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Application of the Canadian Water Quality Index (CCME-WQI) for Aquatic Life to Assess the Effect of Tharthar Water upon the Quality of the Tigris Water, Northern Baghdad City,Iraq

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Abstract

The present study aims to assess the effect of the Tharthar Canal as an outlet canal that feeds back from the Tharthar Lake on the quality of the Tigris water. Utilizing a Canadian Water Quality Index (CCME-WQI) for the protection of aquatic life Water samples were obtained every month from January to December of 2020. Six different sites were selected: four along the Tigris River and two on the Tharthar Canal. Seven ecological parameters were used to assess water quality depending on importance and availability: water temperature, Water Temperature, Turbidity, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), pH, Nitrate (NO^{3-}) and Phosphate (PO_4^{3-}). The study demonstrated that the water quality of the Tharthr canal ranked as a fair class, whereas that of the main river fluctuated from marginal class before the confluence area to fair class downstream of the confluence. Also, three variables, including water temperature, turbidity, and total dissolved solids, were not meeting water quality standards.

Keywords: Ecological Parameters, River Confluences, Tharthr Lake, Tigris River, Canadian Water Quality Index.

1. Introduction

Water is the most precious resource and abundant compound on the planet's surface [1]. It is important for every form of life, and life without water is impossible as we know it [2]. Water covers around 71% of the Earth's surface, while oceans hold 96.5% of all the water on the planet [3]. Rivers cover only 0.58 percent of Earth's non-glacial land surface [4].

The simplest method for evaluating the condition of water quality is the Water Quality Index (WQI), where it becomes easy to compare quality levels in various sites of rivers and streams to give priority to the necessary treatment of a site [5; 6]. The CWQI is an objective-based index that compares measured water quality values to guidelines to create a number that usually ranges from 0 (worst quality) to 100 (best quality) [7]. In order to calculate the Canadian WQI, at least four variables must be sampled four times [8]. The water quality index of the river's water is affected by various factors such as industrial, agricultural, and human activities [6]. The CCME-WQI for the protection of aquatic life was applied to determine the conditions of different inland waters in Iraq. [9] used this index to assess the water quality of the Al-Radwaniyah-2 drainage. They showed that high turbidity values, TDS, total hardness, magnesium, and fecal coliform were the main reasons for the poor quality of the river. While, [10] found that the CWQI value in Kuffa River changed from good to marginal class. They linked this to the high levels of turbidity and total dissolved solids. Also, [11] showed that the index of Al-Shamyia River water ranged from marginal to good categories. Whereas, [12] found that high values of lead and zinc deteriorated the water quality of the Al-Gharraf River. [13] tested this model to assess the water quality of the Al-Hussainiya River within Karbala City. [14] indicated that the WQI in the Diyala River varied between poor and marginal classes as a result of an increase in the values of total phosphorus and TDS. This model was also applied by [15], who showed that the quality of Al-Diwanyiah River water ranged from poor to marginal. Also , [16] pointed out that the effluent of the Al-Diwaniyah textile factory into the river deteriorated the water quality of the river.

Different indices were applied to assess the water quality of the Tigris River. The National Sanitation Foundation (NFS-WQI) was used by [17] to indicate that the bad quality of Diyala water affected water quality in the Tigris. This, in turn, reduced the values from 52 upstream of the confluence to 46 downstream of the confluence. Also, [18] and [19] employed the Weighted Arithmetic Water Quality Index (WAWQI) for determining the quality of the Tigris River. They showed that the values varied from good to very polluted and attributed them to the direct discharge of different pollutants into the river without any treatment. in addition to differences in regional and hydrological characteristics along the river. Moreover, [20] utilized the Overall Water Quality Index and showed that Tigris water fell under medium-class, attributing that to the increase in turbidity, TDS, and fecal coliform. Whereas, [21] showed that coliform bacteria polluted Tigris water and lowered the overall index. [22] employed a pollution index. They showed that the water quality of the Tigris degraded in southern Baghdad City due to decreasing flow and increasing effluent from industrial and agricultural activities.

