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Water Quality Index and Microbial Assessment of Lake Qarun, El-Batts and El-Wadi Drains, Fayoum Province, Egypt

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ABSTRACT

This study was carried out on Lake Qarun and 2 drains (El-Batts and El-Wadi) that discharging wastewater into it, at Fayoum Province, Egypt, to assess the Water Quality Index (WQI) and miicrobial load of their waters. This investigation was conducted during the period from autumn 2017 to summer 2018. The general annual averages of WQI values of Lake Water were poor for irrigation (69.61) and very poor for aquatic life (78.53). El-Batts and El-Wadi Drains were poor both for irrigation (55.45) and for aquatic life (54.45). Moreover, total viable bacteria count (TVBC) at 22°C ranged between 3 $\times 10^3$ CFU/ml and 450 $\times 10^3$ CFU/ml, and the TVBC at 37°C varied from 0.4 $\times 10^3$ CFU/ml to 330 $\times 10^3$ CFU/ml . Total coliform (TC) in the range of 0.3 $\times 10^3$ - 46 $\times 10^3$ MPN /100ml water , Fecal coliform (FC) in the range of 3×10^2 - 460$\times 10^2$ MPN /100ml water . Fecal streptococci (FS) in the range of 3 $\times 10^2$ - 1100 $\times 10^2$ MPN/ 100ml water and the numbers of *E.coli* fluctuated between 0.1×10^2 and 60 $\times 10^2$ CFU /100ml water. The obtained values of physical, chemical and microbial parameters of Lake and drains water were compared with the standard values set by FAO (1994) for irrigation and CCME (2007) for aquatic life. It was found that the values of tested parameters were higher than the recommended standards and this affects the biota in the studied area and is expected to cause healthy problems.

INTRODUCTION

Lakes and reservoirs are major resources as these hold about 90% of the world's surface freshwater and are the key freshwater resources for agriculture, fisheries, domestic, industrial, recreational, landscape entertainment, and energy production. However, these utilizations depend on the desirable water quality that should be based on a well-balanced environment in terms of its physical, chemical, and biological characteristics. The lentic surface water quality in reservoirs, lakes, or ponds is severely affected by anthropogenic pollution, and many efforts have already been made to assess and manage their water quality.

Information and case studies reviewed in this entry indicate that the lakes and reservoirs are at risk from overexploitation, over enrichment, toxic contamination, and sedimentation.

The entry may inspire future environmental and water resource professionals to take necessary actions to mitigate lake and reservoir pollution (Karmakar and Musthafa, 2013).

Lake Qarun has many drastic changes that affect the potential economic role as a site for living natural resources. The main reason came from gradually increasing salinity over the last century. The increase in salinity depends on the input of drainage water (controlled by irrigation practices) and the subtropical climate of the lake leading to high temperature and seasonal fluctuations in water evaporation rate (Anwar *et al.,* 2001). The quality and quantity of surface water bodies such as lakes depend upon the climate, catchments, geography of the area and the inputs and outputs both natural and manmade (Gray, 1994). The water quality of lakes can be degraded due to microbiological and chemicals contaminants. The monitoring and assessment of water quality of freshwater lakes such as Lake Qarun in Egypt is therefore imperative because humans, wildlife and aquatic life consume their water (Bronmark and Hansson, 2002). The aquatic environment is subjected to different types of pollutants via intrusion of industrial, agricultural and domestic waste water.

Many factors affecting Lake Qarun ecosystem include the climatic conditions, amount of discharged wastewater, seepage from the surrounding cultivated land and geological aspects (Abdel-Satar *et al*., 2003). The most of agricultural drainage water reaches the lake by two main drains, El-Batts and El-Wadi, whereas there are minor drains poured its drainage water into the lake by means of hydraulic pumps but in small amounts (Authman and Abbas, 2007).

Coliforms group and *Escherichia coli* are great importance among bacterial indicators used in water quality definition and health risk (Giannoulis *et al*., 2005). Presence of pathogens is usually accompanied by the presence of the classic indicators of contamination such as *Escherichia coli*, Enterococci and other aerobic bacteria. Coliform bacteria have long been used to indicate fecal contamination of water and thus a health hazard.

The fecal streptococci are considered to be alternative indicators of fecal health hazards. Furthermore, classic indicators can be considered as efficient detectors of pathogens in most cases (Schaffter and Parriaux, 2002). The indicator bacteria such as fecal coliforms (FC) and fecal streptococci (FS) are used for assessment of fecal pollution and possible water quality deterioration in fresh water sources is widely used (APHA, 2005). Presence of any strain of *E. coli* is likely indicative of fecal contamination of water source (Mugnai *et al.,* 2015).

Lake Qarun was previously studied regarding to water quality (Gupta and Abd El-Hamid, 2003; Mansour and Sidky, 2003; Ali and Fishar, 2005; Fathi and Flower, 2005; Mageed, 2005; Authman and Abbas, 2007; Hussein *et al.,* 2008; Dardir and Wali, 2009; Abdel-Satar *et al.,* 2010; Ahdy *et al.,* 2011; Abou El-Gheit and Abdo, 2012; Abdel Wahed *et al.,* 2015; El-Sayed and Mosad, 2017; Soliman *et al.,* 2018).

The increasing pollution of water resources in Lake Qarun and the consequent effects on aquatic environment and human health is an issue of great concern.

Also, the lake is under severe environmental stress. So, this study focuses on the studying of the evaluation of physical and chemical characteristics of Lake Qarun water. Also, calculate the Water Quality Index (WQI) and microbial assessment of Lake Water.

