Journal of Techniques, ISSN: 2708-8383, Vol. 5, No. 4, 2023, Pages 141-147
DOI: https://doi.org/10.51173/jt.v5i4.1326

JOURNAL OF TECHNIQUES

Journal homepage: http://journal.mtu.edu.iq

RESEARCH ARTICLE - ENGINEERING

Water Quality Index of the Tigris River in the Central of Iraq

Noor A. H. Alharbawee[1*], Ahmed Jasim Mohammed[1], Wesam Mahmood[2]

[1]College of Science, University of Baghdad, Baghdad, Iraq

[2]Institute of Technology / Baghdad, Middle Technical University, Baghdad, Iraq

[*] Corresponding author E-mail: nalharbawee@gmail.com

Article Info.

Article history:

Received
12 March 2023

Accepted
18 May 2023

Publishing
31 December 2023

Abstract

An attempt has been made to evaluate the water quality of the Tigris River in the central of Iraq. 13 physical and chemical factors were monitored at 5 monitoring stations from October 2021 to September 2022. Water quality index (WQI) technique, namely, the Bascaron Water Quality Index (BWQI) was used to explore the quality of the river, which is one of the most applied indices to assess the river's water quality. The result presented was that the WQI final values dropped from the north to the south gradually and were determined to be between 57.08 and 70. The Jisr Diyala station had the lowest WQI rating, while the Balad station had the greatest value. The water quality of the Tigris River in the study area has been classified as "medium" water quality according to BWQI. This is mostly caused by the increase of agricultural, domestic, and industrial activities that increase the amount of pollution in the river when the water is flowing southward.

Publisher: Middle Technical University

Keywords: Water Quality Index; Bascaron WQI; Tigris River; Water Pollution; Water Quality.

1. Introduction

One of the best old ways to judge the quality of water is to compare the value of a parameter in a sample of water to the acceptable range for that parameter. For an accurate assessment of the river's water quality, it is important to find out a lot of different things. Even for professionals in the water industry, it might be hard to figure out how to interpret and list these parameters. In addition, it does not always provide a comprehensive view and an integrated understanding of the quality of the water [1, 2]. Consequently, several approaches, like multivariate statistical methods and water quality indexes, have been applied to address this issue [3-6]. In this research, the water quality index was employed as a supporting tool to give clear, straightforward, and intelligible information on the Tigris River's water quality state.

The water quality index (WQI) is the total number of observations of water quality criteria that are used to make a single number that shows the overall quality of the water. This means that a lot of information about the quality of water is combined into a single value [7-9]. Most of the time, the WQI is measured on a scale from 0 to 100 [10], where higher numbers mean better water quality and lower numbers mean worse water quality [11-13]. It can also be used to describe the quality of water for different uses, such as drinking, farming, and industry. Important WQI phases are [14, 15]:

- Choosing the parameters of the quality of water to be assessed.
- Measurement or analysis of each selected water quality parameter
- Transform the evaluation of water quality factors into a dimensionless value by employing sub-indices and presenting them on the same scale.
- Assigning each water quality measurement weight.
- The accumulation of WQI's component indices to get an overall value for the WQI.

It is possible to divide the sub-indices, which are found in step 3, into the following four categories: linear, nonlinear, segmented linear, and segmented nonlinear [16]. In the case of such indices, the fourth step of the computation for WQI is completely disregarded. In addition, the last step (step 5) can be determined using a variety of methods, including additive aggregation (such as the arithmetic mean), multiplicative aggregation (such as the geometric mean), logical aggregation (such as the minimal operator of Smith indices), and logical aggregation (such as the geometric mean) (e.g., a combination of processes). Combining several methods of investigation is another way to arrive at Step 5. (e.g. square root harmonic mean). Several indices, including [17], the multiplication aggregation [18-20] the logic aggregation [21], and the merging of processes [22, 23], have been established based on addition aggregation functions. There have been numerous WQI models developed in the literature. Lumb et al. (2011) and Sutadian et al. (2016) [11, 24] provide an in-depth analysis of WQI's evolution. In the present investigation, the Bascaron Water Quality Index (BWQI) (Bascaron 1979) was chosen due to its widespread use around the globe [13, 25, 26] In this study,

Nomenclature & Symbols

BOD	Biochemical Oxygen Demand	SO_4	Sulfate
Ca+	Calcium Ion	TDS	Total Dissolved Solids
CL	Chloride	TH	Total hardness
DO	Dissolved Oxygen	TSS	Total Suspended Solids
EC	Electrical Conductivity	Turb.	Turbidity
Mg+	Magnesium Ion	WQI	Water Quality Index
pH	Hydrogen Ion Concentration	WT	Water Temperature

the Bascaron water quality index model was used to find out if it was a good way to measure the quality of the water in the Tigris River Basin and to get direct and easy-to-understand information about the spatial variation.

