rotifera species were ranged between 0.97-4.09 (ind.x10^4) and Ostracoda species were ranged between 0.95-3.20 (ind.x10^4).

The dominance of Copepoda and Cladocera over other zooplankton groups may be related to the decrease of water salinity of the lake as a result of the increase in drainage water entering the Lake, where Copepod species are sensitive to water quality oscillations from natural or anthropogenic causes. Cladocerans are regarded among the most ubiquitous freshwater organisms. They are common in all types of fresh water, but they are more abundant in lakes and ponds than in rivers. The presence of Rotifera groups indicated the polluted condition of the Lake, where many rotifer species are considered as indicators of trophic status **(Zakaria *et al*., 2019)**. The highest values of the zooplankton community were at basin 1000 feddans. This may be related to increase discharge water from El-Umoum and El-Qalaa drains and nutrients increasing with limiting its area.

The bacterial community of the Lake (Water, Sediment and *O. niloticus* organs)

The aquatic ecosystem consists of several components that are directly or indirectly affected by pollution **(Kosygin *et al.*, 2007)**. The pollution of a particular water body can always be linked to industry, sewage or agricultural drainage **(Sathware *et al*., 2007)**. Analysis of bacterial population in an aquatic system is of primary importance for evaluating its trophic conditions **(Panagiou *et al*., 1995)**. The bacteriological quality of water has been assessed traditionally by monitoring the levels of total coliforms (TC) and fecal coliforms (FC). *C. perfringens* has been suggested as an alternative bacterial indicator of fecal pollution because it is consistently associated with human wastes **(Bezirtzoglou *et al*., 1997)**. Fecal indicator bacteria such as coliforms, *E. coli* and enterococci have long been used by the water quality monitoring authorities to detect fecal pollution and the presence of potentially pathogenic microorganisms. The bacteriological examination of the water source to the fish is very necessary to detect the bacteria species being transferred into the fish environments. It can serve as a guide to monitor and protect our fish quality as well as our health **(Abdel-Hamid, 2017)**.

The bacterial load annual average of total bacterial count (TBC), coliform (CF), fecal coliform (*E. coli*) and *Vibrio cholera* (*V. cholera*) in the water at different basins of Mariout Lake was showed in **Table 6**.

Table 6. Annual average of total bacterial count (TBC), coliform (CF), fecal coliform (*E. coli*), and *Vibrio cholera* in the water of Mariout Lake water at different basins during February 2018 to January 2019.

Basins / Bact. Sp. (CFU/ml)	6000 feddans	3000 feddans	1000 feddans	2000 feddans
TBC×10^5	31.20±5.42^a	0.53±0.36^c	0.18± 0.01^d	1.46±0.18^b
CF×10^5	12.67±1.20^a	1.33±0.11^b	0.23±0.01^c	0.18±0.01^d
***E. coli*×10^3**	28.30±3.48^a	0.13±0.03^c	0.43±0.08^b	0.04±0.01^d
***V. cholera*×10^2**	18.00±3.51^a	0.10±0.15^c	1.03±0.03^b	1.00±0.11^b

Means with the same litters in the same row are not significantly different at $P<0.05$

The highest value of TBC (31.2×10^5 CFU/ml) was found in the basin of 6000 feddans, while the lowest value (0.18×10^5 CFU/ml) was recorded in the basin of 1000 feddans. Also, the same trend for the highest value was noticed in CF and *E. coli* which were 12.67×10^5 and 28.30×10^5 CFU/ml, respectively in basin of 6000 feddans. The lowest values were 0.18×10^5 and 0.04×10^3 CFU/ml, respectively in basin of 2000 feddans. *Vibrio cholera* recorded the highest numbers (18.00×10^2 CFU/ml) in the basin of 6000 feddans, while the lowest values were (0.10×10^2 CFU/ml) in the basin of 3000 feddans.

