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Assessment of the Water Quality Index for the Tigris River in Southeastern Iraq

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Abstract - The water quality in the southeast region of Iraq was evaluated in this study, which focused on the Tigris River one of Iraq's primary water sources in Iraq. From August 2022 to July 2023, water samples were taken at four different stations on a monthly and seasonal basis between Al-Qurna and Al-Azayer cities. The study aims to estimate the quality of water in the Tigris River for potable water. Consumers will be able to use the information to identify various degrees of pollution. The eight parameters that were examined were as follows: water temperature, dissolved oxygen (DO), hydrogen ions (pH), turbidity, total hardness (TH), total dissolved solids (TDS), electrical conductivity (EC), and chloride (Cl-1). The four stations along the Tigris River showed different monthly fluctuations in the water quality index. The water quality index showed different monthly and seasonal fluctuations among the four study stations in the Tigris River. In station 1, the mean WQI value was 2.153 ± 0.557, indicating good water quality. However, the lowest WQI value (1.357) occurred in August, indicating poor water quality as the index decreased below 2.0. On the other hand, the highest value (2.800) in June and May indicated good water quality as the index of 2.0. Station 2 had a mean water quality index value of 1.915 ± 0.328, with values ranging from 1.326 in August to 2.150 in October. Station 3 reported a mean WQI of 1.793 ± 0.351, showing the lowest index (1.298) in August and the highest (2.100) in November, February, March, and May. At station 4, the water quality index varied from 1.393 in April to 2.100 in November, February, and March with a mean of 1.689 ± 0.358. Constructed on seasonal fluctuations with a general mean value of 1.869 ± 0.307, the Tigris River's water quality can be considered poor quality. Winter and spring had the highest WQI values (2.151, 2.079), while summer and Autumn had the lowest WQI levels (1.483–1.761). Based on their average values, stations 2, 3, and 4 indicate poor water quality, considering the ideal value of the water quality index. An ANOVA analysis of the water quality index showed significant results ($P < 0.05$, $F = 2.850$, Sig = 0.048). These results suggest that the water in the entire river is unsuitable for potable water.

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تقييم نوعية المياه في نهر دجلة جنوب شرق العراق

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المستخلص - أجريت دراسة لتقييم نوعية المياه في نهر دجلة في جزءه الجنوبي الشرقي والذي يعد من المصادر الرئيسية في العراق وللمدة من اب 2022 الى تموز2023 بين مدينتي القرنة والعزير. جمعت عينات المياه من أربع محطات رئيسية شهرياً وموسمياً وبواقع عينة واحدة ولثلاثة مكررات، اختيرت ثمانية عوامل بيئية لتقييم جودة المياه وهي درجة حرارة الماء والاكسجين الذائب وعكارة الماء والاس الهيدروجيني والعسرة الكلية والمواد الصلبة الذائبة والتوصيلية الكهربائية فضلاً عن الكلوريد. لوحظت تقلبات شهرية وموسمية في جودة المياه لمحطات الدراسة الأربعة خلال مدة الدراسة. بلغت أدنى قيمة لدليل نوعية المياه في المحطة الأولى 1.357 في آب، مما صنفت نوعية المياه بانها فقيرة، بينما كانت اعلاها 2.800 في أيار وحزيران، أذ تشير إلى نوعية مياه جيدة وبمعدل 2.153 ±0.557 تراوحت قيم مؤشر نوعية المياه في المحطة الثانية من 1.326 في آب إلى 2.150 في تشرين الاول مما تشير الى نوعية مياه جيدة وبمعدل 1.915 ± 0.328. وتراوحت قيم دليل نوعية المياه في المحطة الثالثة من 1.298 في اب واعلاها 2.100 تشرين الثاني وشباط واذار وايار وبمعدل 1.793±0.351. وكان معدل قيمة جودة المياه في المحطة الرابعة 1.689 ± 0.358 واختلفت قيمة الدليل بين 1.393في نيسان2.200 في تشرين الثاني وشباط واذار. من ناحية أخرى قيست جودة المياه فصلياً وكان معدل قيمة نوعية المياه لمنطقة الدراسة 1.869±0.307 وصنفت على انها فقيرة وسُجلت أدني القيم لنوعية المياه 1.483 و1.761 في فصلي الصيف والخريف وأعلاها 2.151 و2.079 في فصلي الشتاء والربيع. بينت نتائج التحليل الاحصائي ان هناك فروقات معنوية بين محطات الدراسة ($P<0.05$، $F=2.850$، Sig.=0.048) وأشارت نتائج الدراسة ان مياه نهر دجلة في منطقة الدراسة غير صالحة للشرب.