2. Methodology

2.1. Study area

One of the longest rivers in the Middle East, the Tigris River, has a catchment area of 235,000 km^2 and a length of about 1,900 km, passing through Iraqi land nearly 1415 km. The river shares this role with the Euphrates River as the primary source of water for human consumption, particularly for water supply since they are through the main cities in the region [27]. The Tigris River flows through Syria, Iraq, and Turkey, beginning in the Toros Mountains in southeast Turkey. Baghdad, the metropolis of Iraq, relies primarily on the Tigris River for its water provision. Numerous tributaries include the Botmanse, Kessora, A1-Khabur, Greater Zabs, Lesser Zabs, Al-Adhaim, and Diyala Rivers [28]. From the north to the south flow, the river splits the city of Baghdad into two sides: the right side (Al-Karkh) and the left side (Al-Risafa). The region has a dry, hot, and semi-arid environment with cold winters and an average annual precipitation of about (151.8 mm) [29]. More than eight million residents live in Baghdad, which is regarded as the most populous and developed metropolis in Iraq [30]. Most industrial and municipal waste is dumped into the stream without being properly treated [31].

2.2. Sampling and analysis

Five locations have been selected for sampling on the reach of the Tigris river, namely: Balad (S1), Al-Ghrai'at (S2), Al-Shuhada'a Bridge (S3), Al-Za'franiya (S4), and Jisr Diyala (S5) as shown in Fig. 1 and Table 1. Data for five water quality monitoring locations for thirteen water quality parameters were collected by using polypropylene bottles at seasonal intervals from sampling locations between October 2021 and September 2022. For the analysis of several water quality parameters, sampling was used following the recommendation of standard methods [31]. The bottles have been utilized for the examination of water quality parameters. Sampling bottles have been used to collect water samples for BOD analysis to prevent unanticipated changes, and the analysis of the water samples has been begun as soon as feasible following collection. Samples of microorganisms were collected in sterile, opaque glass containers. Within around 24 hours, the bottles were examined while being stored at +4. The Department of Water Resource Techniques' biological and chemical laboratory, Institute of Technology-Baghdad Middle Technical University, and the Department of Biology's central laboratory, of the College of Sciences, University of Baghdad, have both conducted analyses of the collected Samples.

The tested parameters have included electrical conductivity (EC), water (pH), water temperature (WT), Turbidity (Turb.), Total hardness (TH), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), sulphate (SO_4), Magnesium ion (Mg+), Calcium ion (Ca+), Total Dissolved Solids (TDS), Chloride (Cl), and Total Suspended Solids (TSS).

Table 1. The geographical location of sampling sites

Sites	Sites Name	Latitude	Longitude
S1	Balad	33°59'45.08"N	44°13'28.75"E
S2	Al- Ghrai'at	33°23'10.21"N	44°20'15.94"E
S3	Al-Shuhada'a Bridge	33°20'18.20"N	44°23'15.27"E
S4	Al-Za'afarania	33°13'51.45"N	44°27'27.58"E
S5	Jisr Diyala	33°12'24.79"N	44°29'43.11"E

2.3. Bascaron WQI

The Bascaron WQI (BWQI) was initially developed in Europe (Spain) [32] and it has since found widespread use around the globe [15, 25, 26] The total score is currently being evaluated as a subjective measure of water quality.

$$\mathrm{WQI_{sub}} = k\,\frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \quad (1)$$

Where:
n: the variable's total number,
Ci: the value that was assigned to variable i after it was normalized,
Pi: the relative weight that was allocated for each variable ranged from (1-4) based on how much of an impact it had on the water quality (4 being the most impactful and 1 being the least impactful).
k: the subjective constant that was determined by the observer's subjective perception of the level of river contamination.

The value of k can be either 0.25, 0.5, 0.75, or 1. The fundamental factors that should be used to pick one of these values are outlined in PDE Solutions Inc. (2020) [33]. In contrast, the value of k was taken to be 1, as that was the only way to account for the fluctuations that could be attributed to the variables that were measured [33, 34].

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \quad (2)$$

The fact that a large number of water quality variables may be incorporated in the calculation of the final index using the BWQI is the most significant benefit of using this index. This occurs after the normalization factors and their weights have been assigned. On the other hand, there were only 22 water quality factors that have previously been standardized and weighted in several different studies that were presented (Table 2) [15, 35-37]. The technique of evaluating water quality in this study involves consideration of a total of twelve criteria, including temperature, pH, DO, BOD, EC, Turbidity, Total Hardness (TH), Mg+, Ca+, SO_4, TDS, TSS, and Cl. To get the final BWQI, the normalization factors and their respective weights, which are shown in Table 3, were applied to the parameters that were chosen. The following categorization system was chosen to be used for determining the quality of the water [15, 35]:

- Excellent: 90-100
- Good: 71-90
- Medium: 51-70
- Bad: 26-50
- Very bad: 0-25

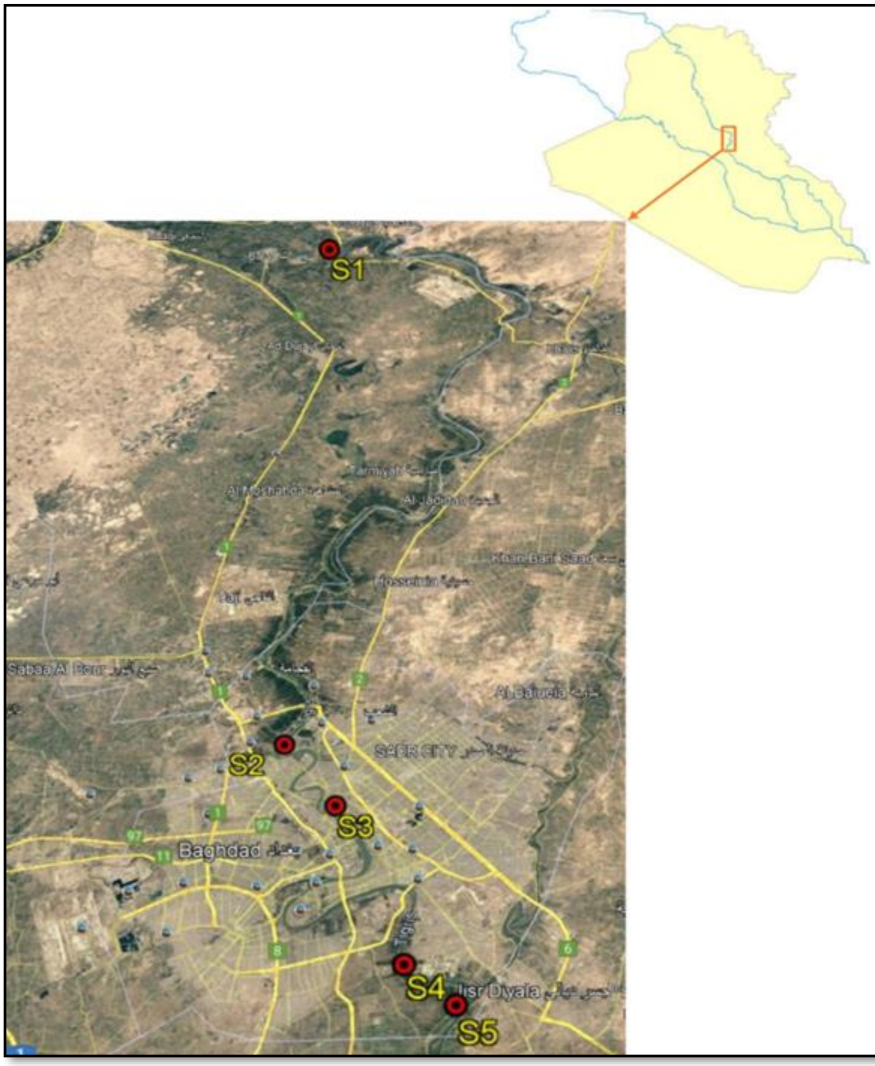

Fig. 1. Study area and sampling locations [38]

The BWQI was selected because it allows for the inclusion of a large number of water quality indicators in the calculation of the final index after weighting the normalization factors and normalization factors' coefficients. The factors for measuring water purity that has already been normalized and weighted in previously published research are shown in Table 3 [15, 35, 36]. In this research, thirteen parameters of water quality (PH, Water Temperature., EC, Turbidity, Total Hardness TH, DO, BOD, Mg+, Ca+, SO_4, TDS, Cl, and TSS) have been evaluated. and NO_3. Na, K, and HCO_3 were not included in the calculation of BWQI as these parameters have no normalization and weight.

Table 2. Water quality variables that have been normalized and weighted in previously reported studies

Variables	Units	Relative Weight (Pi)	Normalization Factor (Ci)										
			100	90	80	70	60	50	40	30	20	10	0
WT	˚C	1	21/16	22/15	24/14	26/12	28/10	30/5	32/0	36/−2	40/−4	45/−6	>45/<−6
pH	-	1	7	7-8	7-8.5	7-9	6.5-7	6-9.5	5-10	4-11	2-12	2-13	1-14