2. Materials and methods

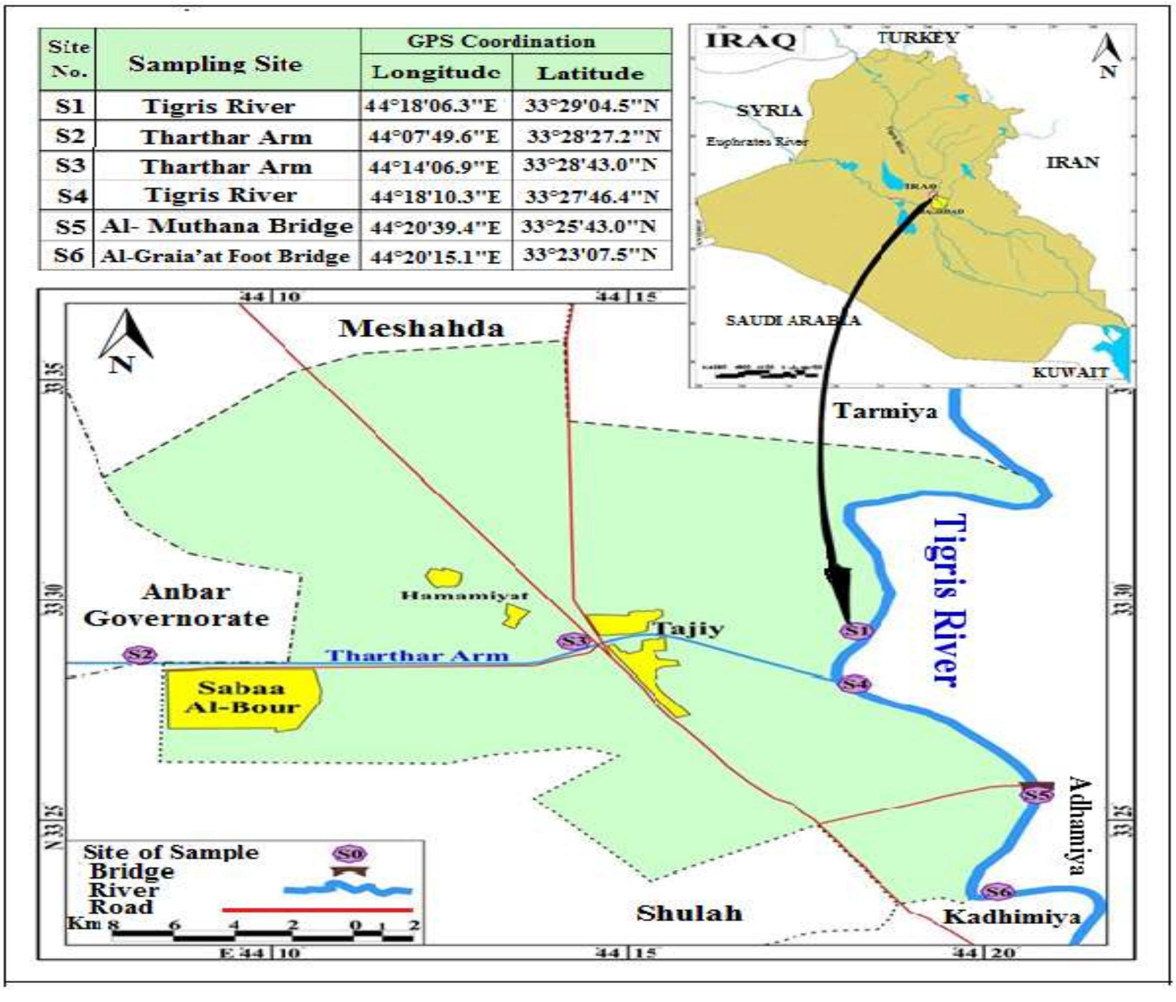
2.1. Study Area

The Tigris River is considered the major water resource for Baghdad Province and splits it into two parts: the eastern part known as "Risafa" and the western part known as "Karkh" [23].

In Baghdad City, the river runs 49 kilometers from Tarmiyah Town until the Diyala River's junction [24]. The Tharthar-Tigris Canal, also known as Dhira'a Dijla, is a man-made canal that takes its properties from the Tharthar Depression. It is converted from the left side of the division regulator, which is on the Tharthar-Euphrates Canal, and then continues east for 65 kilometers till it meets the Tigris River north of Baghdad City. It is designed to discharge up to 600 m^3/s of water directly into the main river [25, 26]. The canal washed the salts out of the stored water, leading to a rise in salinity in the river [25; 26; 27].

