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ASSESSMENT OF WATER QUALITY IN QARUN LAKE

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ABSTRACT

To assess water quality of Qarun lake, forty-six of lake water samples were collected during the period from 2014 to 2015. Value of pH of Qarun lake ranged from 8.22 to 8.32. Value of alkalinity ranged from 9.8 to 33.4 ppm. EC_w values ranged from 26.5 to 40.99 dS.m^{-1}. Qarun lake contained the soluble cations in the following order: Na^+> Ca^{2+}> Mg^{2+}> K^+. The SAR of the studied water in Qarun lake ranged from 274 to 400with a mean value of 337. The highest value of SAR occurred in season 2015 while the lowest one was in 2014. The hardiness value of Qarun lake ranged from 602 to 1567ppm. The COD values were higher than that of ECP501,2015. they ranged from 1168 to 1293 ppm. Different macro and micronutrients were more than the permissible limits. Water Quality Index (WQI) was applied using ten parameters of water quality (pH, Chloride, Chemical oxygen demand (COD), Iron (Fe), Phosphate (PO_4^{-3}), Chromium (Cr), Boron (B), Hardiness, Ammonium and Nitrate). The results indicated that water quality of Qarun lake decayed from the year 2014 to 2015 and could be categorized into Unsuitable class. The effect of anthropogenic activities was obvious on some parameters such as nitrate and ammonium. Monitoring the water quality of Qaroun lake is necessary for proper management.

INTRODUCTION

Water is considered to be one of the most abundant commodities in nature but also misused one. Nowadays, surface water is most exposed to pollution because of its easy openness for dumping of pollutants and waste water. Qarun lake is closed saline one, and it is considered the only outflow of drainage water from the cultivated lands in Fayoum Governorate. The drainage system of Fayoum depression consists of 222 drainage channels; all of them are ended in Qarun lake.

Currently, lakes and reservoirs are facing different grades of environmental degradation, because of urban encroachments, domestic and industrial effluents (eutrophication) and silt. A dramatic increase in population during the last century was recorded, meanwhile, the civic facilities were not build at equality which resulted in converting lakes and reservoirs into dustbin. Most rural and urbanlakes were deteriorated or extinct under such pressure with worldwide environmental concerns, **(Iscen et al 2008).**

A water quality index (WQI) is a mathematical way to summarize huge water quality data into simple terms for reporting to management and the public in a consistent manner. WQI integrates the different data produced after analyses into weights to the different parameters. Using WQI has some advantages including, the ability of the index to, represent various measurements of different variables in a single number, and combine these measurements in a single metric and also its efficiency as a communication tool. At the point when similar goals and variables are utilized, the index can be employed to convey comparative differences in water quality between on destinations over time. Water projected for human use should be safe, healthy, easily accessible, adequate in quantity, contamination free and readily accessible **(CCME, 2005).** The WQI is capable to decrease the bulk of the data into one figure to introduce the data in a simple and reasonable form. It also reveal annual cycles, spatial and temporal changes in water quality at low concentrations **(Shweta et al 2013).**

The WQI is a valuable mean for collaborating information of water quality to large public and to decision makers; it is not a complex predictive model for technical and scientific application**. (Hal-**

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lock, 2002; Yogendraand Puttaiah, 2008). Indices are usually calculated using the values of different physical, chemical and biological parameters of a water sample. Indices are usually used in monitoring programs to evaluate ecosystem quality and then to update the community and decision-makers what is the state of the ecosystem **(Nasirian, 2007 and Simoes et al 2008).** The WQI approach provides standards for assessing successes and failures of management plans for improving water quality **(Rickwood and Carr, 2009)**

Hence, the current research is carried out to assess comparatively the prevailing water quality and portability of Qarun Lake by analyzing water physical and chemical parameters. Also, to evaluate the ability of WQI as a single number calculated from these various indifferent parameters in monitoring Qarun Lake water quality spatially and temporally.