MATERIALS AND METHODS

Area under investigation

Lake Qarun is situated between longitudes of 30° 24' and 30° 49' E and latitudes 29° 24' and 29° 33' N. It is an inland isolated saline water basin of about 40 km length and 5.7 km width and its water depth ranges from 1 to 8 m meters. Its surface area is about 215 km^2 and has a water volume about 1,100,000000 m^3 (Dardir and Wali, 2009; Ahdy *et al*., 2011). Also, the lake is the third largest lake in Egypt and its water surface elevation is about (43.7 m). The length of the lake is 42 km, and the width varies between 5 km - 9.54 km. The water depth varies between 5 m in the east to 12 m in the west.

Sampling

Water samples were collected seasonally and taken from the subsurface (about 30 cm) at ten stations to cover the whole lake area, in addition to, two samples from El-Batts and El-Wadi Drains. A Ruttner Water Sampler bottle with capacity of 2 L was used to collect the samples that were kept in well cleaned plastic bottles for chemical analysis, and microbial samples were collected using sterilized glass bottles then, brought to laboratory in an iced insulated container during transport. The locations and names of collection water samples are represented in (Table 1, Fig. 1).

Table 1: Long. and Lat. and names of collection samples in Lake Qarun.

Stations	Features of stations	Average of Depth (m)	Longitude	Latitude
1	Opposite to El-Bats Drain	2.00	30° 48′ 47.2″	29°31′ 04..1″
2	Opposite to El-Oprerg	3.00	30° 47′ 23.1″	29° 28′ 58.1″
3	Far North-East of Lake	4.00	30° 44′ 58.1″	29° 30′ 56.5″
4	Opposite to Abou Nema lasn	5.00	30° 42′ 53.9″	29° 29′ 11.4″
5	Hkor Maeiouf (Middle lake)	5.00	30° 40′ 57.4″	29° 29′ 37.4″
6	North of El-Karn Island (Middle lake)	7.50	30° 37′ 10.9″	29° 29′ 36.8″
7	Opposite to El-Wadi Drain	2.50	30° 37′ 43.4″	29° 26′ 49.4″
8	Opposite to Maser for reconstruction	5.50	30° 34′ 51.3″	29° 27′ 41.0″
9	West Lake	4.00	30° 31′ 09.6″	29° 25′ 42.4″
10	Malahet Mizar (Far West of Lake)	4.00	30° 26′ 08.4″	29° 26′ 37.1″
11	El-Batts Drain	1.50	30° 49′ 20.8″	29°32′ 52..4″
12	El-Wadi Drain	1.50	30° 38′ 08.4″	29° 30′ 23.5″

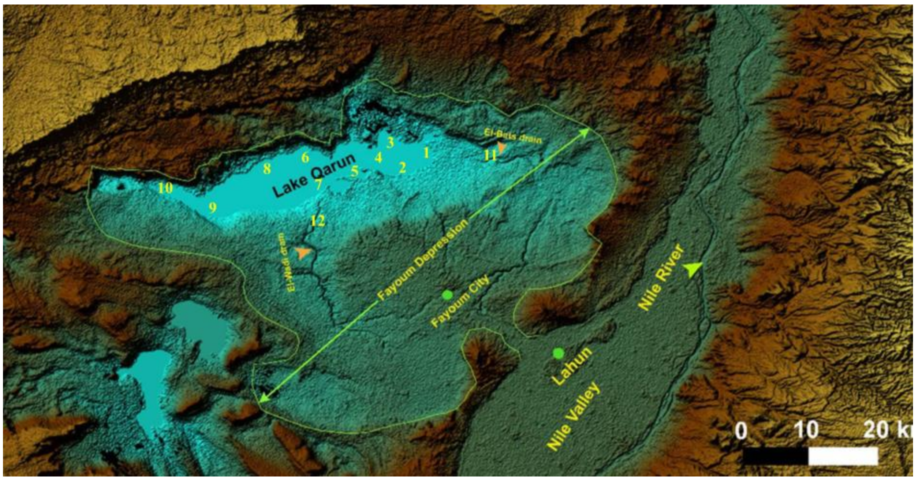

Fig. 1: Map of collection water samples locations in Lake Qarun.

Physical and chemical analyses

Physical, chemical and microbial analyses of water samples were done according to the methods described in American Public Health Association (APHA, 2005). Water temperature (°C), pH and electrical conductivity (EC, mS/cm) were in-situ measured using Hydrolab model Multi Set 430i WTW. Transparency and depth were measured using a white/black Secchi Disk (20 cm in diameter). Total solids

(TS) were measured by evaporating a known volume of well mixed sample. A total dissolved solid (TDS) was determined by filtering a volume of sample through a glass fiber filter (GF/C), and a known volume of filtrate was evaporated at 105°C. Total suspended solids (TSS) equal the difference between TS and TDS. Dissolved oxygen (DO, mg/L) was assayed using a modified Winkler method. Biological oxygen demand (BOD) was determined by using the 5 days incubation method. Chemical oxygen demand (COD) was carried out using the potassium permanganate method. Water alkalinity was determined immediately after sampling collection using phenolphthalein and methyl orange indicators. Chlorisity was measured using Mohr's method and Sulfate by turbidimetric methods. Calcium and magnesium were detected by using a complexemetry method by direct titration using EDTA solution. Sodium (Na) and potassium (K) were measured using Flame Atomic Absorption Spectrophotometer (FAAS) Model JENWAY PFP.7 U.K. Ammonia was determined by the phenate method. Nitrite was determined using a colorimetric method with formation of a reddish purple azo-dye. Nitrate was measured as nitrite after cadmium reduction. Orthophosphate and total phosphorus (TP) were estimated by using the ascorbic acid-molybdate method. Reactive silicate was determined using the molybdate method.

Microbial analysis

Total Viable Bacterial Count (TVBC)

Pour plate method was used for enumeration of total bacterial counts at 22°C and 37°C using plate count agar media containing (g/1): tryptone, 5.0; glucose, 1.0; yeast extract, 2.5; agar, 15; and pH adjusted at 6.8± 0.2.