2.2. Study Site Description

Samples were collected monthly for one year (2020). Four sites were detected along the river, while two sites were on the canal (**Figure 1**). The first site is located at 33°29'04.5"N; 44°18'06.3"E, north of the confluence of the Tharthar Canal with the Tigris River, termed the upstream Confluence Hydrodynamic Zone. The Second and the third sites are placed on the canal at 33°28'27.2"N; 44°07'49.6"E and 33°28'43.0"N; 44°14'06.9"E. The fourth site is located at 33°27'46.4"N; 44°18'10.3"E, about 300 meters immediately below the confluence zone. The fifth site is located about 6 kilometers below the confluence (33°25'43.0"N; 44°20'39.4"E). the sixth sampling site is close to the Al-Graia'at Bridge area, with a distance of 12.8 kilometers from the confluence at 33°23'07.5"N, 44°20'15.1"E.



Site No.	Sampling Site	GPS Coordination	
		Longitude	Latitude
S1	Tigris River	44°18'06.3"E	33°29'04.5"N
S2	Tharthar Arm	44°07'49.6"E	33°28'27.2"N
S3	Tharthar Arm	44°14'06.9"E	33°28'43.0"N
S4	Tigris River	44°18'10.3"E	33°27'46.4"N
S5	Al- Muthana Bridge	44°20'39.4"E	33°25'43.0"N
S6	Al-Graia'at Foot Bridge	44°20'15.1"E	33°23'07.5"N

Figure 1. Shows the study area northern Baghdad City. Map scale of 1/100000.

The discharge rates of water fluctuated between 474 m^3/s in April and 681 m^3/s in July for the Tigris River, while those in the Tharthar-Tigris Canal fluctuated between 83 m^3/s in August and 250 m^3/s in January (**Figure 2**). Measurements taken from the Iraqi Ministry of Water Resources in 2020.

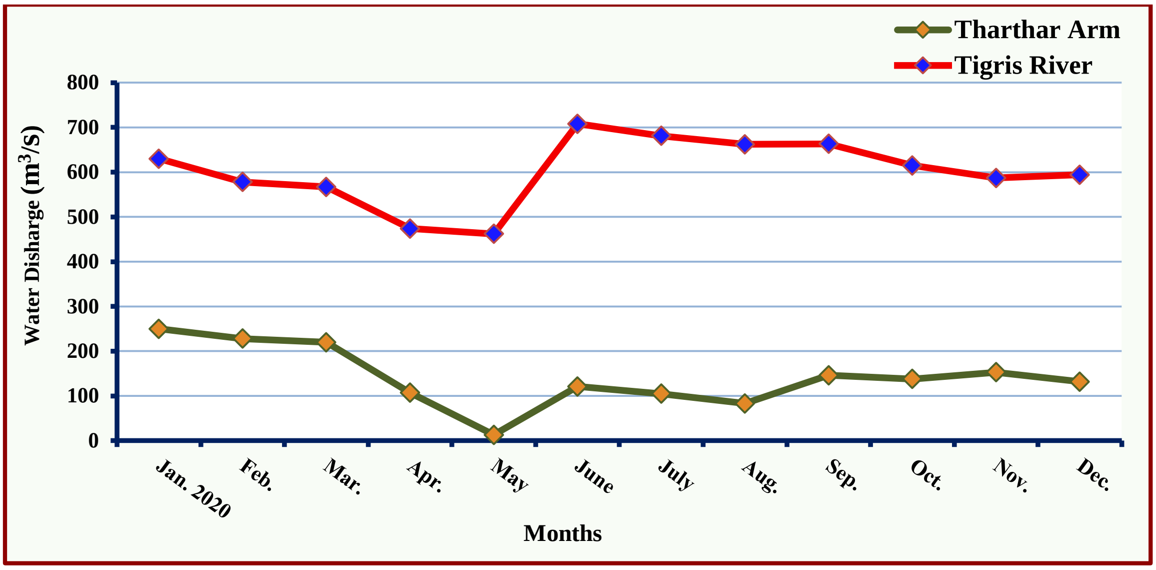


Figure 2. Water discharges in the canal and main river during 2020.

