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Article

Change in Hydro- Chemical Properties and Water Quality of a Lentic Ecosystems: Baghdad Touristic Island Lake

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ABSTRACT

Protecting a lentic ecosystem became important during acute water scarcity and global warming worldwide, particularly in Iraq. The study investigated the change in hydro-chemical properties and water quality index (WQI) of Baghdad Touristic Island Lake as a lentic ecosystem during the change in Iraqi climate. Three sites were selected in the lake to study the hydro-chemical properties and its water quality. Lake water is alkaline, very hard, good aeration and oligotrophic. Results recorded alteration in water properties in some parameters while other was within presumable values. WQI results revealed the alteration in water quality and ranged between poor- and marginal criteria for protecting the organism's life. Therefore, it needs to enhance the lake management and keep it within oligotrophic states to prevent eutrophication and support the lake's survival for tourism.

Keywords: Water Quality, Lentic Ecosystems, pollution

INTRODUCTION

For the continuance of life on Earth, water is one of the most crucial resources; without it, there is no life. The two different sorts of water sources are surface water and groundwater. The surface water found in lakes, rivers, and reservoirs are examples. Although it is situated below the surface, groundwater [1] Water is the most fundamental necessity for living. Aquatic life and other ecosystems depend on clean water. Therefore, protecting water resources from careless usage and intentional pollution is essential for the welfare of all humanity. In many developing nations, water scarcity, pollution, and a lack of access to a reliable, safe, inexpensive water supply are significant concerns. Several human activities can seriously affect the quality of the water. Monitoring water quality is crucial to ensure people access safe water. To assess the quality of the samples, water samples are taken and tested [2]

The water supply crisis is a global issue. According to the World Economic Forum's most recent global risks report, the water supply crisis is one of the top five challenges that must be addressed over the next decade. By 2025, most African nations will have exhausted their available water supplies. The lack of available

water resources results from global warming, climate change, and excessive water use. Urbanization, as well as agricultural and industrial activity, have all increased due to population expansion. Eutrophication, increased salinity, acid mine drainage, and faucal pollution are signs that these factors lower water quality. [3] The multidimensional nature of the data can be reduced by using the index to compile all data on water quality mathematically. In general, the measurements and basic water descriptions are given. As a result, the index can evaluate water quality in accordance with the required state specified by water quality objectives, shed light on how water quality influences human activities, and give important environmental elements more weight. The index is a helpful resource for outlining the state of the water column, sediment, and aquatic life in order to categorize the water's suitability for usage by people, aquatic life, wildlife, and other entities [4,5]
Examining the physical and chemical features, the composition of the algae and invertebrates, and the geography of the study region helps to estimate the water quality (WQ) [3]. In order to compare different bodies of water, water quality indices (WQIs) were developed [6] The most reliable method for assessing water status is the water quality index, which gives the general public and governmental decision-makers a clear image [7] Alobaidy showed that the actions of humans and population growth had an impact on water quality [8]
The Water Quality Index (WQI) is a mathematical technique that transforms a substantial amount of water quality data into a single value that represents water quality and establishes the kind of treatment required [9,10,11] Additionally, it is applied as a broad idea for prospective water issues in a particular location [11] WQI seeks to classify waters according to their physical, chemical, and biological properties [2,13]

MATERIALS AND METHODS

Study area: The current study was carried out on Baghdad Touristic Island Lake (BTIL). Three sites were selected for water quality monitoring (Figure 1). The first site was on the northern lake shore between latitude 33°46'39.6 N and longitude 44°20'32.4 E. In contrast, the second site represents the middle of the lake at the Tower area and is located between latitudes 33°12'247 N and longitude 44°09'25.2 E. The third site is located on the lake's southern side, between latitudes 33°22'366 N and longitude 44°19'47.4 E.

Sampling: monthly water samples were collected from the lake subsurface for sites from October 2021 to May 2022 using clean bottles of polyethylene for collection. The results presented as wet and dry seasons. Water samples were kept in a cool box and analyzed for physicochemical parameters in the laboratory except for water temperature, pH and total alkalinity. The physicochemical parameters included; water temperature, pH, Electric conductivity (EC), salinity (S ‰), Total dissolved solids (TDS), dissolved oxygen (DO), Total Alkalinity (TA), Total Hardness (TH), Sodium (Na^+), Magnesium (Mg^+), Sodium (Na^+), Potassium (K^+), total phosphorus (TP), total nitrogen (TN). The Canadian Council of Ministers of Environmental Water Quality Index (CCME WQI) for protecting aquatic life was calculated using six parameters: WT, pH, S ‰, DO, TP, and TN. All physicochemical parameters measured according to [14]

