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Evaluating the Water Quality of the Tigris River Between Khawaja Khalil and Sheikh Mohammed Villages, Northwest Iraq

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ABSTRACT

The study examined the physical and chemical parameters of some areas of the Tigris River in the northwestern part of Nineveh Governorate, covering three sites, starting from Khawaja Khalil village, passing through Daranjokh, and ending with Sheikh Mohammed village, for the period from October 2024 to March 2025. The total platelet count (TPC) of bacteria was also calculated to assess the suitability of the water for human use. Physical, chemical, and biological parameters such as air and water temperature, pH, total dissolved solids (TDS), total alkalinity, electrical conductivity (EC), active phosphate (PO4), nitrite (NO2), sulfate (SO4), turbidity, biological oxygen demand (BOD), and total suspended solids (TSS) were measured. Some tests were conducted in the field, while others were conducted in the central laboratory of the left coast of Mosul. Most of the studied parameters were found to be compatible with international and Iraqi water specifications, with a slight increase in the total platelet count (TPC) that did not affect the water quality, especially at station No. (3) which reached (51.25 * 102) cells/ml, and the biological demand (BOD) reached 2.4mg/ L. The pH values ranged between (7.50-8.90), the air temperature between (8-20)°C, the water temperature between (7-18)°C, the electrical conductivity between (190-2064) µS/cm, and the turbidity between (33-196) N.T.U. The total dissolved solids (TDS) values ranged from (800-1207) mg/L, and the total basicity values ranged from (131-190) mg/L, while the highest value for phosphate was 0.89mg/ L microgram/L, and the highest value for nitrite was 51mg/ L, while the highest value for sulfate was 269mg/ L.

INTRODUCTION

Water resources have witnessed a marked deterioration in recent decades due to poor management and lack of attention. This has exacerbated the problem of water pollution, which is characterized by changes in the physical, chemical, and biological properties of water, and the resulting impact on its natural functions within the aquatic ecosystem. This pollution occurs as a result of the release of chemicals, microorganisms, thermal energy, or radiation into water, whether groundwater or surface water, such as rivers, oceans, and lakes **(Khatri *et al.*, 2020)**. Providing safe drinking water is one of the most prominent challenges facing the world, as statistics indicate that approximately 844 million people around the world do not have access to clean drinking water services **(Abbas *et al.*, 2019)**.

The Tigris River in Mosul is the only water source the city relies on to meet its various service needs, whether human, industrial, or agricultural. Studies indicate that the river is exposed to significant environmental pressures due to the discharge of liquid waste from residential buildings, factories, hospitals, and service institutions, in addition to irrigation water and agricultural drainage **(Prahardika *et al.*, 2022)**. This has made it a major reservoir for these wastes, especially given the city's lack of effective sewage networks and treatment plants. These wastes cause changes in the physical and chemical properties of the river water, leading to changes in taste, color, and odor, which directly impacts its suitability for human and animal use. They also significantly impact aquatic organisms in terms of density, distribution, and diversity, which is reflected in their abundance in the river ecosystem **(Kannah & Shihab, 2022)**.

Chemical pollutants pose a significant threat to living organisms. They affect the structure of living cells, attacking the proteins that make up many vital enzymes and inhibiting their activity within the body. They also disrupt cell membranes and impede osmosis, disrupting essential biological processes and preventing the delivery of nutrients necessary for cellular energy generation **(El-Khayat *et al.*, 2022).**

MATERIALS AND METHODS

Study area

This study was conducted on the Tigris River in the northwestern part of Nineveh Governorate. The study area extended from the Khawaja Khalil area, which is approximately 23km from the center of Mosul City, to Sheikh Mohammed, which is approximately 16km from the city center, passing through Daranjokh, within the administrative borders of the governorate. The Tigris River course in this stretch is characterized by clear morphological diversity, as it includes straight, curved, and branched sections. The lands surrounding the river course vary in use, ranging from agricultural to residential areas, including villages and rural areas. Sample collection sites were identified using the Maps.me application, and these sites were plotted on the map, as shown in Fig. (1).