كلمات مفتاحية: نوعية مياه، تقييم، نهر دجلة، العراق

Introduction

The quality of surface water and groundwater has been adversely affected by various human activities, including urbanization, construction, agricultural activities, industrial applications, and natural processes, these activities can introduce pollutants into water bodies, which can cause harm to both humans and wildlife (Akhtar *et al.,* 2021). Comparing the values of experimental parameters with the values of the existing recommendations forms the basis of water quality assessment methods. Appropriate pollutant source diagnosis is often achieved by monitoring, which might be subject to regulatory constraints. Another method involves estimating the WQI, which is an easy mathematical technique for evaluating the quality of water. The Water Quality Index (WQI) is a measure of water quality that is derived from an assessment of physical and chemical variables (Rubio-Arias-Arias *et al*., 2013).

The overall pattern of water quality across space and time is not simple to generalize (Al-Sudani, 2021). It is therefore critical to implement water quality monitoring programs to keep these pollutant sources in check, detect any effects on aquatic systems, and assist health authorities in controlling pollution and ensuring the safe use of surface water for drinking water plants (Jabar and Hassan, 2022). The improper management of water resources of Iraq has led to a decline in the quality of the river water. In Iraq, the process of water quality monitoring is unregulated because of the country's uncertain environment and a lack of financial resources. Consequently, it is crucial to simulate river water quality in emerging nations, such as Iraq (Abed *et al.,* 2021). Among the rivers flowing across Western Asia, the Tigris ranks second in length. It begins in eastern Turkey and flows southward through Baghdad city as an alluvial plain, with an average flow rate of 540 m3/s between 2005 and 2020 over its 1850 km length.

The bed is mostly composed of small pebbles, clay, and silt (UN-ESCWA, 2013). The Tigris River encounters human and natural issues such as water scarcity, plant growth, and mud accumulation. Water from the Tigris River is essential for Iraqi households and businesses. Due to growing worries about future water scarcity and its inherent susceptibility to contamination, water quality assessment in Iraq has emerged as a pressing national priority in recent years (Oleiwi and Al-Dabbas, 2022).

