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Water Quality of the Tigris River in Rashidieh Area - North of Mosul - Iraq Using the Canadian Indicator

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ABSTRACT

The city of Mosul contains a single water source, which represents the main artery of this city, namely the Tigris River. It was necessary to study and evaluate the quality of water, especially in the Rashidieh area since it represents the beginning of the entry of the Tigris River from the northern region, as well as addressing the extent of pollution in it and the extent of water susceptibility to self-purification.Water samples were collected from the Rashidieh area, and five sites were selected along the course of the Tigris River passing within that area. The results of the current study showed that the average temperature ranged between 10.25-14.25°C, and some indicators were measured and the highest value of the pH function was recorded (2.4) at the second site and the lowest value was recorded (0.08) at site 5. Moreover, the average values of TDS, DO, T.H, $PO3^{3-}$, $NO3^{-}$ and Cl^{-} ranged from 253.7–338.7, 5.29-8.46,115.6-254.8, 0.248–5.26, 1.73-18.08, and 30.5–56mg/l, respectively, and most of the values were within the permissible limits and fall within the Iraqi and international standards, except for the acid function, dissolved oxygen and phosphate that recorded values exceeding the permissible limits, especially in the Rashidiya estuary area, the second site, which greatly and significantly affected the Tigris River. Therefore, the sites were classified based on the values of the Canadian index, and the values ranged from good for the Tigris River to poor quality for the Rashidiya estuary and questionable for site 3, while site 4 and 5 were classified as acceptable, and thus the ability of the Tigris River to self-purify was not at the required level.

INTRODUCTION

Water is necessary for all forms of life since it plays an important and effective role in the vital activities of living organisms for drinking water is one of the necessary requirements for humans that cannot be dispensed with for any reason, and must meet quality standards in terms of taste, color and smell, as well as physical, chemical and biological specifications **(Klawitter & Qazzaz, 2021)**. Aquatic ecosystems face many challenges due to the industrial, agricultural and social development that the world is witnessing and the resulting release of civil, industrial and agricultural waste into the environment, which motivated the global public opinion to track indicators that indicate decreasing water quantities and increasing pollution in it **(Al-Saad, 2023)**.

Due to the urgent need for fresh water aligned with the water deficit, the whole world should intensify their efforts to reduce these problems by conducting continuous studies on the water sources to identify the resulting effects and ways to address them **(Al-Hamdani, 2022)**. For Iraq, despite having significant water sources, most the inhabitants suffer from the lack of potable water and many cities use groundwater, due to the extension of this water wealth by excreting a huge amount of various pollutants into the freshwater stream and converting it to sewage trocars **(Mustafa & Jankeer, 2007)**.

In addition, there is no proper planning in the construction of cities, which led to a doubling of the amount of domestic, industrial and agricultural water, as well as the entry of waste into water bodies. Therefore, it has become necessary to monitor the water quality as a result of the continuous qualitative change in the aquatic environment **(Al-Obaidi, 2013)**.To assess the self-purification ability of the Tigris River within the Rashidieh area, a study was conducted examining various physical and chemical properties at five different sites along the river.

MATERIALS AND METHODS

Water samples were collected from the Rashidiya area, which is located north of the city of Mosul on the Tigris River, which has an estimated population of about 70,000 people. Five sites were selected along the course of the Tigris River passing within the area under study, and those sites are presented in Table (1) and Fig. (1).

