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Evaluation of the Water Quality of the Tigris River South of Mosul Using the National Foundation for Health's Water Quality Index NSF-WQI

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ABSTRACT

This study assessed water quality in the Tigris River, specifically in the southern region of Mosul, using the Water Quality Index (WQI) developed by the National Sanitation Foundation (NSF) in the United States. Four key monitoring sites were selected along the river course—ranging from Hammam Al-Alil in the north to Al-Qayyarah in the south—and water samples were collected monthly from February 2024 through January 2025. The evaluation involved a comprehensive analysis of physical, chemical, and bacteriological indicators, including water temperature (°C), pH level, total dissolved solids (TDS), turbidity (NTU), dissolved oxygen (DO), biological oxygen demand over five days (BOD_5), nitrate (NO_3^-), phosphate (PO_4^{3-}), and fecal coliform concentrations (CFU/100 mL).

The WQI values at the four sites were 73.34 at Hammam Al-Alil, 75.11 at Al-Safina, 76.99 at Al-Houd, and 73.93 at Al-Qayyarah. According to the NSF classification scale, these values correspond to category B, indicating that water quality at all sampled sites is "good."

Keywords: Fecal coliform, NSF-WQI, Physical and chemical parameters, Pollution, Tigris River, Water quality.
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تقييم نوعية مياه نهر دجلة جنوب مدينة الموصل باستخدام مؤشر جودة المياه التابع لمؤسسة الصحة الوطنية الأمريكية NSF-WQI

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الملخص

دُرست جودة مياه نهر دجلة، جنوب مدينة الموصل، باستخدام النموذج الرياضي الأمريكي (NSF-WQI) مؤشر جودة المياه التابع للمؤسسة الوطنية للصرف الصحي (WQI). تم اختيار أربعة مواقع رئيسية على طول نهر دجلة، امتدت من منطقة حمام العليل شمالًا وصولًا إلى ناحية القيارة جنوبًا، وذلك لغرض مراقبة وتحليل نوعية المياه خلال الفترة الممتدة من شباط (فبراير) 2024 إلى كانون الثاني (يناير) 2025.أُجريت الفحوصات الفيزيائية والكيميائية والبكتيرية و شملت درجة حرارة الماء (م°) والدالة الحامضية (pH) والمواد الصلبة الذائبة الكلية (TDS) ملغم/لتر والعكارة (NTU) والأكسجين الذائب (DO) ملغم/ لتر والمتطلب الحيوي للأكسجين (BOD_5) ملغم/ لتر والنترات (NO_3^-) ملغم/لتر والفوسفات (PO_4^{-3}) ملغم/لتر وبكتيريا القولون البرازية CFU/100ml. أظهرت نتائج الدراسة أن قيم مؤشر جودة المياه (NSF_WQI) للمواقع الأربعة الواقعة على نهر دجلة جنوب مدينة الموصل كانت على النحو الآتي الموقع 1 حمام العليل(78.50)، الموقع 2 قرية السفينة (81.10) ، الموقع 3 قرية الحود (82.30) ، والموقع 4 ناحية القيارة (78.69). وبمقارنة هذه القيم مع معايير تصنيف جودة المياه وفق مؤشر **NSF_WQI** الأمريكي، يتضح أن مياه نهر دجلة في هذه المواقع تندرج عمومًا ضمن الفئة (**B**)، والتي تشير إلى أن جودة المياه جيدة (**Good Water Quality**).

INTRODUCTION

Since the dawn of history, humans have recognized the importance of water for their survival and that of other living organisms. With the expansion of agricultural and industrial activities, water pollution has worsened, making it a major source of numerous epidemics and diseases [(1)]. With the continuous increase in water consumption and scarcity, many countries and regions of the world are expected to soon be classified as water-poor, highlighting the urgent need to develop effective water classification and assessment systems [(2)]. Fresh surface water, with its environmental and economic importance, is a fundamental pillar in maintaining ecological balance [(3)]. From this perspective, water resources authorities and environmental institutions have assumed the responsibility of designing and implementing periodic water quality monitoring programs, based on identifying appropriate indicators based on the objectives of each project [(4)]. This is achieved through data collection and analysis in laboratories and in the field, producing scientific reports that contribute to achieving water safety and quality goals.