MATERIALS AND METHODS

Description of the Study Site

A total of 46 monitoring stations were established along Qarunlake seasonally from 2014 to December 2016 and the locations of the selected monitoring stations are given **Figure, 1**. Two liters of water, about 30 cm beneath water surface were taken for each sample. All water samples were filtered and the filtrates were analyzed for pH, EC, nitrate, ammonium, phosphorus, boron, dominant cations and anions, heavy metals and chemical oxygen demand (COD). Qarun lake water samples were collected as recommended by **Jones et al (1971).**

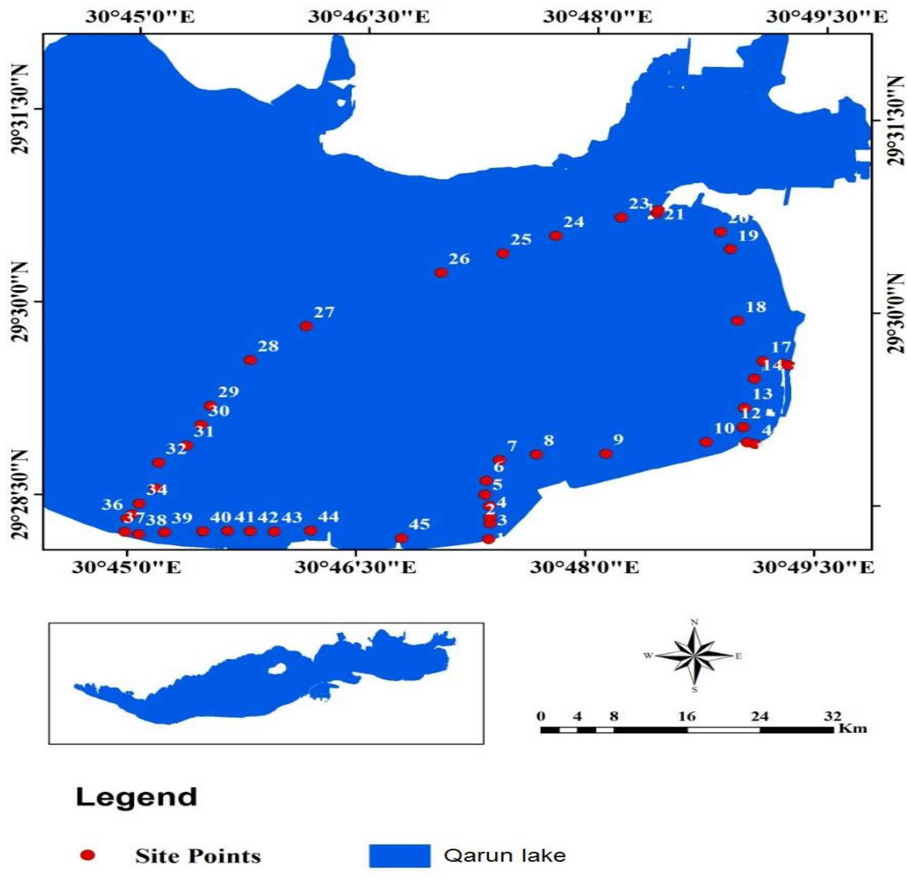

Fig. 1. Sampling stations of Qarun lake

All samples were collected and sent to the laboratory on the same day. The sampling strategy used to investigate the chemical quality in Qarun lake usually employs a single sample, or a series of samples collected simultaneously.