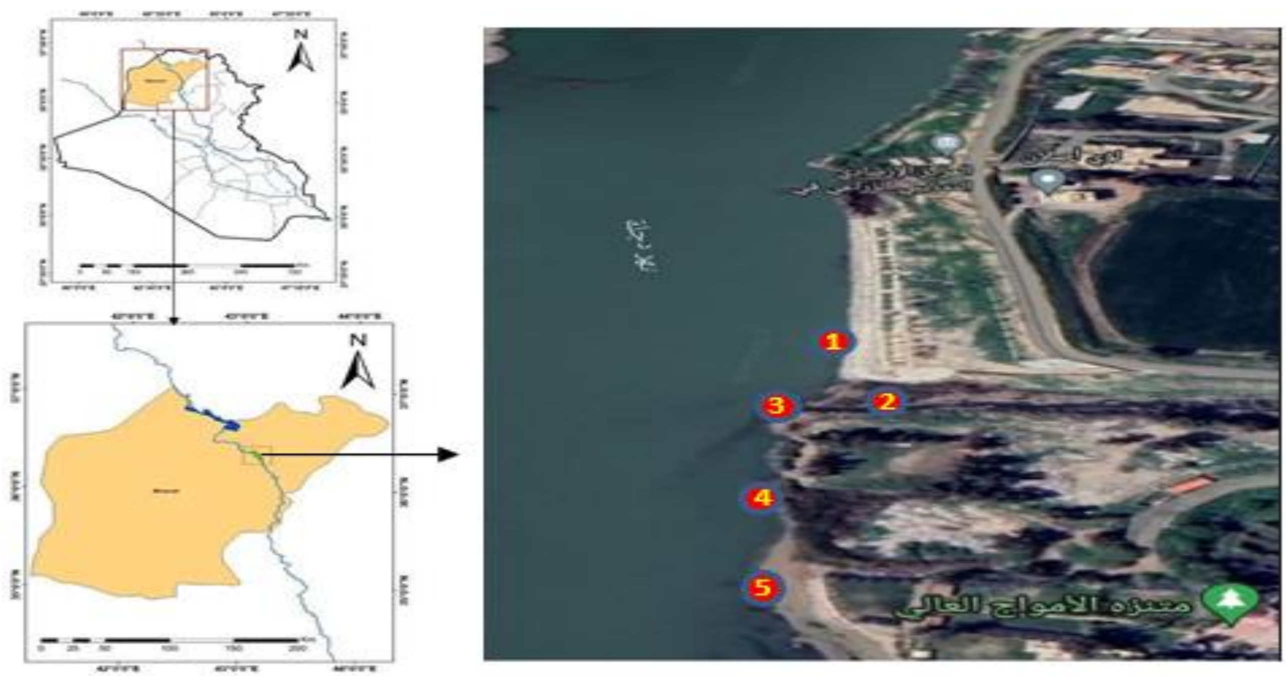

Fig. 1. A map showing the sites under study (From Google maps)

Table 1. Description of the sites under study

Site	description
1	The Tigris River before its confluence with the mouth of Rashidieh
2	Errachidia estuary is 100m away from the first site
3	Represents the confluence of the Tigris River with the mouth
4	250m after the mouth (location 2)
5	500m after the mouth (location 2)

The physical and chemical tests were carried out according to the method of **Abbawi and Hassan (1991)** and **APHA (2017)**. The tests included both field and laboratory analyses. Field tests included temperature measurement using a graduated zebic thermometer from 0 to a 100 degrees Celsius, and the measurement of total dissolved solids was conducted using the electric power meter TDS-C°-meter YL. Moreover, the pH was measured using a LIUNOVIP meter. The dissolved oxygen in the samples was fixed in the field using 250ml glassware, following the modified azide method by adding 2ml each of

Winkler solutions A and B. In the laboratory, the total hardness of the water was determined using the Na_2EDTA titration method.

The phosphate concentration was measured according to the tin chloride method, and using the optical spectrophotometer of the type FAITHFUL 721. The absorption of the samples was measured at a wavelength of 690nm, while the nitrate concentration was measured applying the indole method, using the optical spectrophotometer of the type FAITHFUL 721; then, the absorption of the samples was measured at a wavelength of 395nm.

For the chloride concentration, the Mhor's method was used, where a certain volume of water sample was taken and drops of potassium karmate index (K2CrO4) were added to it and titrated against the standard silver nitrate solution (N0.0141) until the color changed from yellow to reddish-brown, taking into account the work of Planck's solution to correct the results. These data were collected and arranged by locations and months to determine the water quality, using the SAS program, and applying the Dunkin' Multi Test Levels to compare the averages of values at the level of significance of *P* bigger than 0.050. Similar letters indicate that there were no significant differences between the values and vice versa, and the values of the water quality index were calculated using the Canadian mathematical model and classified into five categories, as shown in Table (2).