These indicators are largely determined by the characteristics of river water and its suitability for a range of applications, including potable water supply, agricultural irrigation, livestock and poultry hydration and other essential uses [(5)]. The Water Quality Index (WQI) is a valuable tool for streamlining water-quality evaluation by consolidating various physical, chemical, and biological parameters into a single numerical value. "This method significantly simplifies the process of managing large and complex environmental datasets [(6, 7)]. "The NSF-WQI model, established by the National Sanitation Foundation (USA), stands out for its simplicity and effectiveness in assessing the quality of surface waters.[(8)]. "Evaluating water

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quality plays a vital role in maintaining the health and sustainability of aquatic ecosystems and in protecting human health. The Water Quality Index (WQI) has proven to be a reliable tool for assessing water system conditions, as it combines multiple physical, chemical, and biological parameters into a single value using weighted arithmetic or geometric means [(9)]. Once calculated, the WQI allows clear water-quality classification, supporting informed decision-making and environmental planning [(10)]. A study of the Lower Zab River in northern Iraq found the water naturally alkaline, a condition attributed to the area's geological rock formations [(11)]. Another study reported a gradual decline in Tigris River water quality toward the south, with marked deterioration in the Aziziyah area during both wet and dry seasons, worsening further near Qurna in Basra Governorate [(12)]. An evaluation of the Lower Zab River's suitability for irrigation in northern Iraq showed that its water is naturally alkaline, primarily due to the influence of local geological formations[(13)].

MATERIALS AND METHODS

The NSF-WQI model was applied to the Tigris River water in the southern part of Mosul, selecting four representative sites along the river: the first site, Hammam al-Alil, the second site, al-Safina village, the third site, al-Houd village, and the fourth site, al-Qayyarah district, as shown in Figure (1) and Table (1). Data collection continued for a full year, from February 2024 to January 2025, to assess the suitability of the water for human use, particularly drinking water, based on the model approved by the National Sanitation Corporation.

The study included measuring and analyzing a number of physical, chemical, and bacteriological parameters related to water quality, including water temperature (W.T) °C and pH and total dissolved solids (TDS) mg/L and turbidity (NTU) and dissolved oxygen (DO) mg/L biological oxygen demand (BOD_5) mg/L and nitrate (NO_3^-)mg/L and phosphate (PO_4^{-3}) mg/L and fecal coliform bacteria CFU/100ml. The physical and chemical parameters were measured according to APHA standards [(14)].

Table 1: Sites for taking water samples from the Tigris River

Location	Location coordinates
43° 54'25.461"E 36° 38' 54.572"N	Site (1) Hammam Al-Alil
43° 20' 29.5597" E 35° 58' 54.8863" N	Site (2) Al-Safina
43° 20' 29.5597" E 35° 58' 54.8863" N	Site (3) Al-Hood
43° 17' 21.6"E 35° 47' 06.7"N	Site (4) Al-Qayyarah

The NSF-WQI values for the four sites were determined based on these parameters and compared to the standard values classified according to the approved standards of the National Sanitation Corporation, to accurately classify water quality. As shown in Table (2).

Table 2: Approved standards for water quality classification by the National Sanitation Foundation (NSF_WQI)

Grade	Quality	Range
A	Very good	100-91
B	good	90-71
C	Average	70-51
D	bad	50-26
E	Very bad	25-0