Estimation of Total Coliforms (TC) and Fecal Coliforms (FC)

Numbers of total coliforms and fecal coliforms were determined using most probable number (MPN) technique; three dilutions of each sample were used, three replicates tubes containing MacConkey broth media are containing (g/l): peptone, 20.0; NaCl, 5.0; lactose, 5.0; sodium taurocholate, 5.0; bromocresole purple, 0.01 and pH adjusted at 6.8± 0.2 . Double and single strengths were used for 10, 1.0 and 0.1 mL, respectively. All tubes were provided with Durham fermentation tubes. The inoculated tubes were incubated at 35 ± 0.5 ^{0}C for 48hr. and at 44.5 ^{0}C (in water bath) for 24 hr. for fecal coliforms. Acid and gas formation refer to positive result. The positive tubes were streaked on the Eosin Methylene Blue (EMB) agar plates using sterile loop and incubated at 37 ^{0}C for 24 hr. and microscopic examination was take place as confirmatory test.

Estimation of Fecal streptococci (FS)

Azide dextrose broth media are containing (g/l): peptone, 15.0; beef extract, 4.5; NaCl, 7.5; sodium azide, 0.25 and pH adjusted at 6.8± 0.2, double and single strengths were used, all tubes were inoculated and incubated at 35±0.5 ^{0}C for 48 h. Positive results scored as turbidity due to the growth of Streptococci group.

Estimation of *Escherichia coli*

By membrane filtration method, water samples were filtrate using filter paper (0.45 µm pore size) to trapping bacterial cell and the filter carefully transferred into Eosin Methylene Blue agar media are containing (g/l): peptone, 10.0; lactose, 10.0; K_2HPO_4, 2.0; eosin Y, 0.4; methylene blue, 0.065; agar, 15; finally pH adjusted at 6.8± 0.2. The plates were incubated at 44.5 ^{0}C for 24 h. After incubation the membrane filters were examined for typical colonies; 2-3 mm in diameter, smooth with entire edge and green metallic sheen. Colonies were counted.

Water quality index

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water (Al-Mohammed and Mutasher, 2013). The calculation method of WQI was developed by Brown *et al.*, (1972), which has been widely used by many scientists (Balan *et al.*, 2012; Chowdhury *et al.*, 2012 and Tyagi *et al.*, 2013). The mathematical formula of this WQI method is given by:

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} QiWi}{\sum_{i=1}^{n} Wi}$$

Where Qi is the sub quality index of i^{th} parameter (or Qi is the quality rating scale of each parameter). W = weight unit of each parameter, n = number of parameters.

Calculation of Qi value

$$\mathrm{Qi} = \frac{(Vi - Vo)}{(Si - Vo)}$$

Vi = measured value of i^{th} parameter, Si =standard permissible value of i^{th} parameter, Vo =ideal value of i^{th} parameter in pure water, Vo = zero for all parameters except for pH =7.0 and DO = 14.6 mg/l (Tripaty and Sahu, 2005).

Calculation of Wi value

Calculation of unit weight (Wi) for various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$\mathrm{Wi}\ \alpha \frac{1}{\mathrm{Si}} \quad \text{Or} \quad \mathrm{Wi} = \frac{\mathrm{K}}{\mathrm{Si}}$$

Where K is the proportionality constant of the ‘‘Weights’’ for various water quality characteristics:

$$\mathrm{K} = \frac{1}{\sum_{i=1}^{n} \frac{1}{\mathrm{Si}}}$$

WQI has been classified into 5 classes, the water quality is rated excellent, good, poor, very poor and unfit when the value of the index lies between 0.00-25, 26-50, 51-75, 76-100 and >100, respectively, according to the values shown on (Table 2).

Table 2: Water Quality Rating (WQR) as weight arithmetic WQI method

WQI value	Water Quality Rating (WQR)	Grading
0-25	Excellent	A
26-50	Good	B
51-75	Poor	C
76-100	Very Poor	D
Above 100	Unsuitable for drinking purpose	E

RESULTS AND DISCUSSION

Water Quality Monitoring

Water quality monitoring refers to the acquisition of quantitative and representative information on the physical, chemical, and biological characteristics of a water body over time and space (Sanders *et al.*, 1983). The impact and behavior of contaminants in an aquatic ecosystem is complex and may involve adsorption–desorption, precipitation–solubilization, filtration, biological uptake, excretion, and sedimentation–suspension. Besides natural processes affecting water quality, there are also anthropogenic impacts, such as man-induced point and non-point sources, xenobiotic, and alteration of water quality due to unwise water use and river engineering projects (e.g., irrigation, damming, etc.).

Temperatre

The water temperature of Lake Qarun water incresed during summer season and was found to be 27.40 °C and the lowest temperature recorded was 14.30 °C during winter season and the general average was 20.66 ^{0}C. The drains water temperature ranged between 15.10 - 27.40 °C. There is no clear thermal stratified recorded in the lake due to shallowness of the lake (~ 4 m depth in average) and it is considered being homoeothermic in nature. This result agree with that reported by Mageed, (2005) and Authman and Abbas, (2007). The water temperature values showed the expected seasonal pattern with no differences between the sampling stations, coincident with that reported by Kagalou *et al.,* (2001) and Sivri *et al.,* (2007).

Transparency and Depthes

The changes in water transparency values ranged from 20 to 150 cm with a general average of 55.20 cm in the lake water. The maximum value was found at site 10 during spring season and the lowest was found at site 1 during winter season. This may be due to; the discharging drainage water from the drains in the eastern and middle sections is loaded with suspended particles led to decreasing transparency compared with the western part. For drains water was ranged between 10.00 – 100.00 cm. The low observed transparency could be attributed to the effect of fertilizers and feed used in fish farming, the disposal of untreated sewage and agricultural effluents into the two drains. These results are agreed with that reported by Abdel-Satar *et al.,* (2010). The changes in depth values of Lake ranged from 2.0 to 7.50 m, with a general average of 4.25 m. The maximum value of depth was found at site 6 and lower was at site 1. For drains was found to be in the ranges of 150 – 160 cm.