Sampling Methodology

Water samples were collected manually from each sampling station and were taken at a depth of 30 cm below the water surface. After determining the depth of the water, the polyethylene pail was placed in a metal holder attached to a string and thrown into the water. By regulating the rate at which the pail is lowered to the bottom it is possible to obtain a sample that approximates an integrated sample of the water between the surface and the bottom. However, the pail should not be allowed to touch the bottom to avoid stirring up of the sediment. At the time of sample collection, the sample container was rinsed with the sample solution and the rinse portion discarded. Acid washed 5 L capacity polyethylene bottles were used for storing the water and were brought to the laboratory within six hours of collection. Part of the water samples were then immediately acidified with (1:1) HNO_3 maintained to a pH < 2 upon receipt in the laboratory. Normally, 3 mL of (1:1) acid per litre of samples is sufficient for most ambient water samples. The low pH inhibits adsorption of the metal ions onto the surface of the container and prevents the formation of trace metal precipitates or the co-precipitation of trace metals with the other major constituents. Chlorine-containing acids, such as hydrochloric or perchloricacid, should be avoided as a preservative when atomic absorption methods are to be used for the determination of trace metals.

An amount of 100 ml water samples were used for chemical oxygen demand (COD) determination. Concentrated sulphuric acid from Ajax Chemicals was used to preserve water samples for COD analysis and the pH was maintained to less than two. In order to ensure integrity, samples must be transported to the laboratory for analysis in a manner avoiding extreme environmental conditions, such as excessively high or low temperatures.

Water Quality

Physicochemical Characteristics

Integrated water samples were taken from each station for the different physicochemical factors using grab sampler. The filed parameters such as pH, and conductivity were measured immediately in situ. The other parameters (ammonum, nitrate total phosphorus, chemical oxygen demand, suspended and dissolved solids, alkalinity, water hardness, chloride, and sulfate) were analyzed in the laboratory within 24 hours, while sodium, potassium and heavy metals were measured within 30 days.

All Samples were analyzed for various water quality parameters as per standard procedures given by **APHA, (1998) and Baruah & Barthakur (1997).**

Application of the WQI

This study is an attempt to evaluate water quality of Qarun Lake. For this purpose, ten water quality parameters have been selected which were:

pH, Chloride, Chemical Oxygen Demand, Nitrate, Ammonium, Alkalinity, iron, Chromium, Boron and Phosphate. Values used for each parameter are the mean value of the 46 sites under this investigation.

In the formulation of WQI, the importance of various parameters depends on the intended use of water; here, water quality parameters are studied from the point of view of suitability for fish consumption. The ‘standards’ (permissible values of various parameters) for the fish water used in this study are those recommended by the Egyptian standard. The calculation and formulation of the WQI involved the following steps:

In the first step, each of the ten parameters has been assigned a weight (*AWi*) ranging from 0 to 4 depending on the collective expert opinions taken from different previous studies. The mean values for the weights of each parameter along with the references used are shown in **Table 1**.

However, a relative weight of 1 was considered as the least significant and 4 as the most significant.

2) In the second step, the relative weight (*RW*) was calculated by using the following equation:

$$\mathbf{Rw} = \frac{\mathbf{AWi}}{\sum_{i=1}^{n} \mathbf{AWi}} \qquad \mathbf{(1)}$$

Where: *RW* = the relative weight, *AW* = the assigned weight of each parameter, n = the number of parameters. The calculated relative weight (*RW*) values of each parameter are given in **Table 2**.

Table 1. Assigned weight values adopted from the personal expert

Parameters	References number								Mean Value
	10	25	34	40	50	60	70	75	
pH	4	1	4	1	1	1	4	1	2.13
Cl, ($mg.L^{-1}$)	1	1	2	2	1	1	0	0	1.00
Alkalinity, ($mg.L^{-1}$)	2	4	2	1	4	4	4	2	2.88
COD, ($mg.L^{1}$)	4	4	4	4	4	4	4	4	4.00
NO^{-}_{3},(mg/L)	3	3	4	4	2	3	4	4	3.38
NH^{+}_{4},($mg.L^{1}$)	4	4	4	4	4	4	4	4	4.00
Fe,($mg.L^{-1}$)	1	1	1	1	2	3	4	1	1.75
$PO^{-3}_{4,}$($mg.L^{-1}$)	3	2	1	2	2	3	4	2	2.38
B,($mg.L^{-1}$)	1	1	1	2	1	1	2	1	1.25
Cr,($mg.L^{-1}$)	1	2	3	4	2	2	1	1	2.00