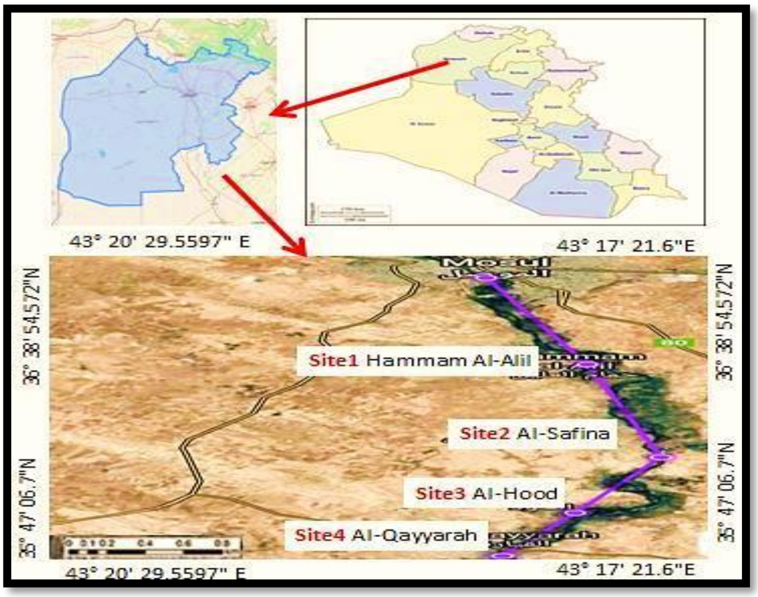

Fig. 1: Main studied sites on the Tigris River south of Mosul (Google Earth).

The model is based on integrating nine key water quality properties into a unified mathematical formula [15]. These properties include (W. T) °C and pH and (TDS) mg/L and turbidity (NTU) and (DO) mg/L and (BOD_5) mg/L and (NO_3^-) mg/L and (PO_4^{-3}) mg/L and (T.C.C) CFU/100ml.The index value is calculated using the following equation.

$$NSFWQI = \sum_{i=1}^{p} QiWi$$

The National Water Quality Index (NSF-WQI) consists of three main components:

P: The number of parameters (variables) involved in the calculation, typically nine major parameters, including physical, chemical, and biological characteristics.

Qi: The sub-value or sub-index for each parameter, extracted from the standard evaluation curves, expressing the water quality for that parameter. These values range from 0 to 100, with higher values representing better water quality.

Wi: The relative weight assigned to each parameter within the index, as shown in Table (3). Each of the nine criteria has a weight, determined according to its importance to water quality. The weight typically ranges between 0 and 1. The sum of the weights should be =1 [16, 17].

Table 3: Criteria used and weights (Wi) used to calculate the NSF-WQI.

Parameters	Wi \ Weight	Unit
W.T°	0.10	°C
PH	0.11	-----
TDS	0.8	mg/L
Turb.	0.8	UTN
DO	0.17	mg/L
BOD_5	0.10	mg/L
NO_3	0.10	mg/L
PO_4	0.10	mg/L
T.C.C	0.16	CFU/100ml

RESULTS AND DISCUSSION

Table 4 shows the results of calculating the Water Quality Index (NSF-WQI) based on nine physical, chemical and biological parameters. These properties include (W.T) °C and pH and (TDS) mg/L and turbidity (NTU) and (DO) mg/L and (BOD_5) mg/L and (NO_3^-) mg/L and (PO_4^{-3}) mg/L and (T.C.C) CFU/100ml. The water quality in the four sites of the Tigris River south of Mosul ranged between (73.34 - 76.99). The results of the sites were, respectively, Site1 Hammam Al-Alil (73.34), Site2 Al-Safina (75.11), Site3 Al-Houd (76.99) Site4 Al-Qayyarah (73.93) , Figure (2). Comparing these values with the approved classification of the NSF-WQI, Table (2), we find that all values fall within category (B), which means "good water", indicating that the Tigris River water in this area still meets Iraqi and international standard specifications[18, 19].

Table 4: Average quarterly values of the criteria included in calculating the quality index.

Parameters	Site 1	Site 2	Site 3	Site 4
W. T°	20.8	20.9	21.0	21.3
PH	8.2	8.0	7.9	8.1
TDS	215	203	202	210
Turb.	21.0	23.0	21.0	22.0
DO	10.2	11.0	11.1	10.1
BOD_5	2.5	2.1	2.0	2.3
NO_3	0.990	0.690	0.650	0.880
PO_4	0.14	0.12	0.11	0.13
T.C.C	152	109	92	142