E. Cond.*	µS/cm	1	<750	<1000	<1250	<1500	<2000	<2500	<3000	<5000	<8000	<=12000	>12000
DO	mg/L	4	>=7.5	>7	>6.5	>6	>5	>4	>3.5	>3	>2	>=1	<1
TDS	mg/L	2	<100	<500	<750	<1000	<1500	<2000	<3000	<5000	<10000	<=20000	>20000
TSS	mg/L	4	<20	<40	<60	<80	<100	<120	<160	<240	<320	<400	>400
Ca	mg/L	1	<10	<50	<100	<150	<200	<300	<400	<500	<600	<=1000	>1000
Mg	mg/L	1	<10	<25	<50	<75	<100	<150	<200	<250	<300	<=500	>500
TH	mg/L	1	<25	<100	<200	<300	<400	<500	<600	<800	<1000	<=1500	>1500
Cl^-	mg/L	1	<25	<50	<100	<150	<200	<300	<500	<700	<1000	<=1500	>1500
SO4	mg/L	2	<25	<50	<75	<100	<150	<250	<400	<600	<1000	<=1500	>1500
PO4	mg/L	1	<0.025	<0.05	<0.1	<0.2	<0.3	<0.5	<0.75	<1	<1.5	<=2	>2
TP	mg/L	1	<0.2	<1.6	<3.2	<6.4	<9.6	<16	<32	<64	<96	<160	>160
NH4	mg/L	3	<0.01	<0.05	<0.1	<0.2	<0.3	<0.4	<0.5	<0.75	<1	<=1.25	>1.25
NO3	mg/L	2	<0.5	<2	<4	<6	<8	<10	<15	<20	<50	<=100	>100
NO2	mg/L	2	<0.005	<0.01	<0.03	<0.05	<0.1	<0.15	<0.2	<0.25	<0.5	<=1	>1
BOD	mg/L	3	<0.5	<2	<3	<4	<5	<6	<8	<10	<12	<=15	>15
COD	mg/L	3	<5	<10	<20	<30	<40	<50	<60	<80	<100	<=150	>150
Oil & grease	mg/L	2	<0.005	<0.02	<0.04	<0.08	<0.15	<0.30	<0.60	<1.00	<2.00	<=3.00	>3.00
Turbidity	NTU	2	<5	<10	<15	<20	<25	<30	<40	<60	<80	<=100	>100
Surfactant as MBAS	mg/L	4	<0.005	<0.06	<0.10	<0.25	<0.50	<0.75	<1.00	<1.50	<2.00	<=3.00	>3.00
Total coliform	MPN _ 100/ml	3	<50	<500	<1000	<2000	<3000	<4000	<5000	<7000	<10000	<=14000	>14000

3. Results and Discussions

3.1. Physicochemical characteristics

Five stations in the research region were used to monitor the water quality throughout the period (Oct 2021 to Sep 2022) as the monitoring stations are displayed in Fig. 1. PH, water temperature, (EC), (TBR), (TH), (DO), (BOD), (Mg+), (Ca+), (SO_4), (TDS), (Cl), and (TSS), parameters have been chosen for the assessment of surface water quality characteristics. Table 3 presents the average annual value of the selected parameters for each sampling location during the study period, which has been measured by this study.

The finding shows that the PH annual average value ranged between 7.68 and 8.05, which indicates that the Tigris River samples ranged from nearly neutral to sub-alkaline at all stations. The highest value was recorded at the Al-Shuhada'a Bridge station in the heart of Baghdad, and the lowest at the Balad station to the north. According to the limitations of IQS and WHO standards [39, 40], the resulting PH values are acceptable. The average annual water temperature value was almost equal at all stations, the highest value has been recorded at Al-Ghrai'at station at 21.3 °C, the minimum value was at Jisr Diyala at 19.9 °C, and the other three stations were between them and agreed with Al-Murib et al.'s (2019) [41]finding with a slight difference (Table 3). The difference may occur due to the sampling time during the day because all the sampling work has been done in the early morning in faraway destinations from the analysis laboratory.

The EC varied between 511.5 mg/L at the Balad station and 896.75 mg/L at the Jisr Diyala station, in addition to at other locations in between, the results show. The added pollutant load caused the EC value to significantly rise as the river moved south. The Jisr Diyala station recorded the lowest turbidity value, 25.18 NTU, and the Balad station recorded the highest value, 43.08 NTU other stations varied as shown in Table 3. The main cause of the increasing annual average value for turbidity at Balad Station is the high flow rate of the river's water in this area because of releases from the Samarra Dam [42]. On the other hand, the river flow gradually decreases to the entrance of Baghdad at the Al-Ghrai'at station, which has 32.43 NTU and 30.85 NTU at the Al-Shuhada'a Bridge station, and the turbidity value has increased at the Al-Za'afarania station with an average annual value equal to 40.93 NTU, the increase at this station being due to the rise of industrial and domestic pollutants. The primary causes of the elevated turbidity are surface runoffs and household waste [43]. The drop of it at the Jisr Diyala station because of the connection of the Diyala River to the Tigris River affects the quality of the water in it and all other variables [44].

Total hardness (TH), another crucial water parameter, is mainly brought on by the existence of anions like carbonates and chloride as well as cations like calcium and magnesium in the water. According to the findings, the TH fluctuated between 262.5 mg/L at the Balad station and 470 mg/L at the Jisr Diyala station, in addition to at other sites in between. The overall hardness value considerably rose as the river flowed southward due to the increased pollutant burden. The average value of DO in the study ranged at all five stations from 4.18 to 7.83 mg/l. The maximum value was measured at the Balad station, while the lowest was measured at the Jisr Diyala station. According to Naubi et al. (2016)[45], water with a dissolved oxygen concentration of under 5 mg/L could be considered unhealthy water, which is what happened at Al-Za'afarania and Jisr Diyala, where the average DO value was below 5 mg/L and its acceptable at the three other stations (Table 3).