Table 2. Relative weight of the water quality parameters

Parameters	Relative weight of the water quality parameters.		
	Water quality standard	Assigned weight (AW)	Relative weight (RW)
pH	9	2.13	0.086
Cl, ($mg.L^{-1}$)	350	1.00	0.040
Alkalinity,($mg.L^{1}$)	200	2.88	0.116
COD, ($mg.L^{-1}$)	600	4.00	0.162
NO^{-}_{3},(mg/L)	100	3.38	0.136
NH^{+}_{4}, ($mg.L^{-1}$)	1	4.00	0.162
Fe,($mg.L^{-1}$)	20	1.75	0.071
$PO^{-3}_{4,}$($mg.L^{-1}$)	30	2.38	0.096
B,($mg.L^{-1}$)	2	1.25	0.051
Cr,($mg.L^{-1}$)	1	2.00	0.081
Sum.		24.75	

3) In the third step, a quality rating scale (*Qi*) for all the parameter except pH was assigned by dividing its concentration in each water sample by its respective standard according to the wastewater guideline recommended by the Egyptian water standards [ECP501], the result wasthen multiplied by 100.

$$Qi = \left(\frac{Ci}{Si}\right) \times 100 \qquad (2)$$

While, the quality rating for pH (QpH) was calculated on the basis of, 100

$$\mathrm{QpH} = \left(\frac{\mathrm{Ci-Vi}}{\mathrm{Si-Vi}}\right) \times 100 \quad (3)$$

Where: *Qi* = the quality rating, *Ci* = value of the water quality parameter obtained from the laboratory analysis, *Si* = value of the water quality parameter obtained from recommended the Egyptian standards of corresponding parameter, *Vi* = the ideal value which is considered as 7.0 for pH.

Equations (2) and (3) ensure that *Qi* = 0 when a pollutant is totally absent in the water sample and *Qi* = 100 when the value of this parameter is just equal to its permissible value. Thus the higher the value of *Qi* is, themore polluted is the water **(Mohanty,2004).**

4) Finally, for computing the WQI, the sub-indices (*SIi*) were first calculated for each parameter, and

then used to compute the WQI as in the following equations:

$$SIi = RW \times Qi \quad (4)$$

$$WQI = \sum_{i=I}^{n} SIi \quad (5)$$

The computed WQI values could be classified as <50 = Excellent; 50-100 = Good; 100-200 = Poor; 200-300 = Very poor; >300 = Unsuitable **(Ramakrishnaiah et al 2009).**

RESULTS AND DISCUSSION

Assessment of water characteristics of Qarun lake

Determined chemical characteristics of Qarun lake, Fayoum Governorate, are given in **Table 3**. Hydrogen ion concentration of Qarun lake water is quite variable throughout the seasons and pH>7 indicate that alkaline conditions are dominant in the lake. Hydrogen ion concentration is one fo the most important factors affecting the biological activities of most aquatic organisms. Quite high pH values may decrease the fish productivity of the lake because of the polluted water discharged into the Lake. Variation in pH in collected water from different sites was 8.22 to 8.32 at 2014 and 2015, respectively. This may be due to that the Qarun lake is the main drain in Fayoum Governorate which collects most of wastewater from the Governorate. This result is in agreement with that obtained by **Abdel-Satar et al (2010).** Who recorded that lake Qarun water showed alkaline character with pH value ranged from 8.1 – 8.73 and showed great difference among different seasons. **Bhatnagar et al (2004)** recommended that pH <4 or pH >10.5 is lethal to fish/shellfish culture; pH from 7.5-8.5 is highly congenial for *P. monodon*; pH from 7.0-9.0 is acceptable limitms; pH from 9.0 -10.5 is sub-lethal for fish culture.