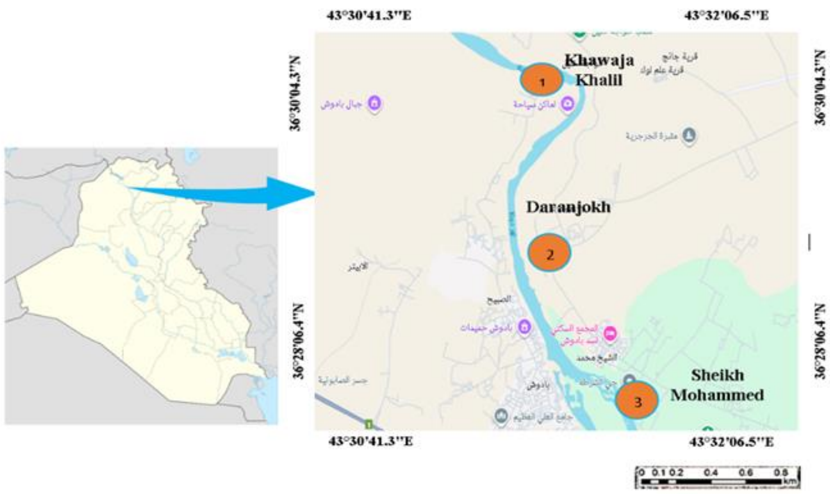

Fig. 1. Map of the studied area showing sites along the Tigris River

Samples collection

Samples were collected monthly from October 2024 till March 2025. Collection began in the morning at Station 1 near Khawaja Khalil, followed by Station 2 near Daranjokh, and finally Station 3, located at Sheikh Mohammed **(Al-Sarraj *et al*., 2014)**.

Bacteriological samples:

For this purpose, glass bottles were pre-sterilized using an autoclave at 15 pounds/inch^2 of pressure and 121°C for 15 minutes.

All samples were stored in a refrigerated container, protected from light, until transported to the laboratory for the required analysis **(El-Khayat *et al*., 2022)**.

Samples for physical and chemical tests:

After washing 2.25-liter polyethylene bottles three times with sample water, they were used to collect samples from selected sites along the Tigris River. 250-ml Winkler bottles were used to measure the amount of dissolved oxygen in the water. Opaque bottles were filled to measure biomass oxygen. After filling the containers and bottles to their maximum capacity, without any bubbles, the transport process and water movement showed no changes in several properties. The plastic bottles were tightly sealed, and the necessary information was recorded on each bottle. The samples were then placed inside a cork container in three replicates and were transported to the side laboratory in Mosul city center for tests related to chemical and physical properties **(Ahmed & Al-Shandah, 2024)**.

Temperature degree:

They were measured using a mercury thermometer graduated between 0 & 100 degrees Celsius after immersing the bulb in river water for two minutes, and the air temperature was left in the shade for the same time **(Al-Shanona *et al.*, 2020)**.

Electrical conductivity:

The electrical conductivity of water was measured using a Multiparameter Analyzer, type CONTRAST 830. The device was calibrated and the results were expressed in microseconds per centimeter (µS/cm).

Turbidity:

The turbidity values of the samples were estimated in Nephelometric Turbidity Unit (NTU), and were measured in the laboratory using a Turbidity meter, model LAB-IR, Lovibond Germany, after shaking the sample well.

Total dissolved solids (TDS):

The TDS was measured in the laboratory using a German-made inolab device in mg/L, and the readings were recorded.

Total suspended solids (T.S.S):

To determine the suspended solids concentration in the water from the study sites, the method described by **ASTM (1984)** was used. 500cm^3 was filtered using GF/F filter paper (0.45 µm). The total suspended solids concentration was calculated using the following equation:

Total suspended solids concentration (mg/L) = A - B × 1000 / sample volume (cm3).