Table 2. CCME WQI categorization schema **(Kumar *et al.*, 2014)**

Category	**WQI**	**Status**
1	95–100	excellent
2	80–94	good
3	65–79	fair
4	45–64	marginal
5	0–44	poor

The Canadian sports model is of high accuracy and is widely used globally in assessing water quality, and the values of the Canadian index are found by calculating its three factors **(Al-Saffawi, 2018)**, as follows:

This indicator aims to simplify and standardize the method of assessing the water quality to facilitate its understanding and use by the concerned authorities. Moreover, this model depends on three main components:

1. Range: This component represents the percentage of variables that have exceeded the standard limits compared to the total number of variables (even once). It is denoted by F1, and calculated as in the following equation:

$$F1 = \times 100\ \frac{Number\ of\ Failed\ Variables}{Total\ Number\ of\ Variables} \quad \text{--------}\ (1)$$

2. Frequency: It represents the percentage of individual tests that exceeded the permissible limits divided by the total number of tests. It is denoted by F2, calculated as in the equation:

$$F2 = \frac{Number\ of\ Failed\ Tests}{Total\ Number\ of\ Tests} \times 100 \qquad \text{---------} \quad (2)$$

3. Amplitude: Measures the number of tests exceeding the permissible limits, denoted by F3.

It is measured in two ways:

The first method: the number of times during which the individual concentrations exceed the permissible limits, called the deviation (Excursion) and calculated as in the equation

$$\text{Excursion i} = -1\left\{\frac{Failed\ Test\ Valuei}{Objective}\right\} \qquad \text{---------} \quad (3)$$

The second method: represents the sum of individual tests exceeding the permissible limits, and is calculated by adding individual deviations and dividing them by the total number of examinations (exceeded and non-exceeded). This variable is called the sum of adjusted deviations (Normalization of Excursion) and is symbolized by nseas in the equation:

$$nse = \frac{\sum_{j}^{n}=1\ excursion}{total\ number\ of\ lests} \qquad \text{------------} \quad (4)$$

Finally, the capacity value was calculated from the following equation:

$$F3 = \frac{nse}{0.01\ nse + 0.01} \qquad \text{------------} \quad (5)$$

After finding the values of the three factors, the Canadian model was calculated from the following equation:

$$CWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \qquad \text{---------} \quad (6)$$

CWQI results were divided into 5 specific categories that refer to water quality, which were excellent, good, acceptable (moderate), bad (doubtful), and very poor, as shown earlier in Table (2).

RESULTS AND DISCUSSION

The study's results indicated that water temperature values fluctuated between 8-19°C during the study period (Table 3). The water temperature at the Tigris River, before its confluence at the mouth (Raw Location 1), was 10°C in January and 18°C in April. Significant differences were noted between average values of 9.6-16.8°C for these months (Table 5), attributed to variations in testing times and seasonal temperature fluctuations. The highest recorded temperature was 19°C at the Rashidia mouth in April, which is within the permissible water temperature criteria (Table 3), which is less than 35°C. These findings are consistent with previous studies, including those by **Al-Hamdani (2022), Kannah and Shihab (2022)** and **Al-Saad (2023)**, where temperatures ranged between 19-21°C.

Total dissolved solids (TDS) values ranged from 243- 386mg/ L for the first and second sites, respectively, a variation attributed to significant waste presence downstream (Table 4). Despite this increase, the values remained within the permissible limits, under 1000mg/L (Table 3). These results differ significantly from those reported by **Al-Muktar (2018)**, where TDS values ranged from 123- 635mg/ L, influenced by the load of salts, bases, acids, industrial and agricultural wastes, and detergents **(Salman, 2015)**.

The pH values ranged from 6.34 at Site 2 to 8.37 at Site 5. The lower pH value is often due to sewage and estuaries being relatively basic, but tending toward acidity over time due to the decomposition of organic matter and the release of carbon dioxide by microbial activity **(Ali, 2015)**. The pH values were within the permissible limits (Table 3). Table (5) shows no significant differences between average pH values in January and February, with slight differences between March and April, consistent with previous studies **(Ali, 2015; Al-Hamdani, 2022; Shihab & Kannah, 2023)**, where pH values ranged from 7.5-8.01.