Alkalinity is a measure of the total concentration of chemical bases in pond water such as, hydroxides, carbonates, bicarbonates, phosphates and borates, dissolved calcium, and magnesium. Alkalinity is usually defined as the water's ability to resist changes in pH Lime leakage out of concrete ponds or calcareous rocks, denitrification, sulphate reduction and photosynthesisare mainly in charge for increasing alkalinity. Meanwhile, respiration, nitrification and sulphide oxidation reduce alkalinity **(Cook et al 1986)** to a lower degree which. Thereafter increases again because of evaporation and organic matter decomposition . On the other hand, low alkalinity indicates that even a small quantity of acid may make a large pH change. The alkalinity concentration in Qarun lake was 9.8 ppm in 2014 and increased by 3.4 fold in 2015 **Table, 3**. **Santhosh and Singh (2007) stated that** the supreme alkalinity range for fish culture is ranged between 50 and 300 ppm.

Table 3. Mean values of pH, ECw, soluble ions values, chemical oxygen demand (COD), Alkalinity, Hardiness, sodium adsorption ratio (SAR) as well as concentrations of some macro and micronutrients in the Qarun lake during 2014 and 2015

Parameters		Season, 2014	Season, 2015
pH		8.22	8.32
EC	$dS.m^{-1}$	26.5	40.9
Na	↓	2997	4551
K		176	125.5
Ca		286	212
Mg		435	435
Cl		3461	7254
HCO_3^-		359	388
NO_3^-		19.8	28.6
NH_4^+	$Mg.L^{-1}$	11.9	27.4
PO_4^{-3}	↑	0.007	0.076
Fe		0.011	0.031
B		1.21	2.42
Cr		0.954	1.18
COD		1168	1292
Alkalinity		9.80	33.4
SAR		273	399
Hardiness		602	1567

Salinity is the most important parameter for determining irrigation water suitability. Measurement of electrical conductivity (EC) in lake water provides rather sufficient information about the quantity of dissolved material found in water. Data in Table, 3 indicate that EC_w values of Qarun lake ranged from 26.5 to 40.9 $dS.m^{-1}$. Concerning differences in EC_w values of water samples in different both sites the lowest value was in 2014 while the highest one was in 2015.

Regarding soluble cations and anions of the collected water samples, Qarun lake contained higher values of these ions as expected. Increasing such ions concentrations in Qarun lake was more remarkable for sodium, that reached about 4551 ppm. Generally, Qarun lake contained the soluble cations in the following order: Na^{+}> Ca^{2+}> Mg^{2+}> K^{+}. The highest soluble cations values were observed in season 2015 while the lowest values were recorded in season 2014. In case of soluble anions, the dominant one was chloride that increased by about 2.1 fold in the season 2015 compared to that of 2014. Carbonate ions were absent in the different water samples.

High sodium concentration affects soil permeability and water infiltration. It also has a direct contribution to the total water salinity and may has harmful effects to sensitive crops like fruit trees. Sodium Adsorption Ratio (SAR) is used to estimate the sodium hazard of irrigation water. Water that have a high SAR continually leads to a collapse in the soil structure. Moreover, the sodium substitutes the adsorbed calcium and magnesium on the soil clays and causes dispersion of soil clay particles.

This kind of dispersion leads to soil aggregates breakdown and makes the soil becomes compact after drying and gradually impervious to water infiltration. The highest value of SAR occurred in 2015 while the lowest one was in 2014. Concerning the salinity and sodicity status of the water resources in El-Fayoum governorate, **El-Quesy and El-guindi (1981)** mentioned that the quality of the agricultural drainage water in El-Fayoum was moderate throughout the yearly months. Also, they found that the ranges of total soluble salts and the adjusted SAR at the beginning and the end of El-Wadi and El-Batts drains were 600-1600 and 6.0-20.0 ppm, respectively. Generally, the hardiness of the studied Qarun lake was higher than that of the permissible limits, **ECP-501.** The highest value was recorded in 2015, whereas, the lowest one was in 2014. This may be due to the natural waters, depending on the soil activities in catchment area. **Bhatnagar et al (2004)** mentioned that hardness values of water lower than 20 ppm causes stress 75-150 ppm hardness is optimum for fish culture and hardness >300 ppm is fatal to fish life as it rises pH, and results in non-availability of nutrients. Though, some euryhaline species may have high tolerance limits to hardness.