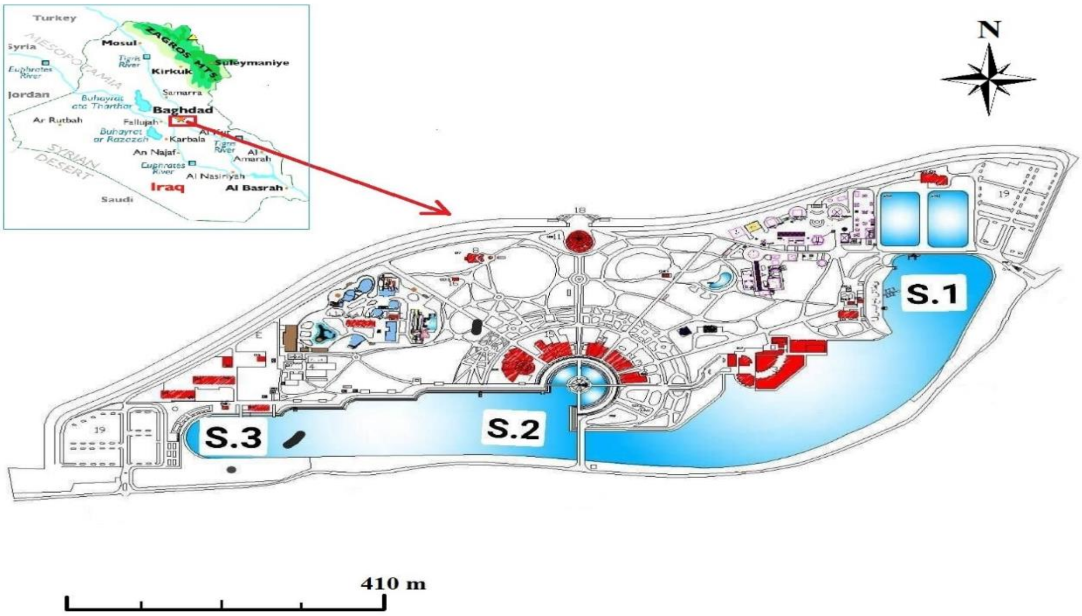

Figure 1. Map of the study area

Calculation of CCME WQI: The calculation of WQI is based on the formulation defined in the WQI 1.0-Technical report in Canada [15]. Three major factors influence this index. The first is a scope determined by the percentage of factors within the specified range of the total number of calculated factors. The second major factor in this index is frequency, which determines how often the water quality objective was exceeded. Finally, the amplitude is represented by the third factor. Combining the three factors as a number with no units arranged between 0-100 and the highest values indicates good water quality. Lower values indicate poor water quality [16], as referred to (Table 1).

Formulation of CCME index:

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) * 100$$

F (Frequency)

$$F_2 = \left(\frac{Number\ of\ failed\ test}{Total\ number\ of\ test}\right) * 100$$

F (Amplitude)

When the test value must not exceed the objective

Excursion= $\left[\frac{Failed\ test\ value}{objective}\right] - 1$

When the test value must not fall below the objective

Excursion= $\left[\frac{Objective}{Failed\ test\ value}\right] - 1$

$$nse = \left(\frac{\sum_{i=1}^{n} excursion}{Number\ of\ test}\right)$$

$$F_3 = \left(\frac{nse}{0.01\,nse + 0.01}\right)$$

$$\text{CCME WQI} = 100 - \left[\sqrt{\frac{F_1^2 + F_2^2 + F_3^2}{1.732}}\right]$$

CCMEWQI values	Ranks
100-95	Excellent
94-80	Good
79-60	Fair
59-45	Marginal
44-0	Poor

Table 1. Water quality classification

Statistical analysis: The hydro-chemical parameters were analyzed in triplicate, and the mean and standard deviation were calculated using R-statistical programming package [17] for the water quality index. Student's T-test was applied, and a post-HOC test and Pearson's correlation were used for the WQI.

RESULTS

The climate of Iraq is continental to subtropical semi-arid, and the entire Iraqi region has undergone a rapid change in response to global warming [18,16] Hence, the dry and wet seasons are characterized features of this area, so in this study, all results presented as aforementioned seasons.