Where (A) represents the weight of dry filter paper and suspended solids; (B) represents the weight of the filter paper only.

pH:

It was measured using a Thermo ECO Tester pH2 pH meter after calibration with buffer solutions of different pH values (9, 7, 4). The methods followed were approved by **APHA (1998)**.

Total alkalinity:

Total alkalinity was measured by taking 50ml of the sample and adding 3 drops of methyl orange indicator, then titrating with 0.02N sulfuric acid until the color changed to reddish orange. $CaCO_3$ was expressed in mg/L, knowing that total alkalinity was calculated using the following equation: Total alkalinity = (V H_2SO_4 × N H_2SO_4 × 1000 × Eq.wt of $CaCO_3$) / (V sample), according to **APHA (2017)**.

Chloride:

Chloride was determined according to **ASTM (1984)** by taking a volume of 25ml of well-filtered sample, adding a small amount of hydrogen peroxide to the sample, then adding drops of potassium chromate indicator K2Cr2O7, followed by titrating with standard silver nitrate solution (0.0141N) until the color changed from yellow to leather red, and the concentrations were calculated using the equation:

$$Cl^- \text{ (mg/L)} = \frac{(B-A) \times 35.45 \times N \times 1000}{\text{ml of sample}}$$

Where,
A = Volume of silver nitrate solution in the burette;
B = Volume of silver nitrate solution used to titrate distilled water;
N = Molarity of silver nitrate;
35.45 = Equivalent atomic weight of chlorine

Dissolved oxygen (DO):

According to the procedures of **Mackerath (1963)**, dissolved oxygen was measured; glass bottles were filled with water samples from the study sites gently to prevent air bubbles. 2ml of manganese sulphate was added, followed by 2ml of potassium iodide to stabilize the oxygen. The bottle was turned upside down several times, gently, and the sample was kept away from sunlight. Then, 2ml of concentrated sulfuric acid was added and shaken well. In the laboratory, 100ml of the sample was taken, and the yellow solution amounting to 203ml was titrated with sodium thiosulphate ($Na_2S_2O_3$), and expressed in mg/liter.

Biological oxygen demand (BOD_5) :

Biological oxygen demand was calculated using the method used to measure dissolved oxygen after incubating the samples in dark bottles for five days at 20°C. They were treated using the same method used to measure dissolved oxygen concentration according to the following equation: DO5 – DO1 = BOD5. The results were expressed in mg/L **(APHA, 1998).**

Phosphate PO_4:

Active phosphates were measured according to the method of Murphy and Riley, published by **Strickland and Parsons (1972)** using a spectrophotometer (EC1011 CECLL) at a wavelength of 885 nanometres. The results were expressed in micrograms of phosphorus-phosphate atoms/litter.

Sulphate SO_4^{2-} :

Sulfate ions were estimated using the turbidimetric method. A volume of 0.5-1ml of sample water was taken and was completed with distilled water to obtain a 100ml. Then 5ml of the condition reagent solution was added, and mechanical shaking was carried out at a constant speed using a magnetic stirrer. Then, barium chloride crystals were added while continuing mechanical shaking for another minute. After that, the concentrations were read and calculations were carried out by comparing them with the standard curve. Dilution was carried out to prevent exceeding the appropriate concentration for this method. The results were expressed in mg/L **(APHA, 2017)**.

Nitrate NO_3^{1-} :

Nitrate was measured using the ultraviolet spectrophotometric screening method **(APHA, 1998)**, using an ultraviolet/visible spectrophotometer type L K B, Biochrome. The absorbance of each sample was measured at wavelengths of 220 and 275nm. Nitrate concentration was determined from the equation for each curve using standard solutions and expressed in mg/L.