Chemical oxygen demand (COD) test is one of the most important tests made to determine the strength or polluting power of polluted water. It is a chemical test which measures the amount of oxygen consumption to oxidize organic matter in waste water. **Table, 3** shows that the collected water samples from Qarun lake water were rich in organic matter and recorded high values of COD. It is clear that the COD values in Qarun lake were higher than that of ECP501. Concerning differences in COD values of water samples in different seasons, the recorded highest value was in 2015 while the lowest one was in 2014. This may be due to the nature and dominants byproducts transported to Qarun lake. The high COD values indicate the relatively higher polluting power of such water due to effluents rich in organic materials. These results are in accordance with those obtained by **Hussein et al (2008)** who indicated that the COD values in El-Batts drain ranged between 1265.0 - 2365.0 mg/l and 1165.0 - 1843.0 mg/l in El-Wadi drain.

The obtained data show that NO_3^- concentration was higher than NH_4^+ at different sampling times. The nitrate concentration in Qarun lake water was 1.4 fold in season 2015 that of NO_3^- in the season 2014. This difference may be attributed to the byproducts, which were transported into Qarun lake. Also, this may be due to increasing the biological oxidation of organic wastes as a result of increasing temperature, **(Gray, 1994).** Whereas, ammonium concentration of Qarun lake ranged from 11.9 to 27.4 ppm. The highest value was recorded in the season 2015 whereas, the lowest one was in 2014 Generally, soluble nitrogen concentration increased in Qarun lake, this may be due to excessive application rates of nitrogen fertilizers, pesticides, growth hormones and others pollutants transported into waterways by natural drainage. The magnitude of this increase was more remarkable in 2015 and this may be related to the increase in plant debris, animal excrement, nitrogenous fertilizers and discharge of sewage and industrial wastes besides the increased activities of microorganisms in decomposition of residues and fixation of atmospheric nitrogen as have mentioned by **Mahida (1983).**

Orthophosphate was analyzed and expressed as phosphorous. The $P\text{-}PO_4^{+++}$ concentration varied between 0.007 and 0.080 ppm **Table, 3**. Concerning differences in phosphorus concentrations of water samples in different seasons, the highest value was in 2015 while the lowest one was in 2014. This may be due to that Qarun lake received most of wastewater of Fayoum Governorate. These waters contain large amounts from nitrogen and phosphorus compounds that are excreted by humans and animals, nitrogen fertilizers, pesticides, growth hormones and others pollutant transported into waterways by natural drainage. Beside the above-mentioned reasons, phosphatic detergents in sewage water are also important contributors of increasing phosphorus concentration in such waters. Both nitrogen and phosphorus occur in small amounts in natural waters, but their concentrations greatly increased by human activities. **Chhatwal et al (1993)** found that more than 80 % of the nitrogen and 75 % of the phosphorus added to surface waters originate from man- made sources.

The obtained data indicate that boron concentration in Qarun lake ranged from 1.21 to - 2.42 ppm. The highest value was in 2015 while the lowest one was in 2014. Iron and chromium concentrations recorded higher values in lake water regardless of the season of water sampling, **Table, 3**. The concentrations of Fe and Cr in 2015 were 2.8 and 1.3 fold of their concentrations in 2014, respectively. Differences in concentration of Fe and Cr with time may be due to, mainly anthropogenic sources. On the other hand, the presence of chelating agents, concentration of ligands, oxidation states and redox environment which increased in 2015 and may play a role according to **Goel (1997).** Dynamic exchange of metals may also occur between water and sediments. These exchanges are greatly dependent on redox, pH, oxygenation, salinity and chemical composition of waters **(Stumm and Morgan, 1970).**