BOD is the amount of oxygen consumed by microorganisms in five days to deteriorate organic compounds in freshwater. As shown in Table (3) the average BOD value is limited between (1.5 and 5.25) mg/L. Jisr Diyala station had the highest average BOD5 concentration, while

Balad station had the lowest. When the river passed from the north to the south of the city of Baghdad, the average BOD values in the five monitoring stations raised considerably due to the increasing release of organic wastes. The results show that the calcium Mg+ range was 14.4 mg/L to 49.2 mg/L. The highest value has been indicated at Jisr Diyala station in the south of the study area, the lowest at Balad station in the north, and other stations as well between them (Table 3). In Iraq's freshwater water, calcium Ca+ is one of the most prevalent elements. Water becomes harder and boilers develop incrustation due to a rise in calcium content. The results show that the calcium range was 81 mg/L to 106 mg/L. The highest value has been indicated at Jisr Diyala station in the south of the study area, the lowest at Balad station in the north, and other stations as well between them (Table 3). On the other hand, the range of magnesium Mg+ was 14.4 mg/L to 49.2 mg/L. Jisr Diyala station in the research area's south has the greatest value, Balad station in the north has the lowest, and there are other stations in between as well (Table 3).

Sulphate exists naturally in surface water as SO4. The main sources of SO_4 are discharges from waste disposal, domestic waste, and untreated sewage. The results show that the lowest concentration, 20.64 mg/L, was recorded at Balad station, while the highest was 41.76 mg/L at Jisr Diyala station (Table 3). The SO_4 levels that were discovered are acceptable based on the upper and lower bounds of IQS and WHO guidelines (IQS, 2009; WHO, 2011). All study stations had average annual total dissolved solids levels that ranged from 174 to 324.5 mg/L, with the Jisr Diyala station having the highest value at 324.5 mg/L and the Balad station having the lowest at 174 mg/L and other stations between them (Table 3).

TDS readings greatly rose as the river moved from the north to the south of Baghdad due to extensive anthropogenic activity along the river's path and run-off with a high suspended matter concentration[46]. Table 3 shows the Cl ranged from 228.5 mg/L at the Balad station to 444.38 mg/L at the Jisr Diyala station, in addition to other locations in between. As the river made its way south, the amount of pollutant burden increased, which resulted in a substantial rise in the Cl number. The analysis results show that the Al-Shuhada'a Bridge station has recorded the lowest TSS value, 300 mg/L, while Balad and Al-Za'afarania stations recorded the highest value, 600 mg/L, and the other two stations varied, although the Al-Ghrai'at station has a value equal to 550 mg/L and the Jisr Diyala station has 400 mg/L.

Table 3. Average annual value of the water quality parameters at the sampling location

Sample locations	PH	Water Temp.	EC	Turb.	TH	DO	BOD	Mg+	Ca+	SO_4	TDS	Cl	TSS
Balad	7.68	19.93	511.5	43.08	262.5	7.83	1.5	14.4	81	20.64	174	228.5	600
Al- Ghrai'at	7.91	21.3	736.75	32.43	365	7.53	2	35.4	87	29.28	246.5	306.6	550
Al-Shuhada'a Bridge	8.05	21.23	770	30.85	357.5	7.33	2.75	35.4	84	31.2	253.25	325.9	300
Al-Za'afarania	7.78	20.1	862.5	40.93	417.5	4.73	3.5	31.2	115	35.04	296.25	374.85	600
Jisr Diyala	7.72	19.9	896.75	25.18	470	4.18	5.25	49.2	106	41.76	324.5	444.38	400

3.2. BWQI analysis

The Bascaron Water Quality Index (BWQI) has been utilized to evaluate water purity in comparison to the norm for various uses and to shed light on how much anthropogenic influence affects the quality of the water [15]. The calculation of overall quality indices for all stations is given in Table 4. The highest value of WQI for the Tigris River reached 70 at Balad station, while the lowest value of WQI reached 57.08 at the Jisr Diyala station. The values of the BWQI indicate that the river's water quality is located in the medium range at all of the stations. The average annual value of the thirteen selected variables shows that the majority of the variables have an acceptable case except some of them were significantly affected by the result of the water quality assessment, which was turbidity, TDS, Cl, and TSS at all stations, as well as, the TH and DO recorded value at Za'franiya and Jisr Diyala stations.

Table 4. Lists the BWQI index's sub-index values, proportional weight, WQI, and classification values

Sample locations	Sub-index values (Ci)													BWQI	Categorization
	PH	Water Temp.	EC	Turb.	TH	DO	BOD	Mg+	Ca+	SO4	TDS	Cl	TSS		
Balad	90	100	100	70	100	90	100	80	100	90	50	30	0	70	Medium
Al- Ghrai'at	90	90	100	60	100	90	80	80	90	90	40	40	0	65.41	Medium
Al-Shuhada'a Bridge	90	90	90	60	90	80	80	80	90	90	40	40	30	67.91	Medium
Al-Za'afarania	90	90	90	60	50	70	80	70	90	90	40	40	0	59.16	Medium
Jisr Diyala	90	100	90	60	50	50	80	70	90	90	40	60	0	57.08	Medium
Relative weight (Pi)	1	1	1	2	1	4	3	1	1	2	2	1	4	$\sum P_i = 24$	