Electrical conductivity (EC)

EC at drains were fluctuated between 1.97-2.48 and 2.45-3.20 mS/cm, with overall mean value 2.56 mS/cm, but EC at Lake Qarun water were fluctuated between 11.20-53.60 mS/cm, with overall mean value 43.60 mS/cm. The lowest value of EC was recorded at site 1 opposite to El-Batts drain. While the maximum values were found at site 10 in summer. The increasing in EC values of lake Qarun during summer may be attributed to the decreasing in the water level as a result of high evaporation rate and lowering the amount of drainage water pour into the Lake. On the other side the lower values were recorded durin winter may be due to the direct effect of dilution by drainage water especially areas facing the drians. This is in agreement with that reported by Authman and Abbas, (2007).

Solids (TS, TDS and TSS):

TS, TDS and TSS values found in the ranges of 23.05-48.41, 18.79-36.68 and 1.14-15.51 g/l, and the mean values were 39.27, 32.44 and 6.94 g/l, respectively. For El-Batts and El-Wadi drains they ranged between 2.13-4.32, 1.01-2.93 and 0.22-2.18 g/l, respectively. The increasing in (TS, TDS and TSS) values during summer season, may be attributed to the high evaporation rate while their decrease during cold seasons may be attributed to the dilution effect and raising of the water level in the lake through the drainage water discharging by the two drains during these seasons. These results are agree with that reported by Authman and Abbas, (2007).

The pH Values

The favorable range of pH is 6.5 - 9.0 are most suitable for fish production (Lloyd, 1992). pH values of Lake water are quite variable throughout the seasons and pH >7 indicates that alkaline water conditions are dominant in the Lake. pH values were found in the permissible limits and ranged between 7.29 - 8.84. The high value in autumn season at site 4, while lowest value in winter season at site 1, with an overall average value of 8.29. For drains were ranged between 7.47 - 8.84, Table (3 and 4). The pH values of two drains water were found in the same ranges of lake water.

Oxygen (DO, COD and BOD)

The concentration values of DO and COD were found in the ranges of 3.84 - 12.80 and 7.04 - 17.52 mg/l and the general annual average concentrations were 7.57 and 12.85 mg/l, respectively; while drains were recorded 4.13-10.96 and 2.28 - 9.77 mg/l, respectively. The highest value of BOD in Lake Qarun was 11.80 mg/l at site 4 in autumn season which points out significant entry of organic pollution load to the lake, while drainage water was 10.84 mg/l at El-Wadi drain in spring.

Table 3: Analytical results of Lake Qarun water

Parameters	Mean	SD	Min	Max	Guideline Irrigation (FAO, 1994)	Guideline Aquatic life (CCME, 2007)
Water temp. ^{0}C	20.66	4.66	14.30	27.40		8 - 28
TS (g/l)	39.27	4.93	23.05	48.41		
TDS (g/l)	32.44	3.56	18.79	36.68	2	0.5
TSS (g/l)	6.94	3.01	1.14	15.51		+ 0.025
Trans. (cm)	55.20	27.19	20.0	150.0		
Depth (m)	4.25	1.60	2	7.50		
EC (mS/cm)	43.60	10.13	11.20	53.80	3	
pH	8.29	0.29	7.29	8.84	8.5	6.5 – 9.0
DO (mg/l)	7.57	1.76	3.84	12.80		5.5
BOD (mg/l)	5.93	1.95	2.33	11.8		5
COD (mg/l)	12.85	2.88	7.04	17.52		7
CO_3^{--} (mg/l)	27.28	17.45	0	91.5	3	
HCO_3^- (mg/l)	202.95	53.80	135.0	343.0	610	
T-Alkalinity	230.23	53.87	165.0	343.0		
NO_2^--N (µg/l)	33.62	66.52	4.64	416.14		0.06
NO_3^--N (µg/l)	86.86	113.69	4.56	635.99	10	2.93
NH_3-N (µg/l)	281.96	166.30	53.06	766.52	5	1.37
SO_4^{2-} (g/l)	7.15	3.33	2.37	13.05	0.96	
SiO_2^- (mg/l)	11.05	3.62	5.17	20.61		
PO_4^{3-} (µg/l)	169.29	128.75	6.02	454.69	2	
TP (µg/l)	308.67	198.07	50.30	968.44		
Cl^- (g/l)	14.76	2.62	6.38	20.28	1.063	0.12
Ca^{2+} (mg/l)	597.22	284.42	184.37	1458.91	400	
Mg^{2+} (mg/l)	1537.95	623.06	678.53	3477.76	60	
T- Hardness (g/l)	7.82	3.07	3.25	17.47		
Na^+ (g/l)	9.65	2.44	3.08	15.66	0.919	
K^+ (g/l)	0.53	0.31	0.10	2.04	0.002	
TVBC at 22 °C(CFU ml^{-1})	67.8×10^5	91.7×10^5	3×10^5	450×10^5		
TVBC at 37 °C(CFU ml^{-1})	68.9×10^5	85.7×10^5	0.4×10^5	330×10^5		
TC (MPN/ 100ml)	11×10^4	13.9×10^4	0.3×10^4	46×10^4	Unrestricted irrigation $\leq 10^3$ (WHO, 2006)	
FC (MPN/ 100ml)	53.8×10^3	100.6×10^3	3×10^3	460×10^3	100	
FS (MPN/ 100ml)	128.8×10^3	243.9×10^3	3×10^3	1100×10^3		
E.coli (CFU/100ml)	15.5×10^2	18.9×10^2	0.1×10^2	69×10^2		