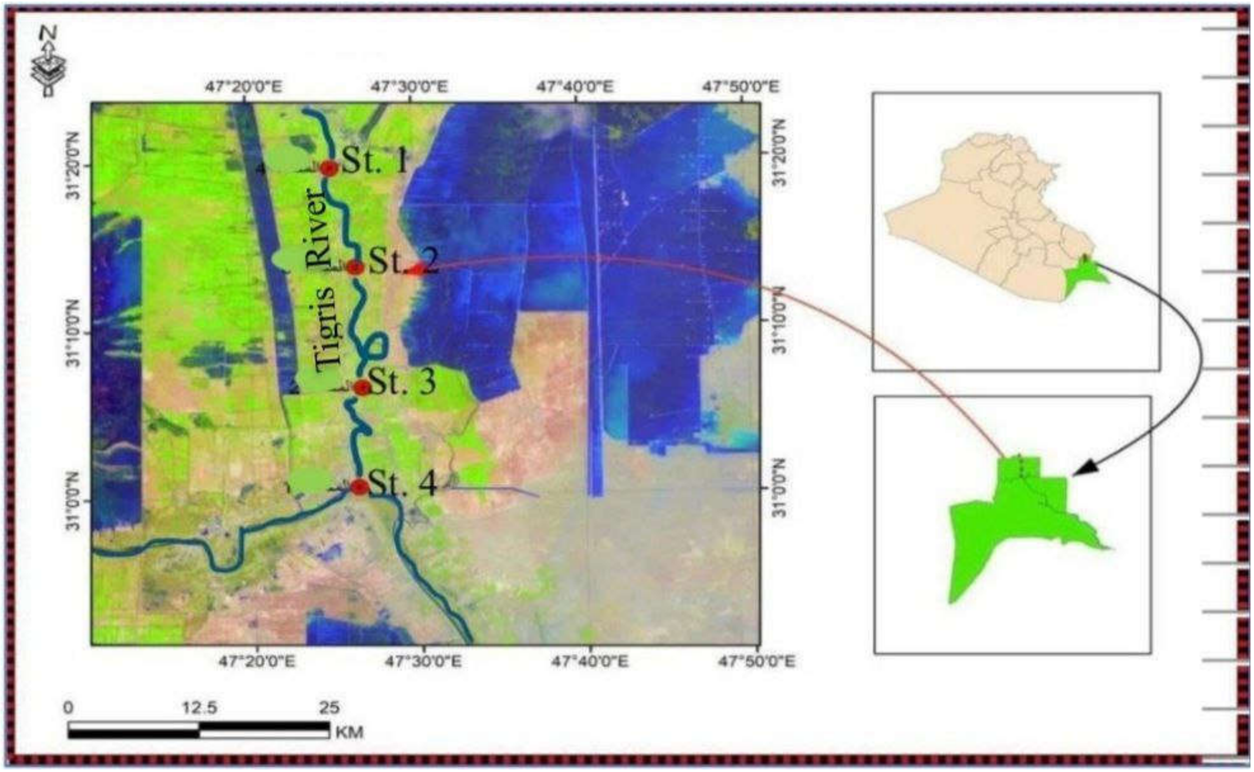
Many studies have evaluated the water quality in inland water bodies of Iraq; Abdullah *et al*., (2019). The estimate the quality of water in southern Iraq at the Euphrates River, the purpose of the search was to assess the quality of the river water to diverse uses, contenting potable water, agriculture, and irrigation and they showed that the water quality ranged between poor and good quality of water. Ewaid *et al.,* (2020) established the quality of water to evaluate the convenience of potable water and they found the rate annual quality of water in the Tigris River is Good. Chabuk *et al.*, (2020) revealed a calculation of the quality of water in the Tigris River, the researchers used the WQI method to evaluate the overall water quality based on the twelve parameters, they presented the state of quality water for the Tigris River was degraded downstream. Al-Barwary (2021) studied and assessed the water of in Iraq quality for potable at the Kurdistan Region city of Zakho. Eleven physiochemical factors were applied to tests on the water during the search, and he concluded, that some locations of well water sources of the Selevania district are suitable for potable purposes. Khaleefa and Kamel (2021) studied and evaluated the water in the Euphrates River and used ten quality water variables to assess for potable purposes they classified the water of The Euphrates River as 'very poor quality. The study objective was to determine the local variability of the parameters and create a water quality index (WQI) for the Tigris River water. Consumers will be able to use the information to identify various degrees of pollution, learn about the water quality, and take steps to fix or avoid problems.

Materials and Methods:

Description of area:

The study area was meticulously delineated, covering the geographical coordinates of latitude 31.2570 N and longitude 47.4376 E, covering an expanse of 52km. Station 1 is located between latitude 31.2570 N and longitude 47.43210 E in Al-Azayer city, station 2 at latitude 31.1651 N and longitude 47.43138 in Al-Sakhrija village, station 3 at located 31.0913 and longitude 47.42750 in Nakhlate village and station 4 at latitude 31.0210 N and longitude 47.43760 in Al-Qurna city (Map 1).