All of the BWQI readings from the places that were looked at showed that the water was polluted and had high levels of TDS, chloride, and TSS as well as DO and Total hardness at Al-Za'afarania and Jisr Diyala stations. This could be because of bad waste management, a lot of urban and rural runoff, sewage, too much application of inorganic fertilizer, and bad operation and maintenance of wastewater systems[47, 48]. Previous readings of the BWQI show that the environmental quality of the Tigris River in the research area may be getting worse. The discharge of pollutants from domestic sewage systems, water from natural and industrial waste releases, agricultural runoff, and other sources to a water resource system can have major impacts in the short and long term on the river's quality[15]. However, the ecological factors and WQI that were used in this study give us a general idea of how dirty the Tigris River is as a whole. Given the high levels of TDS, chloride, TSS, and turbidity, as well as DO and Total hardness in some stations, we can infer from this that the Tigris River water in the research region was mildly contaminated. As a consequence, this water is indeed not suitable for year-round direct public use. Furthermore, every other aspect of the water's purity was within the boundaries established by the Iraqi standards and WHO guidelines for drinking water. To provide clean, potable water for the people of Baghdad, we need to take quick action to prevent the water quality of the Tigris River from further deteriorating.

4. Conclusions

The Bascaron water quality index (BWQI) method was applied to a Tigris River water quality dataset covering the period between October 2021–September 2022. The results indicated that the WQI final values decreased steadily from the north to the south, dropping to a range of 57.08 to 70. The Jisr Diyala station scored the lowest on the WQI, while the Balad station scored the highest. According to the BWQI data, the Tigris River in the research area has "medium" water quality. Most of the thirteen selected variables have acceptable incidents based on their average annual values, but the result of the water quality assessment significantly impacted turbidity, TDS, Cl, and TSS at all stations, as well as TH and DO, which have low values at Za'franiya and Jisr Diyala stations due to their relatively heavily polluted locations. The BWQI methodology was found to be an excellent method for evaluating ecosystems and providing explanations for complex data sets about river water quality.

Acknowledgement

Thanks to the staff laboratories of the Department of Water Resource Techniques at the Institute of Technology-Baghdad/Middle Technical University, and to the staff of the central laboratory at the Department of Biology in the College of Sciences, University of Baghdad.

References

[1] T. A. Joyner and R. V. Rohli, "Atmospheric influences on water quality: a simulation of nutrient loading for the Pearl River Basin, USA," Environmental monitoring and assessment, vol. 185, pp. 3467-3476, Aug. 2013. https://doi.org/10.1007/s10661-012-2803-x.

[2] D. Subhasish, "Fluvial Hydrodynamics: Hydrodynamic and Sediment Transport Phenomena-GeoPlanet: Earth and Planetary Sciences," New Delhi, India, pp. 158-162, Sep. 2014.

[3] A. H. Ismail, M. A. Shareef, and W. Mahmood, "Hydrochemical characterization of groundwater in Balad district, Salah Al-din governorate, Iraq," Journal of Groundwater Science and Engineering Vol, vol. 6, Dec. 2018. http://dx.doi.org/10.19637/j.cnki.2305-7068.2018.04.006.

[4] K. Yürekli, M. Erdoğan, A. H. Ismail, and M. A. Shareef, "How far can hydrochemical characteristics of surface water meet drinking and irrigation criteria: a pragmatic study for the Euphrates river basin, Turkey," Sustainable Water Resources Management, vol. 7, pp. 1-11, Apr. 2021. https://doi.org/10.1007/s40899-021-00507-x2 021.

[5] F. Mahdi, B. A. Razzaq, and M. Sultan, "Assessment of Shatt Al-Arab Water Quality Using CCME/WQI Analysis in Basrah City of South Iraq," Iraqi Journal of Science, pp. 480-491, Jan. 2023. https://doi.org/10.24996/ijs.2023.64.1.42.

[6] K. G. Sabeeh, M. T. Mustafa, A. H. Ismail, and C. Boncescu, "Evaluation of Water Quality at the Confluence Region of Diyala and Tigris Rivers Based on the Weighted Arithmetic Method," Journal of Techniques, vol. 5, pp. 58-65, Mar. 2023. https://doi.org/10.51173/jt.v5i1.1088.

[7] N. S. Hanna, Y. A. Shekha, and L. A.-Q. Ali, "Water quality assessment of Rawanduz River and Gali Ali Beg stream by applied CCME WQI with survey aquatic insects (Ephemeroptera)," Iraqi Journal of Science, pp. 2550-2560, Dec. 2019. https://doi.org/10.24996/ijs.2019.60.12.3.

[8] I. M. Makki and J. K. Manii, "Water Quality Index of Euphrates River Near Al-Musayyab Power Plant," Iraqi Journal of Science, pp. 3002-3008, Oct. 2020. https://doi.org/10.24996/ijs.2020.61.11.21.

[9] S. I. Wadeea, R. M. Hamdoon, and M. S. Al-Zuhairy, "Effects of Industrial Wastewater on Water Quality Tigris River at Baghdad Using (GIS) Technique," Journal of Techniques, vol. 4, pp. 1-11, Dec. 2022. https://doi.org/10.51173/jt.v4i4.569.