Water quality index (WQI) is considered unique and valuable assessment to represent the complete water quality status in a one term that helps for the selection of suitable treatment procedure to meet the concerned problems. Water quality assessment is defined as the evaluation of the water physical, chemical and biological status in relative to the natural state, anthropogenic effects and future uses. WQI decreases the amount of parameters and data used in measuring water quality to a one simple expression to simplify interpretation of the data and allow public access to such data. The computed annual WQI values ranged from 202 to 634 during 2014 and 2015 and therefore, it can be categorized into unsuitable class **(Figure, 2)**. To reach a better perspective on the causes of water quality deterioration in the Qarun lake the correlation coefficients between water quality parameters and WQI were calculated and represented in **Table 4**. The correlation coefficient between WQI and COD was 0.08. High COD values indicate a possibility of organic pollution of the water in this area. Therefore, a continuous monitoring is needed. The correlation coefficients between WQI and alkalinity was 0.24. The results showed that Cl values were very higher than the permissible level recommended by the **ECP-501** for irrigation water. The correlation coefficients between WQI and Cl was 0.23. The chloride (Cl) is considered a significant parameter of water quality, whether that used for domestic, industrial or agricultural usage. The obtained results show that Cl^- values were frequently higher than the minimal allowable level recommended by the **(WHO 2004)** for irrigation and aquatic biota. In addition, the correlation coefficients between WQI and Fe, Cr, or B were -0.03, 0.23 and -0.19 respectively. On the other hand, the correlation between WQI ،and NO_3^- , NH_4^+ or PO_4^{-3} were 0.39, 0.88 and 0.26, respectively. From the correlation coefficient values between WQI and water quality parameters, it is evident that Cl, alkalinity, NO_3^-, NH_4^+, $PO^{-3}{}_4$ and Cr were the most affecting factors for the computed WQI values of Qarun lake in this study.