Table 4: Analytical results of El-Batts and El-Wadi drainage water drains

Parameters	Mean	SD	Min	Max	Guideline: Irrigation (FAO, 1994)	Guideline: Aquatic life (CCME, 2007)
Water temp. ^{0}C	22.29	4.95	15.10	27.40		8 - 28
TS (g/l)	2.84	0.91	2.13	4.32		
TDS (g/l)	1.97	0.63	1.01	2.93	2	0.5
TSS (g/l)	0.87	0.73	0.22	2.18		+ 0.025
Trans. (cm)	25.63	30.41	10.0	100.0		
Depth (m)	1.55	0.07	150	160.0		
EC (mS/cm)	2.56	0.48	1.97	3.20	3	
pH	7.89	0.42	7.47	8.84	8.5	6.5 – 9.0
DO (mg/l)	6.44	2.33	4.13	10.96		5.5
BOD (mg/l)	3.13	3.48	0.53	10.84		5
COD (mg/l)	5.20	2.37	2.28	9.77		7
CO_3^{--} (mg/l)	11.56	15.72	0.0	42.0	3	
HCO_3^- (mg/l)	238.75	51.03	161.50	325.0	610	
T-Alkalinity	250.31	50.09	163.50	325.0		
NO_2^{-}-N (µg/l)	327.52	263.94	9.90	723.09		0.06
NO_3^--N (µg/l)	186.35	152.54	47.44	441.75	10	2.93
NH_3-N (µg/l)	2410.74	1470.69	179.84	4579.96	5	1.37
SO_4^{2-} (g/l)	3.17	3.00	0.58	8.70	0.96	
SiO_2^- (mg/l)	10.0	4.43	4.22	16.76		
PO_4^{3-} (µg/l)	390.98	140.55	262.35	627.74	2000	
TP (µg/l)	698.18	249.62	302.18	1097.42		
Cl^- (g/l)	1.23	0.29	0.71	1.72	1.063	0.12
Ca^{2+} (mg/l)	361.22	258.78	116.23	745.49	400	
Mg^{2+} (mg/l)	907.74	657.98	167.81	2130.43	60	
T- Hardness (g/l)	4.64	3.31	1.07	10.63		
Na^+ (g/l)	2.30	2.75	0.70	8.91	0.919	
K^+ (g/l)	0.52	0.77	0.02	1.78	0.002	
TVBC at 22 °C(CFU ml^{-1})	39.3×10^5	22.7×10^5	15×10^5	90×10^5		
TVBC at 37 °C(CFU ml^{-1})	236×10^5	105.02×10^5	145×10^5	460×10^5		
TC (MPN/ 100ml)	46×10^4	31.56×10^4	11×10^4	93×10^4	Unrestricted irrigation $\leq 10^3$ (WHO, 2006)	
FC (MPN/ 100ml)	40×10^3	27.34×10^3	11×10^3	93×10^3	100	
FS (MPN/ 100ml)	201.6×10^3	169.9×10^3	53×10^3	460×10^3		
E.coli (CFU/100ml)	74.5×10^2	19.20×10^2	48×10^2	98×10^2		

The highest value of DO 12.80 mg/l was recorded during winter, which could be mainly attributed to the decrease in temperature, prevailing winds action which permits the increase in solubility of atmospheric oxygen gas. The DO values showed relative decrease during summer was reached 3.84 mg/l which is mainly attributed to elevation of water temperature which lead to decrease in solubility of oxygen gas. In addition to, the oxidation of organic matter by the microorganisms consuming part of dissolved oxygen. These results agreed with that reported by Sabae and Mohamed, (2015); Al-Afify *et al.,* (2018). Generally, the higher values of DO, BOD and COD are indications on higher microbial activities. This was reflected on somewhat elevated values of NH_4^+, NO_2^- and NO_3^-.

COD/BOD ratio

Concerning the biodegradability condition of the aquatic body of the area under investigation the ratio BOD/COD were taken into consideration. This ratio in the order 1:1 is characteristic of the purified water according to the national standard and the ratio 2:1 to 4:1 is specific crude domestic sewage (Anon, 1997). Also, the high ratio of COD/BOD points out excessive quantity of organic matter which is not decomposed by microorganisms. COD/BOD ratios of lake water ranged between 1.07 – 5.32 and its annual average 2.40, while drainage water was 0.59 - 13.51, and its annual average was 4.21. These closer values also show that the structures of organic matter entering to Lake Qarun were similar approximately in all station except the locations 1 and 7 (in front of El-Wadi and El-Batts drains).

Major Anions (CO_3^{-2} , HCO_3^- ,Cl^- and SO_4^{-2})

The carbonate and bicarbonate are the major components of alkalinity of surface water. CO_3^{-2} and HCO_3^- concentrations were found in the ranges of 0.00 - 91.50 and 135.00 - 343.00 mg/l. While drainage water were 0.00-42.00 and 161.50-325.00 mg/l, respectively. The increase in bicarbonate during autumn may be attributed to the decrease in water and air temperatures led to the precipitation of calcium bicarbonate. On the other side, the high concentration values during summer with maximum annual average of 267.08 mg/l may be related to the decomposition of organic matter and/or enhancing the anaerobic processes which increases carbon dioxide in the water column (Elewa, 1993).

The highest value of Cl^- 20.28 g/l was recorded during spring season while the lowest value of 6.38 g/l was recorded during autumn season. This may be attributed to the impacts of salt marches adjacent to the Lake, the seepage of salts from the adjacent cultivated lands and underground water. Furthermore, the high rate of evaporation during hot season (spring and summer) and low water level of the lake; as well as, the decrease in the discharged runoff; regard the main reason for increase in the Cl^- content. These results agree with that reported by Ali and Fishar, (2005); Authman and Abbas, (2007). For drainage water were 0.71 – 1.72 g/l. The SO_4^{2-} values were fluctuated in the ranges of 5.17 – 20.61 g/l for Lake Qarun water, while drainage water (El-Batts and El-Wadi) were 0.58 – 8.70 g/l. As whole, the distribution of major anions (Cl^- and SO_4^{2-}) in lake water may be governed mainly by the evaporation rate, the intrusion of drainage water and consumption of lake salts by the Egyptian company of salt and minerals (EMISAL) (Abdel-Satar *et al.,* 2010).