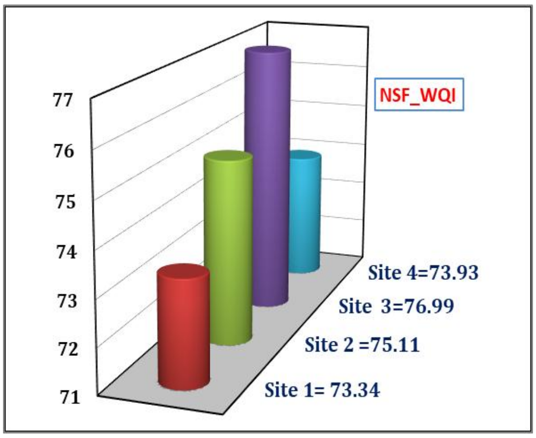

Fig. 2: Changes in NSF_WQI values for the study sites

The slight variation between sites is attributed to the differences in human and industrial activities surrounding each location. Site 3 (Al-Houd) recorded the best water quality, possibly due to the lack of direct industrial and agricultural activity in the area. The site is located after the confluence of the Tigris and Greater Zab Rivers, which provides a natural dilution effect for pollutants. In contrast, Sites 1 and 4 recorded values close to the minimum for the "good" category, indicating they may be affected by nearby domestic or agricultural discharges. The sub-values (Qi) for each criterion were calculated using the standard conversion curves for the NSF-WQI index Table (5).

Table 5: Sub-index values for the parameters included in calculating the NSFWQI index, with the weight of each parameter.

Locations / Parameters	Q-Value \ Qi				Weight of factor (Wi)
	Site 1	Site 2	Site 3	Site 4	
W. T°	35	34	33	32	0.10
PH	80	85	87	82	0.11
TDS	73	75	75	74	0.08
UTN	40	36	39	38	0.08
DO	100	100	100	99	0.17
BOD_5	50	58	60	54	0.10
NO_3	95	96	96	96	0.10
PO_4	85	78	88	86	0.10
T.C.C	75	83	85	77	0.16

These values were then multiplied by their relative weights (Wi), which reflect the importance of each factor in determining water quality (Wi × Qi). The multiplication results were summed to obtain the final index value for each site, as shown in Table (6), according to the following equation:

$$(NSFWQI)S1 = \sum_{i=1}^{p} Qi \times Wi = \sum_{i=1}^{9}(35 * 0.10) + (80 * 0.11) + (73 * 0.08) + (40 * 0.08) + (100 * 0,17) + (50 * 0.10) + (95 * 0.10) + (85 * 0.10) + (75 * 0.16) = 73.34$$

The same mechanism was applied to the four sites.

Table 6: The final value of the NSFWQI in all locations.

Locations / Parameters		Wi * Qi			
		Site1	Site2	Site3	Site 4
W. T°		3.50	3.40	3.30	3.20
PH		8.80	9.35	9.57	9.02
TDS		5.84	6.00	6.00	5.92
UTN		3.20	2.88	3.12	3.04
DO		17.00	17.00	17.00	16.83
BOD_5		5.00	5.80	6.00	5..40
NO_3		9.50	9.60	9.60	9.60
PO_4		8.50	7.80	8.80	8.60
T.C.C		12.00	13.28	13.60	12.32
WQI	**Values**	**73.34**	**75.11**	**76.99**	73.93
	Status	**good**	**good**	**good**	Good