[10] C. Iticescu, G. Murariu, L. P. Georgescu, A. Burada, and C. M. Topa, "Seasonal variation of the physico-chemical parameters and Water Quality Index (WQI) of Danube water in the transborder Lower Danube area," Rev. Chim, vol. 67, pp. 1843-1849, Sep. 2016.

[11] A. Lumb, T. Sharma, and J.-F. Bibeault, "A review of genesis and evolution of water quality index (WQI) and some future directions," Water Quality, Exposure and Health, vol. 3, pp. 11-24, Mar. 2011. https://doi.org/10.1007/s12403-011-0040-0.

[12] S. Marsili-Libelli and E. Giusti, "Water quality modelling for small river basins," Environmental Modelling & Software, vol. 23, pp. 451-463, Apr. 2008. https://doi.org/10.1016/j.envsoft.2007.06.008.

[13] J. Chen, T. Yang, Y. Wang, H. Jiang, and C. He, "Effects of ecological restoration on water quality and benthic macroinvertebrates in rural rivers of cold regions: A case study of the Huaide River, Northeast China," Ecological Indicators, vol. 142, p. 109169, Sep.2022. https://doi.org/10.1016/j.ecolind.2022.109169.

[14] K. A. Shah and G. S. Joshi, "Evaluation of water quality index for River Sabarmati, Gujarat, India," Applied Water Science, vol. 7, pp. 1349-1358, Jul. 2017. https://doi.org/10.1007/s13201-015-0318-7.

[15] A. H. Ismail and D. Robescu, "Assessment of water quality of the danube river using water quality indices technique," Environmental Engineering and Management Journal, vol. 18, pp. 1727-1737, Aug. 2019. http://www.eemj.eu/index.php/EEMJ/article/view/3929\.

[16] T. Abbasi and S. A. Abbasi, Water quality indices: Elsevier, 2012. https://doi.org/10.1016/C2010-0-69472-7.

[17] R. K. Horton, "An index number system for rating water quality," J Water Pollut Control Fed, vol. 37, pp. 300-306, 1965.

[18] R. M. Brown, N. I. McClelland, R. A. Deininger, and J. Landwehr, "Validating the WQI," in Proceedings of the National Meeting of American Society of Civil Engineers on Water Resources Engineering, Washington, DC, USA, 1973.

[19] D. S. Bhargava, "Expression for drinking water supply standards," Journal of Environmental Engineering, vol. 111, pp. 304-316, Jun. 1985. https://doi.org/10.1061/(ASCE)0733-9372(1985)111:3(304).

[20] S. Dinius, "Design of an index of water quality 1," JAWRA Journal of the American Water Resources Association, vol. 23, pp. 833-843,