Water samples were collected from the middle of the Tigris River during the period from August 2022 to July 2023; the samples were collected monthly and seasonally from the stations by using clean polyethylene bottles, and eight parameters were measured. Water temperature (T), electrical conductivity (EC), total dissolved solids (TDS), and potential of hydrogen (pH) were measured with a Hanna instrument (a waterproof HI-9146 pH/EC/TDS/ temp. model), turbidity was estimated with a turbid meter HI- 93703C. The water temperature in Celsius degrees (°C), EC in µS/cm, TDS in mg/L, pH level is reported in pH units and turbidity is reported in nephelometric turbidity units (NTU). The following variables were evaluated in the laboratory: dissolved oxygen (DO) was determined according to Welch (1964) and the results are expressed in mg/L, total hardness (TH) was measured using the method of Lind (1979) and estimated by EDTA titration and the results are expressed in mg/L, while Chloride (Cl^-) were determined according to Baird *et al.*, (2017)



(Map 1) The map and the sampling stations of the study area.

Calculation of the WQI:

The method was determined by Rubio-Arias-Arias *et al.*, (2013). In the first step, each standard received a specific weight (Wi), ranging from 1 to 4, based on its level of significance in establishing the quality of the water. The weightings were assigned as follows: T and turbidity were assigned a weight of 3; pH, DO, and EC were given a weight of 4; TDS was assigned a weight of 4; TH received a weight of 2, and Cl^{-1} was assigned a weight of 1. Table 4 presents information regarding the weights (Wi) and tolerance ranges (Pi). In the second phase, the results of each variable from the ANOVA were reviewed separately to analyze the particular weights of the parameters based on a tolerance range (Pi). Variables with values within the ideal ranges were assigned a Pi value of 1, while those with values beyond the ideal ranges were assigned a Pi value of 2. It is important to note that the Wi and Pi values used in the current study incorporated standards from other studies (Table 1). The following Equation (1), given by Rubio-Arias *et al.*, (2012), was used to determine.

WQI.

$$WQI=\frac{\sum_{i=1}^{n} Pi*Wi}{\sum_{i=1}^{n} Pi} \; K \qquad (1)$$

where:
WQI = water quality index.
Wi = specific weight of each variable (1- 4).

(Table 1) The weight of water quality parameter for drinking water (Rubio-Arias *et al.,* 2013)

Parameters	Wi	Pi	Range Tolerance	Units
Water temperature	3	1	20-25	C°
		2	<20	
		2	>25	
DO	4	1	5-7	mg/L
		2	<5	
		2	>7	
pH	4	1	6.5 – 8.5	-
		2	<6.5	
		2	>8.5	
Turbidity	3	1	5-10	NTU
		2	<5	
		2	>10	
TH	2	1	150-300	mg/L
		2	<150	
		2	>300	
TDS	2	1	120-500	mg/L
		2	<120	
		2	>500	
EC	4	1	250-500	µS/cm
		2	<250	
		2	>500	
Cl^-	1	1	250-300	mg/L
		2	<250	
		2	>300	

The value of Pi determines the tolerance of the result (1 or 2) assigned to each variable according to Rubio-Arias *et al*., (2013). Meanwhile, K is assigned as either 1, 0.75, or 0.50. The constant "K" in the equation represented the degree of contamination present at the sampling time. The researchers assigned a value of 1 to clear water without obvious contamination, 0.75 to water with a low level of turbidity resulting from artificial processes, and 0.50 to contaminated water. The measured WQI were then categorized using Table 2.

(Table 2) Classified based on the assigned values (Rubio-Arias *et al.,* 2012)

WQI Value	Assessment of water quality
>2.5	Excellent
2.0 – 2.5	Good
<2.0	Poor

Results

Parameters for calculating the Water quality index:

The analysis of physicochemical parameters was used to calculate the Water Quality Index (WQI) during the study period. We examined the monthly variations of eight parameters for calculating the Water Quality Index (WQI) at the four stations, as displayed in (Figure 1, Table 3, and Table 4). The water temperatures exhibited a range of 16.5°C to 35°C with a mean of 26.9 ± 1.20°C. Moreover, the water temperature was negatively correlated with pH and DO (r = - 0.538, r = - 0.563) respectively.

