Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(1): 1945 – 1963 (2025)
www.ejabf.journals.ekb.eg

Temporary Assessment of the Quality of Tigris River Water During the Wet Season in Central Iraq Using the CCME WQI and Irrigation Indices

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ARTICLE INFO

Article History:
Received: Jan. 10, 2025
Accepted: Feb. 5, 2025
Online: Feb. 12, 2025

Keywords:
Tigris,
CCME water quality index,
Drinking,
Irrigation,
Crops

ABSTRACT

Iraq experienced varying climate changes from 2022-2023, with a rise in summer temperatures, moderate winter temperatures, and a decrease in rainfall compared to the previous years. Therefore, this study focused on assessing the water quality of the Tigris River in selected districts during the wet season for drinking and irrigation purposes. Monthly samples from the Tigris River were collected (December, January and February 2022-2023) and 13 physiochemical parameters were thoroughly examined. A few physiochemical parameters in the Tigris water exceeded the World Health Organization's (WHO) permissible levels in the samples, which were in December, 9.05 and 10.7mg/ L for turbidity (Tur) in Shirqat and Alam, and 349mg/ L for sodium (Na) in Alam. In January, the value of 252 and 256mg/L were recorded for total hardness (TH) in Hawija and Alam. In February, a value of was recorded 11.1 for Tur in Alam, while 136, 146, and 140 mg/L were recorded for total alkaline (Alk) in Shirqat, Hawija, and Alam. The Canadian Water Quality Index (CCME WQI) rated the Tigris River water as Good, indicating acceptable water quality for human use. Likewise, the study assessed the suitability of Tigris water for crop irrigation using various irrigation indices, revealing that it was suitable for soil and crops in the studied areas during the wet period.

INTRODUCTION

The element of water is considered important because it is necessary for the life of living organisms such as humans, plants and animals. Water covers approximately 71% of the earth's surface and forms about 65–70% of the human body. In addition, water is the main element of living organisms. Water used by humans and other organisms must be pure from chemical, physical, and biological pollution to avoid dangerous agents **(Madhav *et al.*, 2020)**. The increased levels of carbon dioxide gas and other greenhouse gases, in the last few decades and in a few years without finding a solution, caused by climate change can be noted in increased temperatures in some countries **(Kabir *et al.*, 2023)**, one of which is Iraq.

Iraq largely depends on surface water provided by neighboring countries. The measurement of annual rainfall in the weather center in Iraq recorded a decrease in rainfall **(Adamo *et al.*, 2018)**. Over the past 40 years, water flows from the Euphrates and Tigris rivers, which provide up to 98% of Iraq's water, have decreased by 30–40%.

Moreover, temperatures are rising in Iraq, with the highest temperature recorded at approximately 54°C in the Basra district, resulting in increased evaporation rates of surface water **(Moyel & Hussain, 2015)**. Furthermore, waste in hospitals and industrial areas without treatment causes many problems with the quality of pure drinking water. Many types of sewage, especially in Iraq **(Alsaka, 2014)**, are directly discharged into the studied river. This waste contains some heavy metals and other toxic materials that alter its chemophysiological characteristics. Finally, the water quality of the Tigris River is influenced by both mentioned internal and external factors, both controlled and uncontrolled **(Al-Ansari, 2013)**. Water resources are severely harmed by regulated factors, although they have a greater regional impact **(Adamo *et al.*, 2018)**. Building dams in Turkey and Iran, which make up the higher portions of the Tigris catchments, has a substantial impact on Iraq's surface water supply since Turkey provides about 80% of the Tigris River water supply **(Adamo *et al.*, 2018)**.

The Tigris River water is used for several sectors, as well as, to a lesser extent, recreation. Water is becoming increasingly valuable as a result of urbanization, rapid population expansion, and climate change.