Major Cations (Na^+, K^+, Ca^{2+} and Mg^{2+})

Na^+, K^+, Ca^{2+} and Mg^{2+} concentrations of Lake water were found in the ranges of 3.08-15.66, 0.10 - 2.04, 0.18 - 1.46 and 0.69 - 3.48 g/l respectively, and drainage water were 0.70 - 8.91, 0.02 - 1.78, 0.12 - 0.75 and 0.17 - 2.13 g/l respectively. In Lake Qarun water, the predominant cation trend was in the order of $Na^+ > K^+ > Mg^{2+} > Ca^{2+}$ with sodium being dominant cation and the predominant anion trend was in the order of $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{-2}$, with chloride being the dominant anion. These results are in agreement with that reported by (Abdel-Satar *et al*., 2010; Abou El-Gheit and Abdo, 2012).

Nutrient salts

Nutrient salts (NO_2^-, NO_3^-, NH_3, PO_4^{-3}, T.P and SiO_2^-) are plays an important roles in the productivity of the aquatic ecosystems supporting the food chain for phyto and zooplanktons as well as fish (Abdo, 2004). Nitrite is an intermediate product of the aerobic nitrification bacterial process, produced by the autotrophic Nitrosomonas bacteria combining oxygen and ammonia (Bhatnagar and Devi, 2013). Nitrate (NO_3^--N) can get into water directly as the result of runoff of fertilizers. The concentration levels of NO_2^-, NO_3^- and NH_3^- were found in the ranges of 4.64 - 416.14, 4.56 - 635.99 and 53.06-766.52 µg/l, and drainage water were 9.90 - 723.09, 47.44 - 441.75 and 179.84 - 4579.96 µg/l; respectively. These nutrients increase with runoff from agricultural lands especially intensively cultivated lands with large inputs of synthetic fertilizers) and urban wastewater, creating eutrophication (Liu *et al*., 2009).

Phosphorus that enters the aquatic system through anthropogenic sources, e.g. fertilizer-runoff, potentially could be incorporated into either inorganic or organic fraction. Once phosphorus accumulates within a lake, it can cycle through the water column and promote algal blooms indefinitely (Edwards and Withers, 2008).

The concentrations levels of PO_4^{-3} and TP were found to be in the ranges of 6.02 – 454.09 and 50.30 – 968.44 µg/l and drainage water were 262.35-627.74 and 302.18-1097.42 µg/l, respectively; as shown in Tables (3 and 4). The high ortho and total phosphates concentration levels can be explained on the basis of the high amount of agricultural runoff and domestic sewage inflow from the adjacent cultivated land and the neighboring villages to the drains (Sayed and Abdel-Satar, 2009). The ranges of SiO_3^- were ranged between 5.17 - 20.61 mg/l and drainage water was 3.17-20.61 and 4.22 – 16.76 mg/l. The high values of silicates is also may relate to the different agricultural effluents that discharged into Lake Qarun from El-Wadi and El-Bats drains. Generally, the most probably the contamination delivered by the relevant drains containing industrial wastes (such as paints and ceramic remnants), agricultural wastes (fertilizers and pesticides) and sewage wastes as well as the wastes of the fish farms found in the southern part of the lake (El-Sayed *et al.*, 2015).

Long- Term Variations in Water Quality of Lake Qarun

Long- term studies on lake Qarun have provided direct clues to the effect of increased the EC and TS values with increase the evaporation rate. In addition to the increased in the concentrations of Cl^-, Ca^{2+}, Mg^{2+}, Na^+ and K^+. The mean concentration values of nutrient salts (NO_2^-, NO_3^-, NH_3, PO_4^{---} and TP) were found border line between increased/decreased from 2003 till 2017 (Table 5), corresponding to the quality/ quantity of sewage and agricultural wastes discharged from El- Batts and El- Wadi drains into the lake.

Table 5: Long-term changes of physico-chemical parameters in Lake Qarun

Parameters	Mean (Case Study)	2016 1	2015 2	2015 3	2013 4	2012 5	2010 6	2008 7	2005 8	2005 9	2003 10	Average of all (2003-2016) (1:10)
		Lake Qarun										
Water temp. ^{0}C	20.66	23.90		29.85		25.62		27.50	22.91			25.96
TS (g/l)	39.27				37.92		38.36					38.14
TDS (g/l)	32.44		36.04		34.70		35.31	37.80		3.45	18.80	27.68
TSS (g/l)	6.94				3.22							3.22
Trans. (cm)	55.20			110.00	55.50	62.50	61.00		55.00			68.80
Depth (m)	4.25											
EC (mmohs/cm)					40.69	39.42						40.06
EC (mS/cm)	43.60		35.25				42.00					38.63
Salinity (‰)					37.67							37.67
Salinity (g/l)		27.45		27.45				25.90	32.42			28.31
pH	8.29	7.91	8.22	8.35	8.10	8.48	8.23		8.44		7.90	8.20
DO (mg/l)	7.57	6.43		5.40	8.68	10.07	9.38	8.50	7.88		10.00	8.29
BOD (mg/l)	5.93	3.78		4.70			7.24	8.00	5.97			5.94
COD (mg/l)	12.85	32.50		14.75			11.99					19.75
CO_3^{--} (mg/l)	27.28				16.61		24.21				20.00	20.27
HCO_3^- (mg/l)	202.95		172.0		213.06		158.60				290.00	208.42
T-Alkalinity	230.23				229.67	290.83		156.00		142.00		204.63
NO_2^{--}N (µg/l)	33.62	749.87		19.35	12.00		10.09	21.00	13.77			137.68
NO_3^--N (µg/l)	86.86	325.30	19.50	321.40	41.00		38.80	109.00	93.90	90.00		129.86
NH_3-N (µg/l)	281.96	114.30		184.45	350.00		379.00	340.00	163.20			255.16
SO_4^{2-} (g/l)	7.150		11.800		5.30		6.08		8.786	8.50	5.02	7.58
SiO_4^- (mg/l)	11.05	2.79	8	2.40			3.56					4.19
PO_4^{3-} (µg/l)	169.29	249.93	90	30.80	92.00		94.02		59.52	88.00		100.61
TP (µg/l)	308.67			162.60	584.00		586.00					444.20
Cl^- (g/l)	14.76		12.054		11.95		12.978	14.30	13.805	15.00	6.78	12.41
Ca^{2+} (mg/l)	597.22		444		430.00		491.78			374.00	320.00	411.96
Mg^{2+} (mg/l)	1537.95		1124		1040.00		1266.98			108.00	680.00	843.80
T- Hardness (g/l)	7.82					14.43		6.19				10.31
Na^+ (g/l)	9.65		10.119		6.40		6.52		9.064	7.70	5.27	7.51
K^+ (g/l)	0.53		0.319		0.18		0.34		0.364	74.20		15.08