Total platelet count (TPC):

Using a series of decimal dilutions of the studied samples, 1ml of each dilution was taken into a sterile dish, with two replicates of the culture dishes of nutrient agar media. The samples were cultured in the traditional way. The dishes were incubated upside down at a temperature of 37°C for 18-24 hours. The dishes with a number of colonies ranging between 30-300 were approved, and then the number of growing colonies in each dish was multiplied by the reciprocal of the dilution to obtain the number of cells in 1ml of the original sample **(Felis *et al.*, 2020)**.

RESULTS AND DISCUSSION

Physical properties

In Table (1), the physical indicators are clarified, showing the highest and lowest values for some of the physical characteristics of the three sites under study along the Tigris River, from the Khawaja Khalil area to the Sheikh Muhammad area, throughout the study period of six months, from October 2024 to March 2025, as detailed in the following data.

The air temperature ranged between 8 & 20 degrees Celsius. The lowest air temperature was 8 degrees Celsius in March at the second site, and the highest temperature was 20 degrees Celsius at the first site in October. While the water temperature ranged between 7-18 degrees Celsius for the months of March and October, respectively, considering the first site, and this finding is consistent with the study conducted by **Ibrahim *et al.* (2025)**.

Electrical conductivity (EC) values ranged between 190- 2064µS/ cm, where the highest value was reached at Site 3 in October, ad the lowest value was reached at Site 2 in March; this observation concurs with that of prior studies **(Mohammed *et al.*, 2022; Shihab & Kannah, 2023)**. Turbidity values ranged between 33-196 N.T.U, with the highest value being at Site (3) in March, while the lowest value was at Site 2 in

October. As for total dissolved solids, we found that they ranged between 800 & 1207mg/ L, with the highest value being at Site (3) in October, while the lowest value was at Site (2) in March, which is consistent with the study results of **Mahmood *et al.* (2025)** and **Naz *et al.* (2025)**. On the other hand, the value of total suspended solids ranged between 23 and 137mg /L, where the highest value was 137mg/ L at Site 3 in March and the lowest value was recorded at 23mg/ L in October. This may be due to the abundance of rain in March, which increases the turbidity of the water as a result of the speed and volatility of the river water **(Oleiwi & Al-Dabbas, 2024)**. With respect to the acidity function (pH), its detected value ranged between 7.50 & 8.90, where it reached its highest value at Site (3) in February and the lowest was at Site 2 in December. The reason for the high acidity function may be ascribed to the nature of the rocks and layers of the earth in the study area, as well as the possible use of organic fertilizer for agricultural lands near the river, and this corroborates the data mentioned in the research of **Rasheed *et.al.* (2024).**

Table 1. Monthly changes in physical parameters of the sites during the study period

Site	Month	Air. Temp.	Water. Temp.	Ec.	Turbidity	TDS	TSS	pH
site 1	October	20	18	2056	49	989	27	8.50
	November	17	15	1998	52	981	29	7.80
	December	15	14	990	53.5	967	31	8.23
	January	12	11	950	55.3	955	39	8
	February	10	8	904	55.6	923	49	8.23
	March	9	7	890	60.2	905	50	8.70
Site 2	October	18	16	1410	33	976	23	8.20
	November	16	15	1350	36	941	24	8.10
	December	14	13	320	38	923	29	7.50
	January	12	10	291	39	906	32	7.90
	February	10	9	195	40	890	33	8
	March	8	8	190	45	800	39	8
Site 3	October	19	17	2064	97	1207	82	8.40
	November	18	15	2062	105	1200	90	8
	December	16	13.4	1032	105	1111	97	8.30
	January	15.5	12.7	970	112	1110	108	8.50
	February	14	11.8	930	143	1109	121	8.90
	March	12	10	900	196	1013	137	8.20

Chemical properties

The chemical indicators are shown in Table (2) for the three sites under study along the Tigris River in the Khawaja Khalil area throughout the study period, as follows:

The total alkalinity value ranged between (131-190) mg/L, where the lowest value was recorded at Site 2 in October, and the highest value was at Site 3 in March, and this is consistent with the studies conducted before **(Naz *et al*., 2025; Jabbar & Mohammed, 2025)**. DO1 values ranged between 6.4-9.7mg/ L, and the lowest value was in August at Site 2 in early October, while the highest value was in February at Site 3. DO5 values ranged between 4.5 & 10.3mg/ L, for the months of October and March, respectively, at the same site (Site 3). This may be due to the activity of microorganisms at Site 3 because the area is agricultural and rich in organic matter, and because October has little rain, which leads to stagnation of organic matter in the river, causing microorganisms to consume oxygen (**Taher & Saeed, 2022)**.