2.3. Sampling and Measurements

Samples were collected away from the riverbank, about 8–10 meters away, at a depth of 30–50 centimeters. Certain parameters, such as turbidity, total dissolved solids, water temperature, and hydrogen ion concentration, are measured directly at the sampling site. Water temperature, TDS, and hydrogen ion concentration were measured by the Hanna portable multiparameter (model HI9811), and turbidity was measured by the portable turbidimeter (model 6035). A modified Winkler's method was used to determine the amount of dissolved oxygen (DO) [28]. The ascorbic acid method was used to determine eques phosphate, and the absorbance was measured at 860 nm [28]. Lastly, the spectrophotometric technique used for determining nitrate levels [29].

2.4. Data for Index Calculation

Seven parameters will be considered in the index calculation (water temperature, turbidity, TDS, pH, DO, nitrate, and phosphate) based on both availability and importance (**Table 1**) [30].

Table 1. Statistical analysis of physicochemical characteristics at study sites during 2020. The first line signifies minimum and maximum value, the second line signifies Means and Standard Errors.

Site Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	LSD Value
Water Temperature (˚C)	10-27 18.90±1.717	12.1-28.2 21±1.8078	12.4-28.4 1.34±1.837	10.7-28.7 0.916±1.838	10.3 - 28.5 20.23±1.78	10.6 - 28.5 20.35±1.819	2.72 NS
Turbidity (NTU)	8.16-131 34.75±9.603 a	6.2-18.37 11.53±1.300 b	3.68-22.33 3.503±1.71 b	10.9-114 28.65± 8.094 a	11.73-118 32.49±8.238 a	12.2-137 34.26±9.636 a	8.55 *
pH	7.38-7.91 7.642 ± 0.049	7.35-7.88 7.66 ± 0.055	7.34-7.93 .68 ± 0.061	7.44-7.89 7.692 ±0.051	7.51-7.91 7.69 ± 0.425	7.41-7.84 7. 63±0.044	0.944 NS
Dissolved Oxygen (mg/l)	8 - 13.1 9.89 ± 0.49	7.7 - 13.6 10.35 ± 0.499	7.8 - 11.9 691 ± 0.428	7.5 - 12.8 9.96 ± 0.468	7 - 11 9.1 ± 0.38	6.5 - 11.3 9.35 ± 0.44	1.26 NS
Total Dissolved Solids (mg/l)	260-560 395 ± 0.025	330-1.040 563 ± 0.05	330-1.400 505 ± 0.08	330-560 471 ± 0.02	340-480 414 ± 0.012	310-470 406 ±0.014	0.298 NS
NO_3^- (mg/l)	0.681 - 1.074 0.9654±0.038	0.317-1.293 0.588±0.0865	0.269-1.226 0.533±0.082	0.291-0.93 0.497±0.055	0.49 - 0.911 0.6577±0.033	0.58-0.998 0.7704±0.033	0.366 NS
PO_4^{3-} (mg/l)	0.00337-0.02 0.0115±0.001	0.0002-0.0193 0.0061±0.004	0.0002 - 0.016 0.0070±0.001	0.0015-0.019 0.0064±0.001	0.0015 - 0.0237 0.0099±0.001	0.00025 - 0.022 0.0125±0.001	0.0109 NS

Notes: Means followed by different letters in same column differed significantly.
* p-value ≤ 0.05. NS: Not Significant.

2.5. Calculation of the Index

Scope, Frequency, and Amplitude are the three factors that make up the index [8, 31].

2.5.1. Factor 1 (F1):

Factor 1, or scope, signifies the percentage of parameters that exceed standard limitations compared to the overall number of parameters:

$$F1 = \left(\frac{\text{Sum of failed parameters}}{\text{Overall number of parameters}}\right) \times 100$$

2.5.2. Factor 2 (F2):

Factor 2, or frequency, refers to the percentage of tests that exceed established limitations on the overall number of tests:

$$F2 = \left(\frac{\text{Sum of failed tests}}{\text{Overall number of tests}}\right) \times 100$$

2.5.3. Factor 3 (F3):

Factor 3, or amplitude, refers to the number of failed tests were determined in three main steps: The first step is to represent the excursion calculation, calculated as explained below.