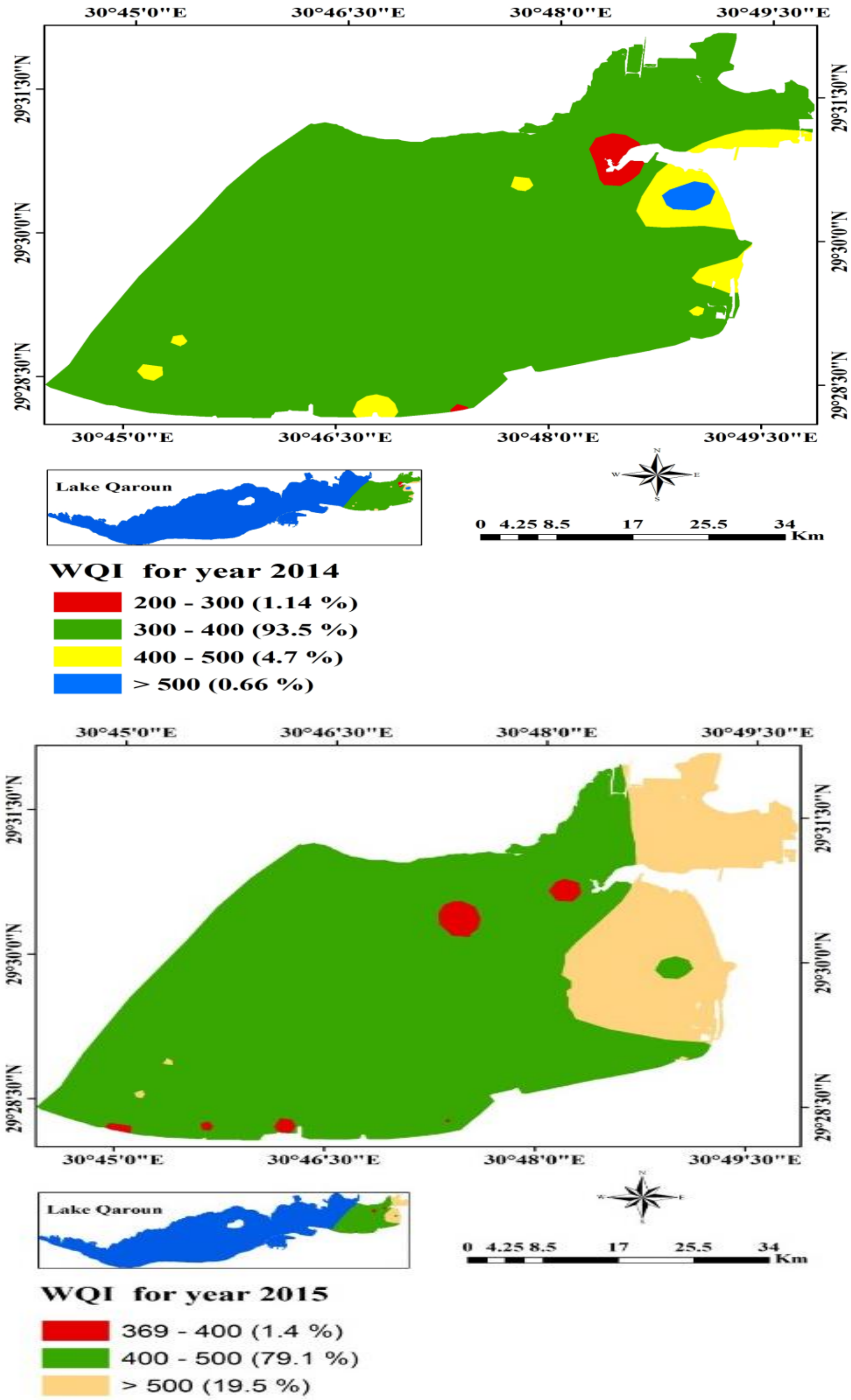

Fig. 2. Changes in the computed water quality index of Qarun lake in 2014 - 2015

Table 4. Correlation coefficient between WQI and water quality parameters

	WQI	pH	Cl	Alkalinity	COD	NO^-_3	NH^+_4	Fe	PO^{-3}_4	B	Cr
WQI	1.00										
pH	-0.09	1.00									
Cl	0.23	-0.55	1.00								
Alkalinity	0.24	-0.43	0.66	1.00							
COD	0.08	-0.42	0.47	0.50	1.00						
NO^-_3	0.39	0.29	-0.22	-0.21	-0.44	1.00					
NH^+_4	0.88	0.14	-0.12	-0.07	-0.24	0.56	1.00				
Fe	-0.03	-0.08	0.06	-0.06	-0.06	0.00	-0.03	1.00			
PO^{-3}_4	0.26	0.18	-0.26	-0.26	-0.28	0.46	0.30	-0.03	1.00		
B	-0.19	-0.15	0.39	0.21	0.32	-0.29	-0.35	-0.04	-0.36	1.00	
Cr	0.23	0.05	-0.19	-0.11	0.17	-0.08	0.24	0.09	0.04	-0.31	1.00

CONCLUSIONS

The water pollution level increases in Qarun Lake during the different seasons and causes adverse effect to the aquatic life and entire aquatic ecosystem. The water quality parameters like alkalinity, conductivity, COD and nutrients concentrations have shown significant increase during this period of study 2014 - 2015. The contribution of biodegradable and non-biodegradable materials declines the lake water quality and increases pollution load in the lake.

Employing water quality index (WQI) in this study introduces an assessment approach of water quality in Qarun lake. We can conclude that regarding water pollution assessment, some indicators must be put into consecration mostly organic pollution. One of the advantages of using a water quality index in assessing the overall water quality is that it sums up plentiful data and information in only single number in an impartial, rapid and logical way. It also evaluates different zones and monitors changes in water quality and also can relate to a potential use of that source of water.

It could be recommended to apply WQI to evaluate water quality index specially when dealing with either puplic or decision makers.

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