Main Basin (6000 feddans) showed the highest significant values of bacterial load (TBC, CF, *E. coli* & *Vibrio cholera*) than other Lake basins. These results due to intensive pollutants entering this basin through discharge the industrial untreated wastewater, domestic primary treated wastewater, and agriculture wastewater which increase organic matter with increasing its nutrients of nitrogen and phosphorus. These results are in agreement with those of **El-Rayis *et al*. (2019)** who indicated that Mariout Lake's main basin is still suffering from the current discharge from the polluted Qalaa Drain (anoxic and with high loaded of nutrients and organic matter). **Hamed *et al.* (2013); Sugumar and Anandharaj (2016); Abdel-Hamid (2017)** recorded that the bacterial load in water increased by increasing organic matter and revealed a positive correlation between TBC and nutrients like phosphates. The main basin (6000 feddans) is considered as highly polluted sites in Mariout Lake followed by basins of (3000 > 2000 > 1000 feddans). It seems that these groups of bacteria are still a powerful tool and the most trusted indicators of water pollution as they are routinely used by **Simpson *et al*. (2002)**. Also, this area comes first being greatly polluted with numerous health-hazardous bacterial counts, such as *E. coli* and *Vibrio spp.* according to the World Health Organization, **WHO (1989)**.

Bacterial indicators detected in the Lake water have been interpreted following the European Commission Manual **(EC, 1997)**, which corresponds to the Egyptian Standard **(Ministry of Health, Egypt, 1996)**. They accept the values of the bacterial test guide up to 50 CFU/ml of sea water for coliform bacteria and 1 CFU/ml for coliform bacteria (*E. coli*). So, the current results revealed that the values exceed the permissible values mentioned by them.

Water and soil pollution are considered to be one of the most dangerous hazards affecting not only in Egypt but also in the majority of world countries. The spoilage of water quality and water's natural balance in its environment is known as water pollution **(Akman *et al*., 2000)**. Sediment is important reservoirs of microorganisms like pathogenic bacteria and exhibits a potential health hazards from possible re-suspension and subsequent ingestion during recreational activities **(Chandran *et al.*, 2011; Staley *et al*., 2012)**.

Bacterial investigation of sediment showed in **Table, 7** for the same Lake basins. The obtained data revealed that the mean numbers of TBC were ranged between (0.37 - 151.30) $\times10^4$ and (0.30-82) $\times10^4$ CFU/g for CF. while *E. coli* and *V. cholera* were ranged between (0.16-85.00) $\times10^3$ and (0.80-95.00) $\times10^2$ CFU/g, respectively.

The results of bacterial levels in sediment showed the same direction as they were in the water where the main basin (6000 feddans) recorded the highest significant difference of bacterial load than other Lake basins. Also, the results of *E. coli* and *V. cholera* in sediment showed an increase than in water, which agrees with those of **Abdel-**

Hamid (2017). Sediments also can impact the quality of water and can contain 100 to 1,000 times as many fecal indicator bacteria than the overlying water **(Van Donsel and Geldreich, 1971)**. Sediments can serve as reservoirs for fecal pollution **(Crabill *et al*., 1999)**. The majority of *E. coli* and enterococci bacteria in aquatic systems are associated with sediments and these associations influence their survival and transport characteristics **(Jamieson *et al*., 2005)**.

Table 7. Annual average of total bacterial count (TBC), coliform (CF), fecal coliform (*E. coli*) and *Vibrio cholera* in the sediment of Mariout Lake at different basins during February 2018 to January 2019.

Basins / Bact. Sp. (CFU/g)	6000 feddans	3000 feddans	1000 feddans	2000 feddans
TBC×10^4	151.30±5.93^a	3.33±0.88^c	0.37±0.03^d	115.30±1.01^b
CF×10^4	82.00±1.73^a	0.30±0.01^b	0.43±0.02^c	1.43±0.21^b
***E. coli*×10^3**	85.00±1.76^a	0.20±0.06^b	0.16±0.33^b	0.20±0.00^b
***V. cholera*×10^2**	95.00±12.58^a	0.80±0.00^c	1.33±0.33^b	1.33±0.33^b

Means with the same litters in the same row are not significantly different at P<0.05

The microbial biota of fresh fish is usually a reflection of the environment in which it was harvested **(Cabral, 2010)**. Bacterial contamination of fish is considered the main cause of signs of spoilage as off-flavor and unpalatable taste and it may constitute a public health hazard as well as many of economic losses **(Hassan *et al*., 2012; Zaky and Salem, 2015)**. The bacteriological examination of the fish environment is important to detect the presence of microorganisms that might constitute health hazards and the death of fish **(Abdel-Hamid, 2017)**.