Monitoring of water quality in the lake is based on evaluating physicochemical parameters in relation to the protection of aquatic life [19,20] The results of the present study of physicochemical parameters were as follows:

WT is an important ecological parameter and has an environmental effect on other physicochemical and biological parameters [21,22] Table 2 illustrates the variation of WT for the period between 1989, 2019 and 2022; results showed the rise in WT values in the present study as a response to raise in temperature degrees at all Iraqi region as an impact of climate change in Iraq.

Total hardness values referred that lake water is very hard (>300 $mgCaCO_3/L$); their results in the present study ranged from 341.37 $mgCaCO_3/L$ (±19.425) in dry season to 345.193 $mgCaCO_3/L$ (±31.406) in dry seasons, which were similar to previous studies [26,27] Most of Iraqi water body are characterized as very hard water and recorded in many studies [30,31,16,26] The hardness is measure indicated of divalent ions/ions in water body. Calcium, magnesium, sodium and potassium are important ions and essential in biological processes [32] The studied ions values were higher than recorded in previous studies [26,27] The high concentration of calcium (73.72- 74.61mg/L) helps the other ions to be lost from the water body. The ions in the present study were sequentially $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$.

Brönmark and Hansson mentioned that both total phosphorus (TP) and total nitrogen (TN) concentrations are good indicators of the lake trophic status [32] If the concentrations of TP and TN were ranged between 0- 5µg/l and 0-4 µg/l, respectively, in the lake, it will be considered as oligotrophic lake. In the current study, all TP and TN recorded concentrations indicated that lake water was oligotrophic.

This study used six parameters to calculate the WQI (Table 3). Salinity, TP and TN were above a permissible value according to Guidelines of CCME WQI for protecting aquatic life and a slight value of DO.

Parameters	2021/2022		2019/2020	1989		Rivers maintaining system	CCME guideline
	Dry	Wet					
	Mean±SD	Mean±SD	Mean±SD	Dry	Wet		
***Water temp. °C**	22.343±4.513	15.08±1.615	21.49 ± 8.19	28	12.9	_	15
EC µS/cm	906.807±40.357	993.499±109.595	638.45 ± 200.94	540.6	843	1500_	_
Salinity ‰	0.552±0.023	0.613±0.067	NA	0.08	0.13	_	_
***pH**	7.759±0.312	7.478±0.199	7.70 ± 0.39	8.1	8.1	6.5-8.5	6.5-9
Total alkalinity (mg CaCO3/L)	153.61±13.291	172.502±23.317	136.83 ± 51.23	171.5	186.3	_	20>
Total Hardness(mg CaCO3/L)	345.193±31.406	341.368±19.425	313.82 ± 91.23	278.3	462.2	_	_
Calcium (mg CaCO3/L)	74.614±10.425	73.719±7.327	68.65 ± 21.32	61.6	102.1	_	_
Magnesium (mg CaCO3/L)	64.881±6.995	66.136±5.105	59.19 ± 19.12	27.2	55.2	_	_
Sodium Na (mg/L)	59.722±6.189	56.473±7.157	NA	5.9	5.07	_	_
Potassium K (mg/L)	7.667±0.833	6.735±0.728	NA	0.8	0.55	_	_
***Total dissolved solids (mg/L)**	630.293±25.299	704.866±94.305	526.00 ± 274.00	NA	NA	1000	500
***Dissolved oxygen (mg/L)**	7.82±0.808	8.139±0.715	7.21 ± 1.18	9.1	10.2	>5	5.5.-9
***Total Phosphorus (mg/L)**	0.486±0.104	0.359±0.178	NA	NA	NA	_	_
***Total Nitrogen (mg/L)**	0.992±0.681	1.262±1.135	NA	NA	NA	_	_

Table 2. Hydro-chemical properties of the present study and previous studies in Baghdad Touristic Island Lake. (*) parameter included in calculation of water quality, (-) not measured, (NA) Not Applicable.

parameters	Minimum	Maximum	Guideline
Water temp. °C	13.4	29.9	15
pH	7	8.2	6.5-9
Dissolved oxygen (mg/L)	6.5	9.1	5.5-9
Salinity‰	586.3	903	500
Total phosphorus (µg/L)	0.1	0.69	0.10
Total nitrogen (µg/L)	0.25	3.1	0.12

Table 3. Hydro-chemical parameters used in the water quality index during the study period and Guideline of CCME WQI for protecting aquatic life

Results showed that the values of water quality in the lake were higher (44.6 ±2.2) in the dry season (Figure 3), while in the wet season was (35.7 ±1.8). These water quality values were lower than those recorded by [22] from July 2019 to February 2020, which indicated the alteration in the water quality of Lake [27]. The water quality varied among the study sites (Figure 4), and the lake's water quality ranged between marginal and poor categories.