- When the failed test value exceeds the objective:

$$\textbf{Excursion} = \left(\frac{\textbf{Faild Test Value}}{\textbf{Objective}}\right) - \mathbf{1}$$

- When the failed test value falls below the objective:

$$\textbf{Excursion} = \left(\frac{\textbf{Objective}}{\textbf{Failed Test Value}}\right) - \mathbf{1}$$

The second step is the calculation of the normalized sum of excursions (nse).
Calculated as below:

$$\textbf{nse} = \frac{\sum_{i=1}^{n} \textbf{excursion}}{\textbf{Sum of tests}}$$

Third step is to calculate the amplitude, which is applied using the flowing formula.

$$\textbf{F3} = \left(\frac{\textbf{nse}}{\mathbf{0.01\ nse + 0.01}}\right)$$

The WQI is calculated as: $\mathrm{CCMEWQI} = 100 - \frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}$

Canadian WQI divided into 5 categories as descriptive below in **Table 2** [8, 31].

Table 2. Water quality categorization according to Canadian WQI for aquatic life.

WQI Values	Rank
95-100	Excellent class
80-94	Good class
65-79	Fair class
45-64	Marginal class
0-44	Poor class

3. Results and Discussion

The study examined several variables to calculate the Canadian water quality index, such as Turbidity, TDS, Water Temperature, pH, DO, Nitrate, and Phosphate, which compared with aquatic life guidelines as objectives (**Table 3**).

Table 3. Standard values of physiochemical parameter of CCME-WQI for aquatic life.

Parameter	Standard values
Water Temperatures ˚C	≥15 ˚C
Turbidity	< 5 NTU
TDS	< 500 mg/L
pH	6.5-9
DO	≥ 5.5
Nitrate	< 13 mg/L
Phosphate	< 0.1 mg/L

Figure 3 shows the percentage values of the Canadian index during the study period. At site 1 upstream of the confluence the value was 61.51% and classified as marginal. On the canal, at sites 2 and 3, the values ranged from 69.32% to 68.59%, respectively and were classified as fair. While at site 4 immediately downstream confluence zone the value was 63.20% and classified as marginal. Away from the confluence, the values were 67.89% at site 5 and 67.18% at site 6, and both were classed as fair. These results depend on the number of failed variables and the number of failed tests, as summarized in **Table 4**.

In addition, statistical analysis for turbidity showed significant differences between the two different running waters at the level P≤ 0.05. Whereas, no significant differences between the two sites on the canal as seen in **Table 1**. This finding could be attributed to the high discharged water in Tigris which led to an increase of turbidity (**Figure 2**) [26].