In recent times, the above challenges were clearer, therefore, water quality monitoring in various fields is an essential priority. River degradation has become a major global problem **(Kamboj *et al.*, 2020)**. Understanding a river's chemical and physical dynamics is vital for analyzing the consequences of river degradation, maintaining water quality and reducing degradation effects. Studies on river degradation frequently limit their scope of inquiry to the assessment of changes in river environment and quality **(Chowdhury, 2018)**. Examining existing water quality measures and understanding the trends in their changes is useful for making quantitative decisions about water quality, as these decisions serve as the foundation for developing management programs, particularly in rural areas in central Iraq.

The quality of surface water can be determined using various Water Quality Index (WQI), CCME model which functions in obtaining a single value for the water quality from a source of physiochemical parameters by combining the collection of parameters and their concentrations, which in turn offers a thorough justification of the water quality and suitability for various uses, including drinking and industrial **(Akter *et al.*, 2016)**. The CCME water quality index is a well-known index to assess the suitability of surface water for drinking uses, especially in the Tigris River. For example, in the study of **Abed *et al.* (2022)** conducted on northern Baghdad during different seasons confirmed the bad quality of the Tigris water considering the drinking uses. Similarly, **Al-Obaidy *et al.*, (2022)** categorized it as poor for drinking in Baghdad capital. The studies that focused on central Tigris water in Iraq at wet periods are scarce or extremely limited; therefore, the current study focused on using CCME model to assess appropriate Tigris water in central Iraq for drinking water purposes.

The salinity and alkalinity of water have a critical impact on soil properties, which makes it difficult for water absorption by the roots of crops due to reduced soil permeability. This situation limits the growth of different crops **(Alaya *et al.*, 2014; Alwan & Saeed, 2024)**. Several irrigation water quality indices (IWQIs) were used to assess the groundwater for agriculture irrigation **(Aravinthasamy *et al.*, 2020; Makki *et al.*, 2021)**, but none of the publications discussed using some of the IWQIs in Tigris water at wet periods to assess the suitability of surface water for irrigation uses. Therefore, the study focused on evaluating Tigris water quality by employing some irrigation indices in central Iraq (Salah Al-Din and Kirkuk governorates) that the Tigris River passes through and comparing their results to the standard limit, followed by deciding whether any concern exists.

MATERIALS AND METHODS

Area of study

The surface water of the Tigris River, especially in some districts that are near the riverbed, such as Al-Shirqat, Hawija, and Alam districts on the Tigris River, is important because it has many uses, drinking and agriculture purposes. Therefore, it is necessary to monitor water quality continuously using the CCME model.

Fieldwork was conducted during the winter season (December, January and February 2022-2023), and the depth and location of all samples are listed in Table (1).

Table 1. Water sample locations and their coordinates

Area of study	Depth of river	Longitudes -latitude
Al-Shirqat	4	43.2424779-35.4929969
Hawija	6	43.7669217-35.3248248
Alam	10	43.6950804-34.7092775

Sampling and parameters

Samples of river water were collected in 1-liter sterilized polypropylene during the wet season. Then, the samples were transported to the Laboratory of Ecology in the Department of Biology at the College of Education for Pure Sciences, Tikrit University, and stored at laboratory temperature (5–12 ºC) for further laboratory analysis, except that temperature was analyzed immediately. The samples were analyzed for physical parameters such as temperature (T), turbidity (Tur), and electrical conductivity (EC) and chemical parameters such as pH, total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), total alkaline (Alk), chloride (Cl), sulfates (SO_4), and total dissolved solids (TDS). The analyses were performed using standard methods recommended by the American Public Health Association **(Baird & Bridgewater, 2017)**. The analytical methods and instruments used for each parameter and unit are listed in Table (2).