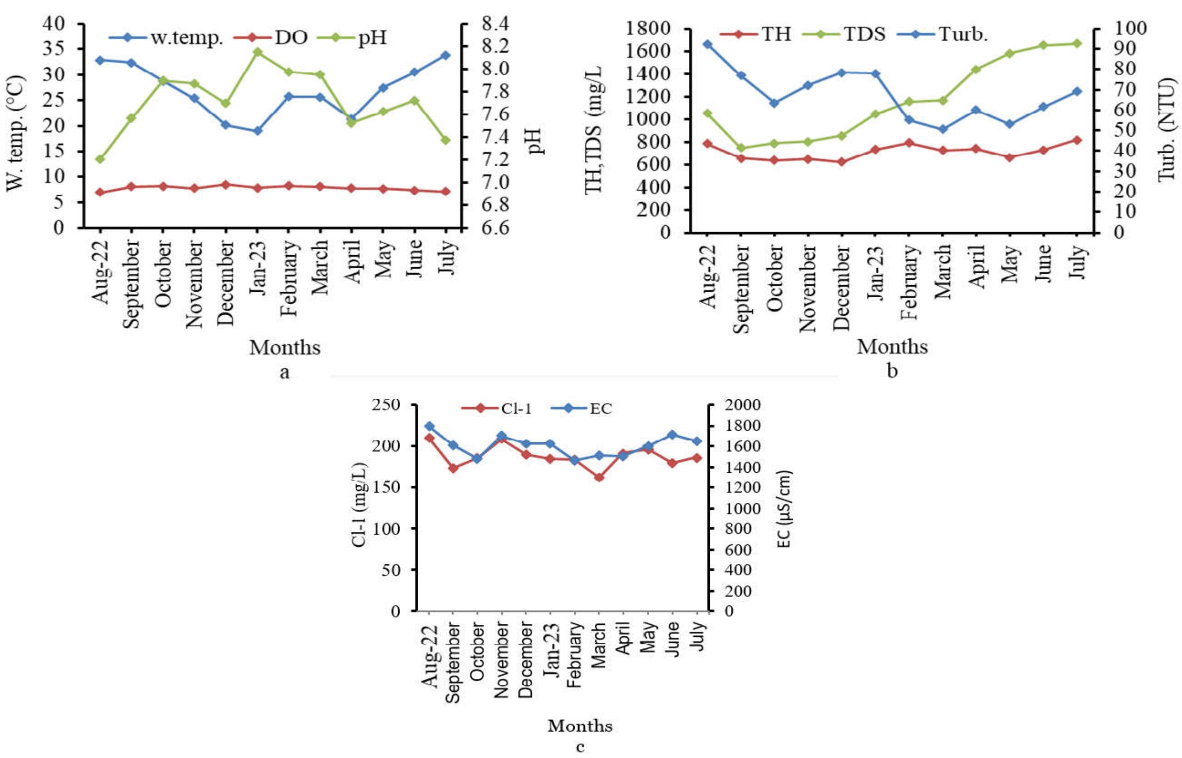
The dissolved oxygen (DO) values at the stations ranged from 6.9 mg/L to 9.01 mg/L, with an annual mean of 7.39 ± 0.20 mg/L. The pH values fluctuated from 7 to 8.7, with an annual mean of 7.27 ± 0.10 mg/L, and no significant differences were observed among the stations. The observed turbidity values ranged from 15 to 115 NTU, with an average of 62.1 ±12.31 NTU.

The total hardness values varied from 575 to 875 mg/L, with an annual mean of 711.55 ± 27.09 mg/L, the correlation coefficients of (r = 0.283), (r = and (r = 0.561) were recorded with water temperature and total dissolved solids respectively.