1 - Shaaban *et al.*, (2016), 2- Abdel Wahed *et al.*, (2015), 3- El-Shabrawy *et al.*, (2015), 4 - Ibrahim and Ramzy, (2013), 5- Saeed and Mohammed, (2012), 6 - Abdel-Satar *et al.*, (2010), 7- Ali *et al.*, (2008), 8- Fathi and Flower, (2005), 9 - Mageed, (2005), 10 - Mansour and Sidky, (2003).

Microbial characteristics of Lake Qarun and drains

Microbial assessments at Lake Qarun water are mention at (Table 3) and microbial results for drains (El-Batts drain and El-Wadi drain) are mention at (Table 4). The bacteriological quality of water was usually controlled by certain parameters like bacterial density in terms of plate count at 22°C and 37°C as well as coliforms as indicator of fecal pollution. In addition to the use of fecal streptococci as a parameter for judgment of water pollution tended to give confirmatory information for the quality of water intended for civic use (Sabae, 1999).

Total viable bacterial count (TVBC) counts at Lake Qarun water at 22°C ranged between 3×10^3 CFU/ml to 450×10^3 CFU/ml, and TVBC at 37°C varied from 0.4×10^3 CFU/ml to 330×10^3 CFU/ml. The highest value at 22°C and at 37°C was recorded at station opposite to El-Oprerg. On the other hand, the lowest values at 22°C and 37°C were recorded at Far North-East of Lake and khor Maeiouf (Middle lake) respectively. These results agree with Ali and Osman, (2010). This may be due to the effect the sunlight (UV ray), organic substances, biological activity and sedimentation (Olayemi, 1993). On the other side, TVBC at drainage water are ranged between 15×10^5 to 90×10^5 CFU / ml at 22ºC and 145×10^5 to 460×10^5 CFU / ml at 37°C, respectively. The highest value at 22°C was recorded in El-Batts drain while the lowest value was recorded at El-Wadi drain. On contrast, the highest values at 37°C were recorded at El-Wadi drain while the lowest value was recorded at El-Batts drain. TVBC at 22°C and 37°C in drains was higher than TVBC in Lake Qarun. The obtained results show high microbial load at drains and subsequently reflected on Lake Qarun. The high load of organic matter in the drainage effluents induced the active multiplication of the bacteria this is in accordance with El-Fadaly *et al.*, (2001) and Sabae, (2004).

Coliforms were internationally recognized in assessing the microbiological quality of water. Total coliform, fecal coliform and fecal streptococci were estimated by most probable number (MPN) technique. Numbers of TC at Lake Qarun were in the range of (0.3×10^3 - 46×10^3). The highest values of TC were recorded at station opposite to El-Batts drain, while the lowest values were recorded at Khor Maeiouf and North of El-Karn Island (Middle Lake). Regional average at Lake Qarun water stations show highest values of (TC) were arranged descending as following: opposite to El-Batts drain, opposite to El-Wadi drain , Malahet Mizar (Far West of Lake), West Lake, Opposite to El-Oprerg, Far North-East of Lake, Khor Maeiouf (Middle lake), Opposite to Abou Nema lasn, North of El-Karn Island (Middle lake) and Opposite to Maser for reconstruction.

Numbers of fecal coliforms (FC) at Lake Qarun were in the range of 3×10^{٢} - 460×10^{٢} MPN /100ml. The highest value of fecal coliforms (FC) was recorded at Opposite to El-Batts drain. Numbers of TC at drains were in the range of 11×10^4 - 93×10^4 MPN/ 100ml water. The highest value of TC was recorded at El-Batts drain. This might be explained by the effect of domestic and agricultural wastes discharge from the urbanized surrounding area (Shaaban-Dessouki *et al*., 1993). FC at drains was in the range of 11×10^3 - 93×10^3 MPN/ 100ml water. The high values of FC might be attributed to the effect of wastewater. The obtained results declare that the stations opposite to El-Batts and El-Wadi drains were recorded high numbers of TC. This might be attributed to the effect of the drains and human activities and pollution effect on bacterial association (Noble *et al*., 2004).

MPN of fecal coliform bacteria at drains were much higher than Lake Qarun. This indicates the true fact, and the source of pollution at Lake Qarun was the drains, which discharge the drainage water (waste water, agriculture waste). The effects of drains at water quality were findings agreed with those previously reported by Fujioka *et al*., (1981) and Sabae, (1999).