The lowest biological oxygen demand (BOD5) value was 0.70mg/ L in October at Site 3, and the highest value was 2.4mg/ L in March at Site 2, consistent with the study conducted by **Almoula *et al*. (2021)** and **Najeeb *et al*. (2025)**. Regarding chloride, data illustrated in Table (2) show that the lowest level was recorded at Site 1, reaching 8.2mg/ L in March, and the highest level was recorded at Site 3, reaching 22.78mg/ L in October. According to the WHO standards, acceptable chloride concentration in drinking water is up to 250mg/ L. The lower levels obtained in our study are considered within the normal range, but the upper limits exceeded the normal range. This may be traced back to the nature of the soil layer through which the river flows, as the dissolution of salt deposits and other chloride-containing sediments may increase chloride ions by varying degrees **(Lateef *et al*., 2020)**. For phosphate, the lowest value was recorded at Site 2, which was 0.11µg/ L in February, while the highest value was recorded at Site 3, with a value of 0.89mg/ L in March. The high phosphate content is attributed to household discharged into the river, as household discharges contain phosphorus-rich powders and detergents. Given the geography of the study area, we noted the increased likelihood of agricultural fertilizers seeping into the river, especially since agricultural areas are close to the riverbed, particularly in the village of Sheikh Mohammed **(Shambara, 2021)**.

The lowest value of sulfate was 107mg/ L at Site 1 in March, while the highest value was 269mg/ L at Site (3) regarding the same month. This percentage is considered normal according to **Rania *et al*. (2025)**. The low sulfate levels are due to the lack of human activity, such as factories and mining operations, as well as the absence of volcanoes and microbial activity, which produces hydrogen sulfide gas (H2S), which, when oxidized, turns into sulfate. In addition, we should not forget the geological composition of the region's rocks, which may be due to their natural composition. Thus, sulphur ions are not produced **(Keraga *et al*., 2017)**. Regarding nitrate, the lowest value was recorded in January, reaching 12mg/ L at Site 2, while the highest value was 51mg/ L at Site (3) in October. These values are considered high compared to studies conducted earlier **(Bream *et al*., 2019; Aoeed *et al*., 2021)**. This elevation may be due to the frequent biological reactions of organic materials, especially proteins, as it is known that organic materials (proteins), when exposed to oxidation and reduction reactions through biological reactions, produce nitrate ions. This indicates the high infiltration of organic materials into the river in the study area, especially in the village of Sheikh Mohammed, and subsequently leads to an increase in microbial activity **(Hmoshi *et al.*, 2024; Sulebey *et al.*, 2025)**.

Table 2. Monthly changes in chemical parameters of the sites during the study period

	Month	Alk	Do_1	Do_5	BOD_5	Cl^-	Po_4	So_4	No_3
Site 1	October	133	6.9	5.3	0.9	15.29	0.14	200	50
	November	137	7.2	5.7	1.2	14.33	0.15	170	45
	December	143	7.3	6.1	1.4	13.01	0.16	156	41
	January	144	8	6.6	1.5	11.2	0.16	133	38
	February	147	8.3	6.7	1.7	11.04	0.17	130	37
	March	147	9	7	2	8.2	0.18	107	36
site 2	October	131	6.4	5.5	1.3	14.22	0.12	204	13
	November	136	7.2	5.9	1.4	12.32	0.13	198	17
	December	140	7.3	6	1.5	11.10	0.13	180	25
	January	140	8	6.5	1.7	10.31	0.14	159	12
	February	141	8.9	6.6	1.8	10.14	0.11	155	17
	March	142	10	7.6	2.4	9.02	0.16	130	33
Site 3	October	139	7.4	4.5	0.7	22.78	0.33	255	51
	November	147	7.6	6.4	0.8	21.99	0.36	253	47
	December	155	7.6	6.6	1.2	20.41	0.47	258	44
	January	159	8.5	7.1	1.2	19.70	0.78	278	40
	February	171	9.7	8.5	1.4	18.92	0.88	267	36
	March	190	11	10.3	2.9	16.09	0.89	269	35