Most samples had dissolved oxygen levels within Iraqi and international standards, exceeding 5mg/ L, except for one value of 4.6mg/ L at Site 2 in April. This decrease may result from increased organic loads and higher temperatures, which reduce dissolved oxygen levels **(Saeed Al-Shakarchi & Al-Shahery, 2020)**. The highest dissolved oxygen level was 9.5mg/ L at the first site in January, attributed to lower pollution levels, water turbulence, and the significant rainfall which decreases temperatures and enhances gas dissolution. Additionally, plankton's photosynthesis contributes to oxygen release **(Al-Mashhadani & Jassim, 2012)**. There were no significant differences in average dissolved oxygen levels between February and April (Table 5), but significant differences existed between sites (Table 4). These findings align with **Salman (2019)**, reporting values between 4.2- 8.4mg/ L, but differ from **Sabawi and Kannah (2023)**, who found values between 4.4- 4.8mg/ L.Total hardness ranged from 54- 277mg/L, within the permissible limits for all months and consistent with Iraqi and international water quality standards (Table 3). Statistical analysis in Tables (4 and 5) indicates significant differences in total hardness values across locations and seasons (P< 0.05). The phosphate concentration in the Rashidiya mouth stream reached 6.4mg/ L, likely due to the use of phosphorus-rich detergents, such as sodium triphosphate and tetrasodium pyrophosphate, which release phosphate ions upon interaction with water **(Al-Safawi, 2012)**.

$$P_3O_{10} + 2H_2O \rightarrow 4H^+ + 3PO_4^{-3}$$

The reason for the high phosphate concentration of the Rashidiya estuary water compared to the water of the Tigris River may be due to the low concentration of dissolved oxygen in the water as well as the previous reasons **(Shihab & Kannah, 2021)**, which led to an increase in the transformation of phosphate compounds from the insoluble form to the dissolved form, which contributed to increasing the concentration of phosphate ions dissolved in the water **(Saeed, 2009)**. The reason for the decrease in phosphate values at site 5, which is less than the permissible limits of Table (3), is due to the ability of water to dilute and spread, as well as the activity of algae and plankton and its consumption as a basic food source **(Al-Shahery & Al-Asadi, 2021)**.

These results are close to those determined in the study of **Al-Safawi (2012)** for the Dalphini Valley, where the value of phosphate was 6.8mg/ l, which is completely close to our results, while the values of nitrates were within the permissible limits (25- 50mg/ l), and the reason may be due to the large consumption of plankton and algae for nitrates as an important and essential nutrient for growth, moreover these results are consistent with the findings of the study of **Talieh (2000)**. The values of chloride were within the permissible limits and low, ranging between 12.99 & 19.99mg/ l, and the reason may be ascribed to the participation of chloride ion in redox processes **(Freese & Nozaic, 2004)**. The results of our study differ from those reported by **Razzouqi (2021)**, who found that the TDS levels range between 250 & 640mg/ L at the mouth of the Wasit. This range is relatively higher compared to our findings. The difference can be traced back to variations in the quality of pollutants present in the downstream areas, which may contain higher amounts of salts, such as sodium chloride, that decompose and increase chloride ion concentration **(Nashat *et al.,* 2017)**.

Table 3. Minimum and maximum limits and averages of the specific values under study

Adjective \ Site	Limit	1	2	3	4	5	WHO (2017)
Water temperature C°	Min	10	11	10	9	8	35
	Max	18	19	17	16	14	
	Me	13.81	14.25	13	11.5	10.25	
pH	Min	0.1	2.4	1	0.6	0.08	6.5 - 8.5
	Max	0.4	6.4	3.3	2.4	0.4	
	Me	0.25	5.26	2.56	1.53	0.248	
TDS mg/L	Min	243	320	291	256	241	1000
	Max	271	386	358	323	276	
	Me	253.7	338.7	305.3	270.2	257.2	
DO mg/L	Min	7.2	4.6	5.5	6	8.1	5<
	Max	9.5	6.6	7.6	9	9	
	Me	7.61	5.29	7.01	7.77	8.46	
T.H mg/L	Min	81	180	159	125	54	500
	Max	125	277	200	200	156	
	Me	115.6	254.8	221	177.1	137.6	
PO_4^{3-} mg/L	Min	0.1	2.4	1	0.6	0.08	0.5
	Max	0.4	6.4	3.3	2.4	0.4	
	Me	0.25	5.26	2.56	1.53	0.248	
NO_3^- mg/L	Min	0.5	25	4.2	2.2	0.7	50
	Max	2.3	8	10	7.8	5.3	
	Me	1.73	18.08	6.22	4.48	2.38	
Cl- mg/L	Min	1.99	13.99	12.99	12.99	12.99	250
	Max	19.99	18.99	16.99	19.99	19.99	
	Me	37.2	56	47.1	34.4	30.5	

Table 4. Significant spatial differences between average values for the sites under study