Numbers of FS at Lake Qarun water were in the range of 3×10^2 – 1100×10^2 MPN/ 100ml water. FS at drainage water numbers were in the range of 53×10^3 –

460 × 10^3 MPN/ 100ml water. The high value of FS was recorded at station opposite to El-Batts drain due to the effect of drainage water which was loaded with agricultural and industrial wastes that affect the cultural condition necessary of bacterial growth as pH and temperature. High values of TC, FC and FS were detected in Lake Qarun stations, which might be attributed to wastewater discharged into the lake water (Isobe *et al*., 2004 & Sabae and Rabeh, 2007) also mention that, the reason of high values in TC, FC and FS was wastewater discharged. US EPA, (2001) reported that the FC / FS ratio indicate the origin of bacterial pollution. FC/FS ratio of 4 or greater indicates a human source. Domestic animals is on average of 0.1-0.6. FC/FS ratio in the present study indicates human, mixed and animal source pollution at Lake Qarun.

Escherichia coli is the best biological water indicator for public health protection because it is present in extremely high numbers in the faeces of all mammals, it does not appreciably multiply in the environment outside its host (Edberg *et al*., 2000). *E. coli* at Lake Qarun water were fluctuated between 0.1 × 10^2 - 60 × 10^2 CFU /100ml water. The high value of *E. coli* was recorded at station opposite to El-Batts drain. But *E. coli* at drains were fluctuated between 48 × 10^2 - 98 × 10^2 CFU /100ml water.

Water quality index

Water quality index Table (6) and Fig. (2), illustrate the values of the WQI of Lake Qarun water and two drains (El-Batts and El-Wadi). The WQI score for irrigation water was computed using guidelines of (FAO, 1994). Protection of aquatic life was computed using guidelines of (CCME, 2007). 13 and 7 variables were used for the calculation of WQI according to irrigation and aquatic life criteria, respectively. The selected parameters for irrigation water include, TDS, pH, HCO_3^-, NO_2^--N, NH_3, PO_4^{-3}, Cl^-, SO_4^{-2}, Na^+, K^+, Ca^{+2}, Mg^{+2} and fecal coliform. On the other side the aquatic life include TDS, pH, DO, BOD, COD, NO_3^--N and fecal coliform.

The present results show that the WQI values of Lake Qarun water were ranged between 58.23 - 84.51 and 51.75 - 83.06 with respect to irrigation and aquatic life protection according to the irrigation guidelines and protection of aquatic life guidelines respectively (Table 6).

Table 6: WQI and its categorization of Lake Qarun water for irrigation and aquatic life utilizations.

Stations	**Irrigation**		**Aquatic life**	
	WQI	**WQR**	**WQI**	**WQR**
1	58.23	Good	73.58	Poor
2	64.00	Poor	81.71	Very Poor
3	59.68	Poor	79.83	Very Poor
4	72.25	Poor	83.06	Very Poor
5	84.51	Very Poor	79.64	Very Poor
6	72.54	Poor	79.11	Very Poor
7	63.95	Poor	69.94	Poor
8	73.38	Poor	81.22	Very Poor
9	74.33	Poor	77.46	Very Poor
10	73.18	Poor	79.44	Very Poor
General Average of Lake	69.61	Poor	78.53	Very Poor
El-Batts Drain	52.75	Poor	56.04	Poor
El-Wadi Drain	58.44	Poor	52.74	Poor
General Average of Drains	55.45	Poor	54.45	Poor

WQI = Water Quality Index WQR= Water Quality Rating

On the other side the WQI for tow drains (El-Batts and El-Wadi) were recorded 52.75 and 58.44 for irrigation & 58.44 and 52.74 for aquatic life protection respectively. The general annual average value of WQI showed that Lake Qarun water recorded 69.61 (Poor) for irrigation guidelines and 78.53 (Very Poor) for aquatic life guidelines respectively. The general annual average value of WQI for tow drains (El-Batts and El-Wadi) were recorded 55.45 (Poor) for irrigation and 54.45 (Poor) for aquatic life protection respectively. Generally, the water pollution has a negative impact both in terms of water use and ecosystems.

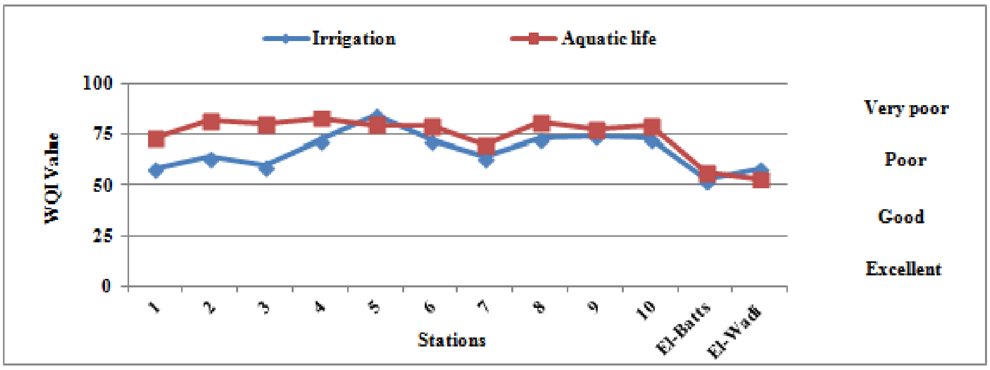

Fig. 2: WQI of Lake Qarun water for irrigation and aquatic life utilizations.

CONCLUSION

From previous results and discussion we can conclude that municipal and agricultural sewage wastes discharged into Lake Qarun causes serious problem of its water quality. The WQI values revealed that the lake water poor and very poor for irrigation and aquatic life guidelines respectively. The lake water is contaminated by feacal and *Escherichia coli* which indicate biological pollution. The evaporation rate of Lake Qarun water and climatic conditions are the most important factors affecting physical, chemical and microbiological characteristics.

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