The variations of bacterial load in skin, muscle and gills of *Oreochromis niloticus* from the different basins of Mariout Lake are shown in **Table, 8**. Where, total bacterial count, coliform group, fecal coliform (*E. coli*) and *Vibrio cholera* in the skin were ranged between 20.10-36.67×10^3, 9.99-12.50×10^2, 0.18-19.90×10 and 0.52-1.47×10 CFU/g, respectively. In muscle, they ranged between 0.41-15.37×10^3, 8.33-11.25×10^3, 0.08-4.40×10 and 0.27-0.38×10 CFU/g, respectively. On the other hand, in gills it ranged between 23.28-46.67×10^3, 21.00-28.33×10^{2,} 0.23-16.90×10 and 0.30-0.77×10 CFU/g, respectively. The total bacterial count showed a significant difference among basins and interaction of basins with organs.

The results showed an increase in the bacterial load in *Oreochromis niloticus* organs of the main basin (6000 feddans) and a basin of 3000 feddans than other basins. This agrees with those of **Al-Harbi (2003)** who observed that the bacterial load in fish was correlated with the bacterial levels in the aquatic environment.

In the present study, the high bacterial load was observed more dominant generally, in gills and skin than muscle. Where, at the time of harvest fish carries a high microbial load on the surface of their skins, in their intestinal tracts and their gills. The type and number of microorganisms that live in fish vary according to the season, the species and the natural habitat. Additional contamination may occur during the harvesting, handling, or processing of the fish, also during the storage and transportation **(FDA, 2019)**. Microorganisms in fish tissue are thought to result from surface, gills, or intestinal contamination, where microorganisms are adsorbed on the surfaces of the fish and found in their intestinal contents, **Austin (1982)**. **FAO (1979)** stated that total bacteria count should less than 10^5 /g and total coliforms should not exceed 10^2/g respectively. While, according to the International Commission on the Microbiological Specification of Foods **(ICMSF, 1982)** the acceptable limit of total bacterial counts and total coliform for white fish is 5×10^5 and 10 CFU/g, respectively and *E. coli* shouldn't be present.

Table 8. Annual average of total bacterial count (TBC), coliform (CF), fecal coliform (*E. coli*), and *Vibrio cholera* in *Oreochromis niloticus* organs (skin, muscle and gills) from Mariout Lake at different Basins during February 2018 to January 2019.

Bact. sp. (CFU/g)	Organs	Basins			
		6000 feddan	3000 feddan	1000 feddan	2000 feddan
TBC×10^3	Skin	36.67±3.26[a]	33.33± 3.81[b]	22.66±0.73[c]	20.10±0.26[d]
	Gills	46.67±4.67[a]	29.67± 2.06[b]	26.21±0.90[c]	23.28±0.88[d]
	Muscle	15.37±0.09[a]	15.00± 2.87[a]	5.20 ±0.31[b]	0.41±0.01[c]
CF×10^3	Skin	10.44±1.20 [b]	12.00±0.58[a]	12.50±0.08[a]	9.99±1.15[b]
	Gills	28.33±1.09[a]	26.70± 1.67[a]	26.10± 2.01[a]	21.0 ± 0.86[b]
	Muscle	10.00±3.51[a]	8.33±1.67[b]	10.31±0.783[a]	11. 25±0.22[a]
E. coli ×10	Skin	19.9 ±1.05[a]	9.2±0.21[c]	11.45±8.53[b]	0.18±0.02[d]
	Gills	16.9±0.40[a]	11.70±0.61[b]	3.80±0.33[c]	0.23±0.03[d]
	Muscle	4.40±0.47[a]	3.70±0.21[b]	1.23±0.12[c]	0.08±0.01[d]
V. cholera ×10	Skin	1.90±0.03[b]	5.47±0.83[a]	0.92±0.10[c]	0.69±0.02[d]
	Gills	0.77±0.01[a]	0.60±0.01[b]	0.30±0.03[d]	0.49±0.01[c]
	Muscle	0.38±0.01[a]	0.30±0.20[b]	0.27±0.01[b]	0.28±0.01[b]

Means with the same litters in the same row are not significantly different at $P<0.05$

This study indicated that, the bacterial loads of *O. niloticus* organs (skin, gills, and muscles) exceeded the standard values, which indicated their inadmissibility as food from a public health point of view which might cause risks to human health due to the consumption of the collected *O. niloticus*.

CONCLUSION

The current study recommends that the necessity of treating the various types of wastewater displaced to Mariout Lake directly through ways of activating the role of treatment stations or establishing sedimentation basins for them in order to improve the quality of the lake water and of the fish product quality.

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