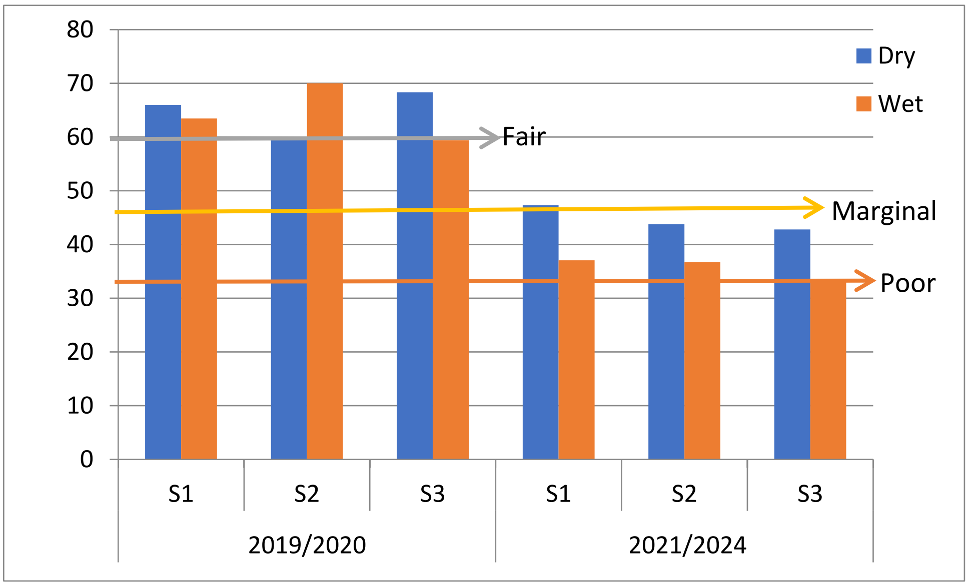

Figure 2. Temporal-spatial changes in the water quality index during two periods (2019/2020 and 2021/2022).

The statistical analysis showed a significant variation between WQI values in dry and wet seasons. In wet seasons, the values of WQI were recorded as the lowest value (33.44) at site 3 and the highest values (37.05) at site 1, which these values indicated the poor criteria of water quality (Table 1, Figures 3 and 4). While in dry seasons, sites 2 and 3 recorded poor WQI (42.80), and site 1 was marginal WQI (47.33).
The Post Hoc Comparisons between season and site results showed a significant variation between site 1 in dry seasons with other sites and seasons (Table 4). However, there was no relation between the wet season in site 1 and site 2. Also, there was no relation between dry seasons between sites 2 and 3.