For total dissolved solids (TDS), the minimum value was 701 mg/L, while the maximum value was 1754 mg/L, with an average of 1143.12 ± 61.76 mg/L.

Electric conductivity exhibited the lowest value of 1070 µc/cm and the highest value of 1970 µc/cm, with an average of 1600 ± 114.47 µS/cm.

Chloride (Cl^-) displayed an annual mean of 187.82 ± 54.67 mg/L, with the lowest recorded value at 77 mg/L and the highest recorded value at 266 mg/L EC demonstrated a significant correlation with chloride (r= 0.528).



(Figure 1) The rates of four stations exhibit along the axis of the Tigris River

(Table 3) Statistical analysis of 8 parameters measured at Tigris River from August 2022 to July 2023.

Variables	First station		Second station		Third station		Fourth station		Mean ± SD
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
Wat. tem.	19 – 33	25.5	17.5 – 33.5	26.3	19 - 34	27.8	16.5 – 35	28	26.9 ± 1.20
DO	7.01- 8.6	7.26	6.9 - 8.65	7.34	7.4 – 9.01	7.56	7- 8.8	7.69	7.39 ± 0.20
pH	7 - 8.7	7.4	6.98 - 8.5	7.19	7 – 8.51	7.21	7 – 8.2	7.29	7.27 ± 0.10
Tur.	15 – 95	50	32 - 87	53.3	49.5 - 104	70.1	61 – 115	75	62.1 ± 12.31
TH	589 - 789	673.8	612 - 867	724.9	598 - 825	711.٥	575 - 875	736	711.55 ± 27.09
TDS	701 - 1623	1062	710 - 1701	1206	755 - 1711	1133	744 - 1754	1171.5	1143.12 ± 61.76
EC	1200 - 1910	1500	1350 - 1750	1500	1500 - 1890	1700	1070 - 1970	1700	1600 ± 115.47
Cl^{-1}	77 – 160	117.8	105 - 199	171.3	186 - 266	226.4	190 - 265	235.8	187.82 ± 54.67

(Table 4) Correlation coefficient rates between physicochemical parameters of the Tigris River from August 2022 to July 2023

Parameters	WT	Turbidity	DO	pH	TDS	EC	TH	Cl^-
WT	1							
Turbidity	0.130	1						
DO	-0.563	-0.297	1					
pH	-0.583	-0.365	0.642*	1				
TDS	0.207	-0.010	-0.564	-0.252	1			
EC	0.370	0.691*	-0.674*	-0.478	0.075	1		
TH	0.283	-0.010	-0.601*	-0.252	0.561	0.095	1	
Cl^-	0.023	0.491	0.409	-0.422	0.068	0.528	-0.016	1

Water Quality Index (WQI):

Table (5) presents the results of the water quality index (WQI) for 4 study stations along the Tigris River. In station 1, the mean WQI value was 2.153 ± 0.557, indicating good water quality. However, the lowest WQI value (1.357) occurred in August, indicating poor water quality as the index decreased below 2.0. On the other hand, the highest value (2.800) in June and May indicated good water quality as an index of 2.0, with a mean of 1.915 ± 0.328.

Station 2 had a mean water quality index value of 1.915 ± 0.328, with values ranging from 1.326 in August to 2.150 in October.

Station 3 reported a mean WQI of 1.793 ± 0.351, showing the lowest index (1.298) in August and the highest (2.100) in November, February, March, and May.

At station 4, the water quality index varied from 1.393 in April to 2.100 in November, February, and March with a mean of 1.689 ± 0.358. Based on their average values, stations 2, 3, and 4 indicate poor water quality, considering the ideal value of the water quality index.

(Table 5) Water quality indices of the four stations along the Tigris River from August 2022 to July 2023.