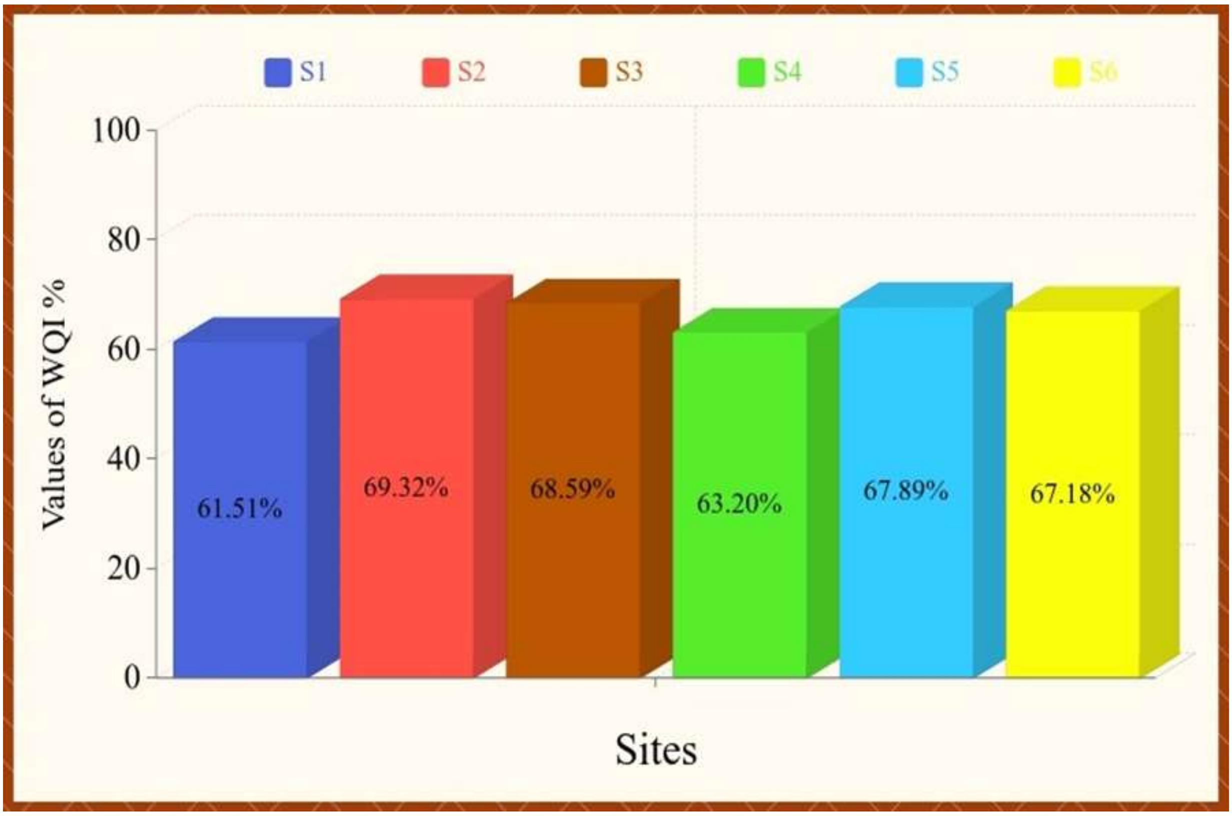


Figure 3. Spatial variations of water quality index among six different sites using the CCME-WQI.

Although the statistical analysis for water temperatures indicates no significant differences among six sites at level 0.05 as shown in **Table 1**. But the temperatures exceeded the standard values especially in cold months coincided with the surrounding air temperature, which decreased during the winter. This fact proved by [26] showed that seasonal variations in water temperature respond to the climate of the region. The statistical analysis of TDS also showed no significant differences (P> 0.05) among all studied sites. However, we found TDS value in Tharthar water exceeded the allowable limits of the Canadian index. Lead to increasing their value immediately downstream of the confluence. We can attribute that to differences in topographic features and geomorphological characteristics within catchment areas in addition to variations in precipitation, climate conditions, and human activities. [25, 27].

Table 4 gives a clearer vision of the conditions of water quality at the study sites and sums up the WQI calculation. As well, shows which water quality variables crossed the allowable levels for aquatic life during the study period.

Table 4. Summary of failed variables and tests for water quality index for each site.

Sites	Number of failed variables	Number of failed tests	Variables with most failed tests
Site 1	3	18	Water temperature, Turbidity, TDS
Site 2	3	22	Water temperature, Turbidity, TDS
Site 3	3	21	Water temperature, Turbidity, TDS
Site 4	3	20	Water temperature, Turbidity, TDS
Site 5	2	15	Water temperature, Turbidity
Site 6	2	15	Water temperature, Turbidity

The present study agrees with many former studies that have been applied to CCME-WQI for aquatic life to evaluate the water quality along the Tigris River inside Baghdad City. [32] showed that the values of the index rated from marginal north of Baghdad to poor class south of Baghdad. They attributed that to an increase in the levels of lead, iron, zinc and turbidity. Also, [33] observed that WQI ranged from marginal in the Al-Kriat area to poor near the Diyala Bridge area. Because of the increase in values of total nitrogen, water temperature and BOD5. Furthermore, [34] showed that water quality was affected by the discharge of Al- Rasheed power plant. Thus, the index changed from fair in winter to marginal in summer, also discharging high-temperature water decreased DO and pH values into the river. Also, [35] explained that the values of this index fluctuated between 56 (marginal) to 69 (fair) near Al-Mishahda Town north of Baghdad related to the Anthropogenic effects.

However, our findings disagree with, [36] finding that the water quality of the Tharthar-Tigris Canal lies within a poor grade. While, in Tigris near the Al-Muthana bridge area is classified as good quality. This contrast may be related to differences in time and sampling sites. Additionally, physicochemical characteristics of the riverine ecosystem change over time dependent on hydrological, climatological, and regional factors.

4. Conclusion

We can conclude that the values of CCME-WQI are affected by the number of parameters that enter its calculation, such as water temperature, turbidity, and TDS in both Tigris and Tharthar water. While the values of PH, DO, phosphate, and nitrate ions remain within the permissible limits. As well, we can use this index to assess the quality of water for different purposes, such as agriculture, freshwater, and drinking purposes, depending on the availability of physicochemical factors.

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Conflict of Interest Statement

The author declares no conflict of interest.

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