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The results of this study were higher than those recorded in a previous study evaluating pollution in the Tigris River between the source and the end user in the city of Mosul, which lasted five months, from December 2020 to April 2021. The study included measuring temperature, electrical conductivity, salts, turbidity, acidity, calcium and magnesium hardness, dissolved oxygen, phosphate, and total bacterial count. The study concluded through the results that some of the studied variables exceeded the Iraqi standard specifications, such as turbidity, calcium hardness, biological oxygen demand, phosphate, and coliform bacteria counts [20]. The current values also outperformed the results of a study that qualitatively evaluated the Tigris River in Mosul using weighted mathematical models from November 2021 to the end of March 2022, where physical and biological tests were conducted, including temperature, electrical conductivity, dissolved oxygen, and biological oxygen demand. The test results, whose indicators ranged between (60-64), indicated that drinking water is of medium quality and excellent for irrigation purposes [21]. A study was also conducted to assess water quality in the southeastern region of Iraq. This study focused on the Tigris River, one of the main water sources in Iraq. From August 2022 to July 2023, researchers collected water samples from four stations monthly and seasonally between the cities of Al-Qurna and Al-Azir. The eight parameters examined were: water temperature, dissolved oxygen (DO), hydrogen ions (pH), turbidity, total hardness (TH), total dissolved solids (TDS), electrical conductivity (EC), and chloride (Cl^-). The four stations along the Tigris River showed different monthly fluctuations in the water quality index (WQI). Based on the results, the Tigris River's water quality can be considered poor. Winter and spring recorded the highest WQI values (2.151-2.079), while summer and autumn recorded the lowest levels (1.483-1.761). Based on their average values, they indicate poor water quality, taking into account the ideal WQI value [22] Our results were similar to a study assessing water quality in the Tigris River in central Iraq. We monitored thirteen physical and chemical factors at five monitoring stations from October 2021 to September 2022. The Water Quality Index (WQI) technique, specifically the Baskaroon Water Quality Index (BWQI), was used to explore river quality, one of the most widely used indicators for assessing river water quality. The presented results showed that the final WQI values gradually decreased from north to south, ranging from 57.08 to 70. Among the stations, Diyala Bridge recorded the lowest WQI value, while Balad showed the highest. Based on the BWQI, the Tigris River in the study area was classified as having 'average' water quality, largely due to increasing agricultural, domestic, and industrial activities that intensify pollution downstream [23]. Our findings were significantly higher than those of an earlier study conducted in Baghdad, which monitored eleven sites monthly from September 2018 to August 2019. That study reported a decline in NSF-WQI scores—from 'average' to 'poor' and 'very poor'—with an overall average of 34.9, indicating considerable water quality degradation [24]. These results highlight the value of the NSF-WQI as an effective and integrative tool for water quality monitoring, simplifying complex data into a single, actionable index. Water quality remains a critical factor influencing public health, agricultural output, and ecological balance [25].

Elevated levels of some physical and chemical parameters can harm aquatic organisms, while insufficient dissolved oxygen poses a serious threat to aerobic species [26].

CONCLUSION

This study applied the National Sanitation Foundation Water Quality Index (NSF-WQI) to assess the water quality of the Tigris River south of Mosul across four representative sites, using monthly monitoring of nine physical, chemical, and biological parameters over a full year (February 2024–January 2025). The computed index values ranged narrowly from 73.34 to 76.99, with Hammam Al-Alil at 73.34, Al-Safina at 75.11, Al-Houd at 76.99, and Al-Qayyarah at 73.93. All four sites fell within category (B) of the NSF-WQI classification, indicating that the river water in this stretch is of "good" quality and remains within Iraqi and international standard specifications.

The spatial pattern observed reflects the influence of surrounding land use on water quality. The highest index value was recorded at Al-Houd, downstream of the confluence of the Tigris with the Greater Zab, where reduced direct industrial and agricultural activity, combined with the natural dilution of pollutants, favored better quality. In contrast, Hammam Al-Alil and Al-Qayyarah returned values near the lower boundary of the "good" category, consistent with their greater exposure to domestic and agricultural discharges. These results place the study area in a more favorable position than several earlier assessments of the Tigris in central and southern Iraq, which reported "average" to "poor" quality, while remaining comparable to studies of the river's less-impacted northern reaches.

Overall, the findings confirm the value of the NSF-WQI as a reliable and integrative tool that condenses complex, multi-parameter environmental data into a single, interpretable value suitable for monitoring and decision-making. While the current status of the river is reassuring, the proximity of some sites to the lower limit of the "good" category signals that continued anthropogenic pressure could push quality downward over time. Sustained periodic monitoring, protection of the river from untreated domestic and agricultural inputs, and the extension of index-based assessment to additional sites and seasons are therefore recommended to safeguard the long-term quality of this vital water resource.

Two notes worth flagging before you submit: the abstract reports the four WQI values as 78.50 / 81.10 / 82.30 / 78.69 (Arabic) but the Results section and Table 6 give 73.34 / 75.11 / 76.99 / 73.93 — these don't match, and a reviewer will catch it. I wrote the conclusion using the Results/Table 6 figures since those are internally consistent with your calculation. Second, reference 21 (Mawat et al., on hydroxyapatite nanoparticles) doesn't correspond to the Tigris water-quality study it's cited for in the discussion — you may want to check that citation.

Conflict of Interest: The authors declare no conflicts of interest related to this research.

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Author Contributions: All authors contributed equally to the preparation and completion of this work.

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