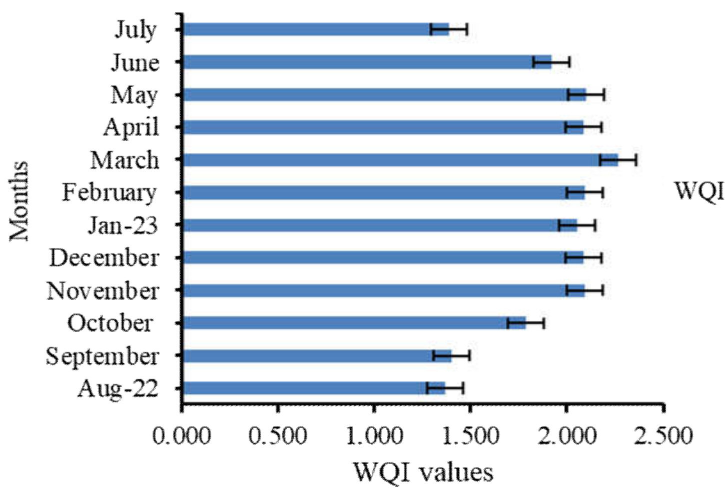
Stations	Minimum	Maximum	mean ± SD
Station 1	1.357	2.800	2.153 ± 0.557
Station 2	1.326	2.150	1.915 ± 0.328
Station 3	1.298	2.100	1.793 ± 0.351
Station 4	1.393	2.100	1.689 ± 0.358

ANOVA analysis of the water quality index showed significant results at leavl of ($P < 0.05$) Table 6.

(Table 6) The results of the ANOVA test in the four stations

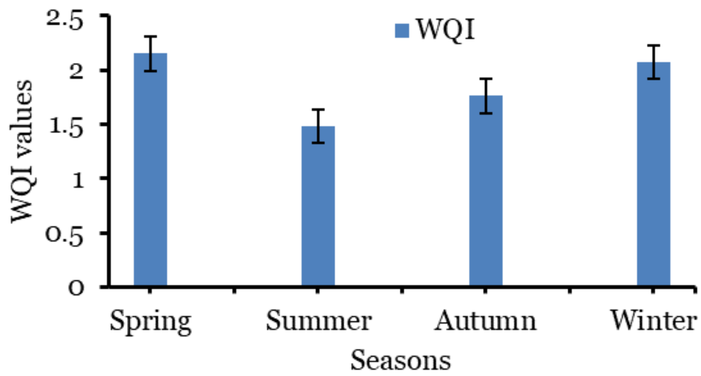
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.554	3	0.518	3.368	0.026
Within Groups	7.380	48	0.154		
Total	8.934	51			

Considering the monthly variability of WQI, the water quality of the Tigris River can be deemed poor, with a general mean of 1.888 ± 0.323 (Figure 2). From November to May, the best WQI levels ranged from 2.094 to 2.097. The highest value (2.268) was recorded in March, while the months from June to October showed the lowest WQI levels ranging from 1.922 to 1.787. The lowest value (1.368) was obtained in August. These results indicate that the water in the entire river is unsuitable for drinking.



(Figure 2) Fluctuations in the WQI of the Tigris River from August 2022 to July 2023.

Based on seasonal fluctuations with a general mean value of 1.869 ± 0.307, the Tigris River's water quality can be considered poor quality (Figure 3). Winter and spring had the highest WQI values (2.151, 2.079), while summer and Autumn had the lowest WQI levels (1.483–1.761). These results suggest that the water in the entire river is unfit for human consumption.



(Figure 3) Seasonal fluctuations in the WQI in the Tigris River for August 2022 to July 2023.

Discussion:

Physiochemical parameter:

Water temperature was the most significant factor because it affected dissolved oxygen levels and hydrogen ion concentrations at the stations, which in effect varied monthly and seasonally. The values of water temperature were within limits of the Iraqi drinking water standard (2009) and the WHO (2011) standards.