Table (3) and Fig. (2) show the bacterial growth and numbers, which can be used to determine the total platelet count (TPC) in the river. In November, the total platelet count (TPC) at site (3) was 51.25 * 10^2 cells/ml, while in March, the lowest value was recorded, at 23 * 10^2 cells/ml for the same site. The average platelet count (TPC) for sites (1, 2, 3) throughout the study period was (36.208 * 10^2 ,33.10 10^2 ,40.45 * 10^2), respectively. From the above, it is clear that the bacterial count is somewhat high, but not to the point of harming the quality of the river water. The platelet counts increase in the autumn at site (3) due to its proximity to Sheikh Mohammed village and the bacterial activity in moderate temperatures and a suitable environment full of organic matter **(Magurran, 2021; Taher & Saeed, 2022).**

Table 3. Monthly changes in the total number of panels at the selected sites during the study period.

	October	November	December	January	February	March	Means
site 1	3800	4700	3500	3200	2904	3000	3620.8
site 2	3650	3800	3300	3100	2700	2500	3310
site 3	4700	5125	3750	3650	3000	2300	4045

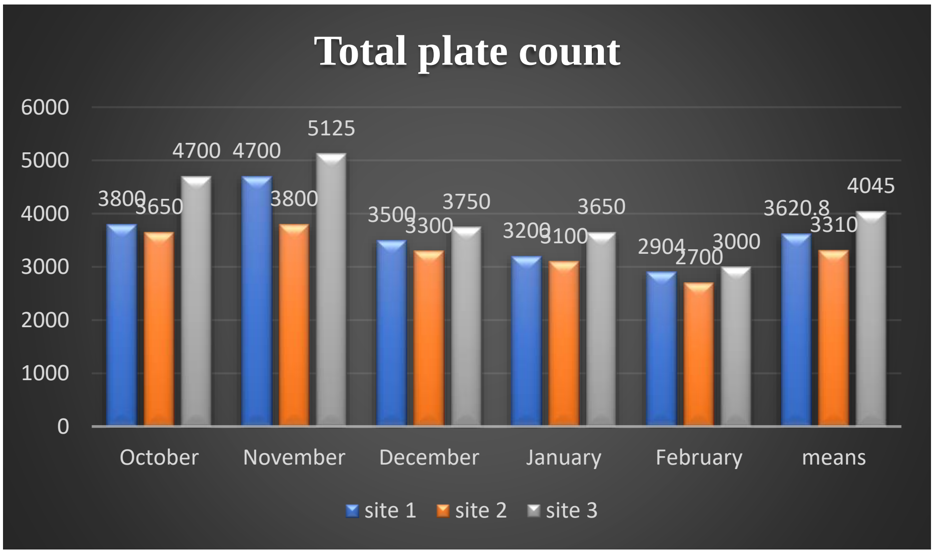

Fig. 2. Monthly changes in total platelet count studied during the study period

CONCLUSION

It has become necessary to monitor the course of the Tigris River from time to time at the sites being studied to determine the current state of the river. In general, the physical and chemical parameters of the Tigris River water at the sites under study were acceptable and consistent with international and local specifications throughout the study period, with the presence of an indicator in the total platelet count (TPC) that did not affect the quality of the water, especially at Station No. (3), which reached (51.25 * 102) cells/ml, given that this area is a source of household and agricultural waste.

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