Site	Water Temperature C°	pH	TDS	DO	T.H	PO_4^{3-}	$NO3^-$	Cl-
1	13.81818ab	7.735bc	253.583de	7.541bc	109.833e	0.225d	1.525e	40c
2	14.25a	7.210d	338.750a	5.175d	242.333a	4.783a	16.4a	58.833a
3	13b	7.486c	303.583b	6.758c	210.666b	2.416b	6.05b	50.25b
4	11.5c	7.758b	269.166c	7.641b	168.416c	1.375c	4.1c	38 min
5	10.25m	7.844a	258d	8.4a	123.666d	0.220d	2.1d	32.75E

Table 5. The temporal significant differences of the studied factors during the months of the study

Month	Water Temperature C°	pH	TDS	DO	T.H	PO_4^{3-}	$NO3^-$	Cl-
January	9.6d	7.810a	300.066a	7.586a	193.466a	2.58a	7.42ab	34.333d
February	10.8c	7.808a	277.066b	7.2ab	189.666b	2.22ab	5.6c	38.466c
March	12.8b	7.766ab	278.733b	7.146ab	181c	1.44b	7.8a	44.46b
April	16.8a	7.042b	282.6c	6.48b	119.8m	0.976c	3.32b	58.6a

The Tigris River waters were assessed using the water quality index (WQI). The purpose of calculating the WQI is to simplify complex data and analyses, making them more accessible and understandable for both specialists and non-specialists. The WQI takes multiple criteria into account, providing a comprehensive and clear picture of water quality **(Lumb & Tribeni, 2006)**. It transforms the extensive information and complex analyses into simple mathematical equations, offering an easy-to-understand summary of water quality. This index serves as a unified tool for evaluating water quality across different regions and conditions **(CCME, 2001)**, providing a preliminary guide to water quality and highlighting potential issues **(Muhammad & Kannah, 2022)**. It gives a general overview of potential water problems in any region **(Kumar *et al.*, 2014)**.

Based on the WQI results for the Tigris River in the Rashidieh area, as shown in Table (6) and referring to Table (2), the water quality was classified as follows: the Tigris River was rated as "good," the mouth of Rashidiya as "poor," Site 3 as "dubious," and Sites 4 and 5 as "acceptable." The water at the mouth of Rashidiya exceeded the permissible levels, primarily due to the high values of factors F1, F2, and F3, which reduced the overall WQI values. These results align with those of **Salman (2015)**, who argued that the water quality of the Tigris River varied from good to poor and acceptable. However, these findings differ from those of Al-**Saffawi (2018)**, who classified the Tigris River as "questionable," and the remaining sites were rated as "poor quality" (11.57, 44.12, 41, 40).

Table 6. Values and classification of water quality of the Tigris River, the Rashidiya region

Site	F1	F2	F3	CCME,WQI	
				Valuable	**Classification**
1	8.23	8.64	8.37	91. 77	good
2	63.64	55.17	47.00	44.30	poor
3	39.55	40.88	37.49	57.84	marginal
4	31.55	29.88	28.49	73.35	fair
5	16.45	19.38	17.57	79.47	fair

CONCLUSION

Based on this study, the water of the Tigris River at the study site was classified as "good" according to the Canadian water quality index. However, there is a clear negative impact from the Rashidiya estuary on water quality, indicating that the water cannot effectively withstand the released pollutants, as its self-purification capacity was insufficient. Additionally, several variables exceeded the permissible limits set by Iraqi and international standards, particularly in the downstream area. These variables include acidity, dissolved oxygen, and phosphorus, highlighting significant concerns regarding the water quality in this region.

RECOMMENDATIONS

1- Conducting awareness for people near the downstream area and warning them not to drink water in and near the downstream area, with the need to conduct intensive and periodic studies on rivers, especially those used for drinking.

2- Immediate treatment through the work of a box stream to transport wastewater on the banks of the Tigris River to the depressions south of the Rashidiya area in order to expose the wastewater to natural treatment processes or through wastewater treatment by placing purification basins before its confluence with the Tigris River to mitigate, helping reduce the severity of pollution, which contributes to improving the quality of this water for agricultural uses, and eliminate the phenomena of pollution on the quality of the Tigris River.

3- Alerting farmers near the Tigris River not to use agricultural pesticides heavily, which causes an increase in the level of phosphorus and salts in the waters of the Tigris River and the extent of their danger to public health.

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