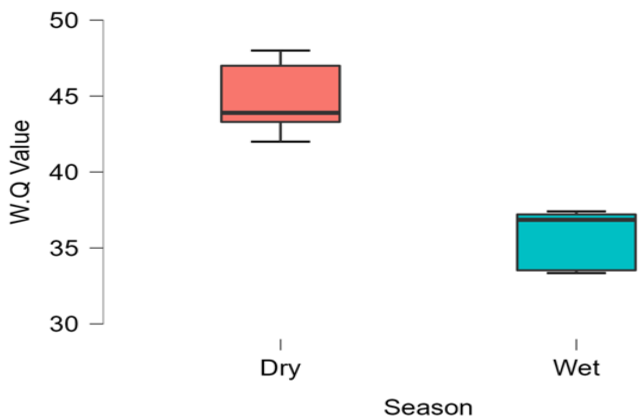

Figure 3. Boxplots of the water quality between the dry and wet seasons

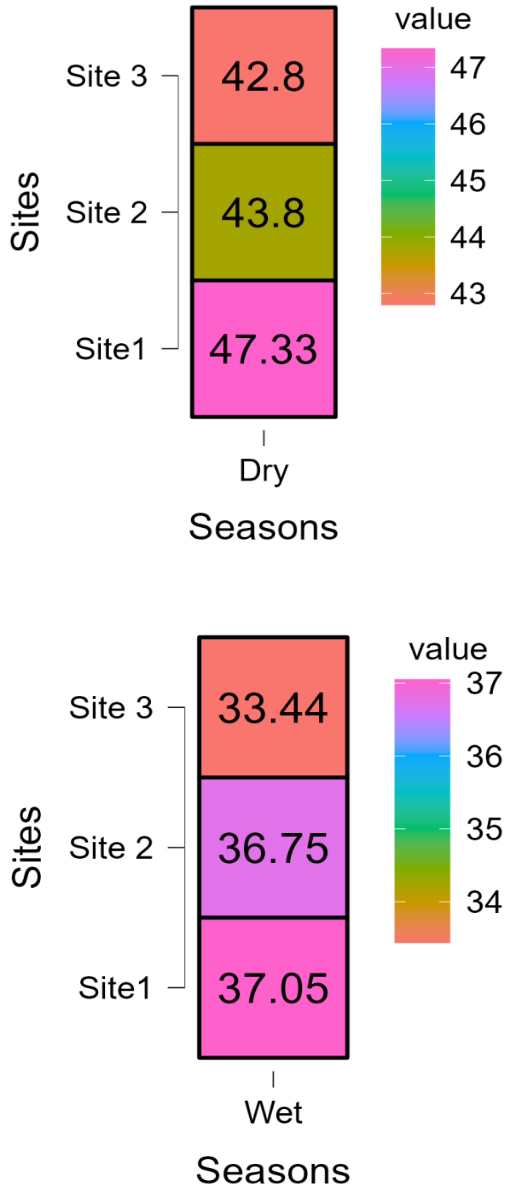

Figure 4. Heatmaps of water quality values between dry and wet seasons

Therefore, the results revealed the change in hydro-chemical properties in BTIL, and the water quality of the lake did not support organisms' life (poor- marginal) and needs to enhance the lake management and keep it within oligotrophic states to prevent eutrophication and support the survival of lake for tourism.

		Mean Difference	SE	t	p_{tukey}	
Dry Site1	Wet Site1	10.284	0.569	18.072	5.987e-9	***
	Dry Site 2	3.533	0.569	6.209	4.996e-4	***
	Wet Site 2	10.580	0.569	18.592	4.419e-9	***
	Dry Site 3	4.533	0.569	7.966	4.512e-5	***
	Wet Site 3	13.894	0.569	24.415	1.251e-10	***
Wet Site1	Dry Site 2	-6.751	0.569	-11.863	6.543e-7	***
	Wet Site 2	0.296	0.569	0.520	0.994	
	Dry Site 3	-5.751	0.569	-10.106	3.762e-6	***
	Wet Site 3	3.609	0.569	6.343	4.108e-4	***
Dry Site 2	Wet Site 2	7.047	0.569	12.383	4.057e-7	***
	Dry Site 3	1.000	0.569	1.757	0.524	
	Wet Site 3	10.360	0.569	18.206	5.535e-9	***
Wet Site 2	Dry Site 3	-6.047	0.569	-10.626	2.190e-6	***
	Wet Site 3	3.314	0.569	5.823	8.902e-4	***
Dry Site 3	Wet Site 3	9.360	0.569	16.449	1.635e-8	***

Table 4. Post Hoc Comparisons - Season ✻ Sites *Note.* P-value adjusted for comparing a family of 6. ** p < .01, *** p < .001

DISCUSSION

The lake water was alkaline (153.61- 172.502) in dry and wet seasons, respectively, while the pH value was in a narrow range (7.48- 7.76) in wet and dry seasons, respectively, and it is within the WHO allowable range [23]. In general, the Iraqi water body is characterized a high buffer capacity of Iraqi aquatic ecosystems [16,20] Omer mentioned that buffering capacity (Alkalinity) is at least 20ppm for the protection of aquatic life and to prevent the rapid change in pH of the lake [25]

EC and Salinity values were recorded as higher than recorded by previous studies [26,27]. The results showed that the lake water is considered oligohaline (0.5-5 ‰) according to [28] A lowest TDS value was 630.29 mg/L (±25.299) in the dry season, and the highest value was recorded in wet seasons (704.866 mg/L (±94.305) and TDS values within the permissible value according to standard values [29] According to TDS values (<1500mg/L) the lake water was freshwater [25]

Moreover, the lake water was well aerated, and the dissolved oxygen was >5 during the study period. However, results showed a decrease in DO concentrations in the present with previous studies on lake[s 26 and 27]. The decrease in DO concentration was referred to the alteration in the water quality of the lake, but still, the current recorded concentration was supporting the life of aquatic organisms [33]

WQI is a tool to summarize a few/ many data in a single term as excellent, good, fair, marginal, or poor [34,35]

CONCLUSIONS

This study aimed to monitor the lake as a water resource and keep it away from eutrophication. It sets the alarm for changes in lake water quality and checks its trophic status to support the use of the lake for touristic purposes.

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