Oct. 1987. https://doi.org/10.1111/j.1752-1688.1987.tb02959.x.
[21] D. G. Smith, "A better water quality indexing system for rivers and streams," Water Research, vol. 24, pp. 1237-1244, Oct. 1990. https://doi.org/10.1016/0043-1354(90)90047-A.
[22] J. Dojlido, J. Raniszewski, and J. Woyciechowska, "Water quality index-application for rivers in Vistula river basin in Poland," Water Science and Technology, vol. 30, p. 57, Nov. 1994. https://doi.org/10.2166/wst.1994.0511.
[23] C. G. Cude, "Oregon water quality index a tool for evaluating water quality management effectiveness 1," JAWRA Journal of the American Water Resources Association, vol. 37, pp. 125-137, Jun. 2001. http://dx.doi.org/10.1111/j.1752-1688.2001.tb05480.x.
[24] A. D. Sutadian, N. Muttil, A. G. Yilmaz, and B. Perera, "Development of river water quality indices—a review," Environmental monitoring and assessment, vol. 188, pp. 1-29, Dec. 2016. https://doi.org/10.1007/s10661-015-5050-0.
[25] A. Ismail and D. Robescu, "Chemical water quality assessment of the Danube river in the lower course using water quality indices," UPB Scientific Bulletin, Series B: Chemistry and Materials Science, vol. 79, pp. 51-62, Dec. 2017. https://www.scientificbulletin.upb.ro/rev_docs_arhiva/full4eb_889358.pdf.
[26] Z. Menberu, B. Mogesse, and D. Reddythota, "Evaluation of water quality and eutrophication status of Hawassa Lake based on different water quality indices," Applied Water Science, vol. 11, pp. 1-10, Mar. 2021. https://doi.org/10.1007/s13201-021-01385-6
[27] R. Price, "Environmental risks in Iraq, K4D Helpdesk Report," Brighton, UK: Institute of Development Studies, 2018.
[28] R. Al-Ani, A. Al Obaidy, and F. Hassan, "Multivariate analysis for evaluation the water quality of Tigris River within Baghdad City in Iraq," The Iraqi Journal of Agricultural Science, vol. 50, pp. 331-342, Feb. 2019. https://doi.org/10.36103/ijas.v50i1.
[29] A. S. Al-Adili and S. M. Ali, "Hydrochemical Evolution of Shallow Ground Water System Within Baghdad City–Iraq," The Iraqi Geological Journal, pp. 134-139, Jan. 2005. https://igj-iraq.org/igj/index.php/igj/article/view/15
[30] Y. Q. Tawfeek, F. H. Jasim, and M. H. Al-Jiboori, "A Study of Canopy Urban Heat Island of Baghdad, Iraq," Asian Journal of Atmospheric Environment (AJAE), vol. 14, Sep. 2020. http://dx.doi.org/10.5572/ajae.2020.14.3.280.
[31] A. H. Ismail, B. S. Abed, and S. Abdul-Qader, "Application of multivariate statistical techniques in the surface water quality assessment of Tigris River at Baghdad stretch," Journal of Babylon University, vol. 22, pp. 450-462, Jun. 2014. https://www.iasj.net/iasj/download/9d6d6110edc05af8.
[32] M. Bascaron, "Establishment of a methodology for the determination of water quality," Bol Inf Medio Ambient, vol. 9, pp. 30-51, 1979.
[33] P. S. Inc., "FlexPDE Manual Version 7.16," ed: Spokane Valley, WA, 2020.
[34] A. Jafari and N. Ashgriz, "Numerical techniques for free surface flows: Interface capturing and interface tracking," Encyclopedia of Microfluidics and Nanofluidics, pp. 2458-2479, Aug. 2015. https://doi.org/10.1007/978-3-642-27758-0_1139-2.
[35] P. R. Kannel, S. Lee, Y.-S. Lee, S. R. Kanel, and S. P. Khan, "Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment," Environmental monitoring and assessment, vol. 132, pp. 93-110, Feb. 2007. https://doi.org/10.1007/s10661-006-9505-1.
[36] T. Kim, Y. Kim, J. Shin, B. Go, and Y. Cha, "Assessing land-cover effects on stream water quality in metropolitan areas using the water quality index," Water, vol. 12, p. 3294, Nov. 2020. https://doi.org/10.3390/w12113294.
[37] B. Abed, A.-R. Farhan, A. Ismail, and S. Al Aani, "Water quality index toward a reliable assessment for water supply uses: a novel approach," International Journal of Environmental Science and Technology, vol. 19, pp. 2885-2898, Jun. 2022. https://doi.org/10.1007/s13762-021-03338-7.
[38] G. Map, https://www.google.com/maps/@33.6319356,44.5798048,9.74z, 2023 Access (1-2-2023).
[39] I. S. IQS, "Iraqi standard of drinking water No. 417," Second modification, 2009.
[40] F. Edition, "Guidelines for drinking-water quality," WHO chronicle, vol. 38, pp. 104-8, 2011.
[41] M. D. Al-Murib, S. A. Wells, and S. A. Talke, "Integrating Landsat TM/ETM+ and numerical modeling to estimate water temperature in the Tigris River under future climate and management scenarios," Water, vol. 11, p. 892, Apr. 2019. https://doi.org/10.3390/w11050892
[42] H. T. Ali and Y. M. A. Al-Hathal, "Tigris River water Qualitative characteristics between Salah al-Din and Baghdad governorates: 10.2478/bjlp-2022-001082," Baltic Journal of Law & Politics, vol. 15, pp. 1251-1265, Nov.2022. https://versita.com/menuscript/index.php/Versita/article/view/564.
[43] R. K. Gangwar, P. Khare, J. Singh, and A. Singh, "Assessment of physico-chemical properties of water: River Ramganga at Bareilly, UP," Journal of Chemical and Pharmaceutical Research, vol. 4, pp. 4231-4234, Sep. 2012.
[44] F. M. Al-Rubaie and N. O. Al-Musawi, "The Effect of Diyala River Water Quality on the Quality of Tigris River Water using GIS Mapping," Journal of Engineering, vol. 25, pp. 71-87, Oct. 2019. https://doi.org/10.31026/j.eng.2019.10.06.
[45] I. Naubi, N. H. Zardari, S. M. Shirazi, N. F. B. Ibrahim, and L. Baloo, "Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality," Polish Journal of Environmental Studies, vol. 25, Jan. 2016. https://doi.org/10.15244/pjoes/60109.
[46] Z. Lateef, A. Al-Madhhachi, and D. Sachit, "Evaluation of Water Quality Parameters in Shatt Al-Arab, Southern Iraq, Using Spatial Analysis. Hydrology 79: 1-33," Oct. 2020.
[47] S. O. H. Al-Shujairi, "Develop and apply water quality index to evaluate water quality of Tigris and Euphrates Rivers in Iraq," International Journal of Modern Engineering Research, vol. 3, pp. 2119-2126, 2013. https://doi.org/10.1007/s12517-020-05575-5
[48] N. Al-Ansari, N. Abbas, J. Laue, and S. Knutsson, "Water scarcity: Problems and possible solutions," Journal of Earth Sciences and Geotechnical Engineering, vol. 11, pp. 243-312, Nov. 2021. https://doi.org/10.47260/jesge/1127.