Water contamination is indicated by the reduction of dissolved oxygen, which is vital for aquatic life. The mixing processes that followed rainfall in the winter months resulted in the highest recorded concentrations of dissolved oxygen, as shown by the DO readings shows that the DO values are within the acceptable range for aquatic life, as stated by CCME (2007), and they are also one of the requirements for the System Maintenance of Rivers Maintenance (2001). One of the most crucial measures of river water quality is the pH value (Saalidong *et al.,* 2022).

The river's water is slightly alkaline, according to the pH values from the four stations. Furthermore, they stayed within Robert and Westcot's (1985); Abdullah (2020) and Abbas and Ajeel (2022) (Figure 1 a). Water clarity is indicated by the turbidity parameter. The quantity of light reaching the river decreases as the concentration of suspended particles increases. All of the stud stations had a very high turbidity level. The primary cause of river turbidity is the discharge of untreated wastewater into the river. There is an excess of acceptable limits (WHO 2004).

The presence of high TDS levels in the river water indicates that sewage and agricultural waste have been released into the water source by an insufficient wastewater treatment plant. All of the sampling stations had total dissolved solids (TDS) levels that were higher than what is considered acceptable for human consumption, by the Iraqi drinking water standard (2009) and the WHO (2011) and Al-Hemidaw *et al.,* (2020). Discharge increased ion concentrations, which led to total hardness results that were higher than Iraqi drinking water guidelines, our findings were confirmed by Rabee *et al.*, (2011) (Figure 1 b).

Chloride (Cl^{-1}) concentrations were found to be within the Iraqi drinking water Standard (2009) and to increase comparatively and gradually downstream at River Station 4, which may be influenced by the effects of pesticides, irrigation, and fertilizers, according to Abdullah *et al.*, (2019). (Figure 1 c).

Water Quality Index (WQI):

The water quality index involves assessing the quality of potable water. At the first station, the WQIs demonstrated favorable results, with the highest WQI drinking water from November to June. During this period, turbidity decreased, and all ion values remained within the safe consumption limits set by both Iraqi and international standards (Zgair, 2022). These are suitable drinking water, which matches Abed *et al.*, (2022) assessment of the Tigris River's water quality in previous research.

Good water quality was documented in the research region during the spring and winter seasons based on reading the water quality user manual. It can be attributed to increased river discharge and precipitation, as well as decreased temperature, resulting in a decrease in parameters such as TDS, EC, TH, and an increase in DO, as demonstrated by Rubio-Arias *et al.*, (2012) on the aquatic ecosystem in Mexico, who used the development of a Water Quality Index, and Ali Abed *et al.*, (2019) on the Tigris River, which has recorded good water quality.

Another observation revealed that the water quality index at other stations was low, displaying values that fell beyond the range of the water quality index. During the study period, poor results were also documented in the autumn and summer seasons. Several factors influenced the physiochemical factors, with turbidity emerging as the primary focus of this study.

Additionally, other ions played a role in distorting the established ranges outlined by WHO and Iraqi standards. Anthropogenic activities, agricultural waste, wastewater, and soil erosion influenced the WQI. A similar study was conducted by Egbueri *et al.,* (2023) who highlighted the effect of these factors on assessed drinking water quality. Ahmad (2023) investigated spatiotemporal changes in water quality parameters of the Sirwan River in Iraq.

Seasonally, the best water quality index was in winter when the water was classified as good (Abdul Hameed *et al.,* 2010). The lowest values of the index were observed from May to September also during spring, summer, and autumn seasons water quality is worse in the dry season than flood season, which may be attributed to the presence values of parameters such as TDS, EC, TH and turbidity were above of Iraqi Drinking Water Standard (2009).

Conclusion:

Environmental considerations led to the conclusion that the water from the Tigris River was not suitable for human consumption. This variance may be attributed to several factors, one of which is the fact that it flows into Qurna City at its downstream station and then connects with the Shatt al-Arab River, which is noted for consuming a significant amount of TDS and TH. Constant monitoring and the deployment of standard decontamination technologies including sedimentation, filtration, and disinfection are necessary for water treatment and quality improvement.

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