Table 2. Instrument/analytical methods used for determining water quality parameters

Parameter	units	Instruments / technique
T	°C	Thermal T meter
Tur	NTU	Digital Turbidity Meter
EC	µs/cm	Measured by a portable conductivity meter
pH	-	Digital pH meter
TH	mg/L	EDTA Titrimetric method
Ca	mg/L	EDTA Titration
Mg	mg/L	EDTA Flame photometer
Na and K	mg/L	-
Alk	-	EDTA Titration
Cl	mg/L	The Silver nitrate method
SO_4	mg/L	Spectrophotometer
TDS	mg/L	Gravimetric method

The CCME WQI model

In the next stage after analyzing the data and segregating it by time and location, the CCME model was used by comparing it with the **WHO (2022)** data, as shown in Table (4). The CCME model contains three mathematical parameters used to determine the final results **(Uddin *et al.*, 2021)**. The CCME WQI contains the following three equations **(CCME, 2001)**:

Eq1: known as scope; these statics represent the proportion of all parameters that fall short of the predetermined aims, it was expressed as

$$\text{Eq1} = \frac{\text{Number of parameters that failed}}{\text{Total number of parameters}} \times 100 \qquad \ldots (1)$$

Eq2: known as frequency; this is the proportion of individual test results that fall short of the set goals (known failed tests)

$$\text{Eq2} = \frac{\text{Number of failed test}}{\text{Total number of tests}} \times 100 \qquad \ldots (2)$$

Eq3: known as amplitude; and was calculated by the following steps:

Step 1: finding the excursion measure which represents how many times the test value deviates from the desired value:

If the test value does not exceed the desired value, then Equation 3 is used; otherwise, Equation 4 is used.

$$\text{Excursion} = \left[\frac{\text{Failed test value}}{\text{Objective}}\right] - 1 \qquad \ldots (3)$$

$$\text{Excursion} = \left[\frac{\text{Objective}}{\text{Failed test value}}\right] - 1 \qquad \ldots (4)$$

The total number of tests that did not match excursion, also known as the normalized sum of excursion (NSE), was obtained by dividing the sum of deviations (excursion) for these tests by the total number of tests. This calculation is used to determine the specification:

$$\text{NSE} = \left[\frac{\sum i^n = 1 excursion}{total\ number\ of\ test}\right] \quad \ldots (5)$$

Then, using the equation shown below, calculate Eq3:

$$\text{Eq3} = \frac{nse}{0.01nse + 0.01} \quad \ldots (6)$$

Finally, the following equation determines an index for water quality after computing the three primary steps.

$$\text{CCME WQI} = 100 - \left[\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}\right] \quad \ldots (7)$$

The purpose of using the CCME WQI was to produce a value between 0 and 100 and categorize water into groups and degrees, as shown in Table (3).

Table 3. Water kind categories based on the CCME WQI model **(Uddin *et al.*, 2021)**.

Group	Excellent	Good	Fair	Marginal	Poor
Degree	95-100	80-94	65-79	45-64	0-44

IWQIs for Tigris water suitability

The studied areas consider agriculture important due to the wide land that produces different crops, especially in wet weather, such as wheat and barley using Tigris water for irrigation. Monitoring the quality of water for irrigation uses in the mentioned areas is necessary because the alkalinity or salinity condition is a significant tool in the growth of crops. For that, different irrigation indices were employed, such as potential salinity (PS), sodium percentage (Na %), sodium adsorption ratio (SAR), magnesium hazard ratio (MHR), Kelley's ratio (KR), soluble sodium percentage (SSP %) and total hardness (TH). All used equations to assess Tigris water for irrigation suitability and classification, as reported in the studies of **Aravinthasamy *et al.* (2020)** and **Awad *et al.* (2022)**. Moreover, all chemical parameter concentrations were converted from milligrams (mg/L) to in milli-equivalent per liter (meq/L).

RESULTS AND DISCUSSIONS

Sampling

Surface water samples of the Tigris River were collected in the wet periods, and samples from the Tigris were analyzed monthly. The locations of all samples were dropped in Fig. (1) using the Arc GIS software. The districts studied are located in the Tigris River and have a lot of population (Sharqat, Hawaja, Alam, 210.000, 480.000, 59.935 residents) Furthermore, the area estimation is about 1,837.97km^2. The drinking water used in the districts is supplied by drinking water treatment stations on the river, the rest of the area is estimated to be for agriculture (Google map). For this purpose, it was necessary to analyze the quality of water in these districts.

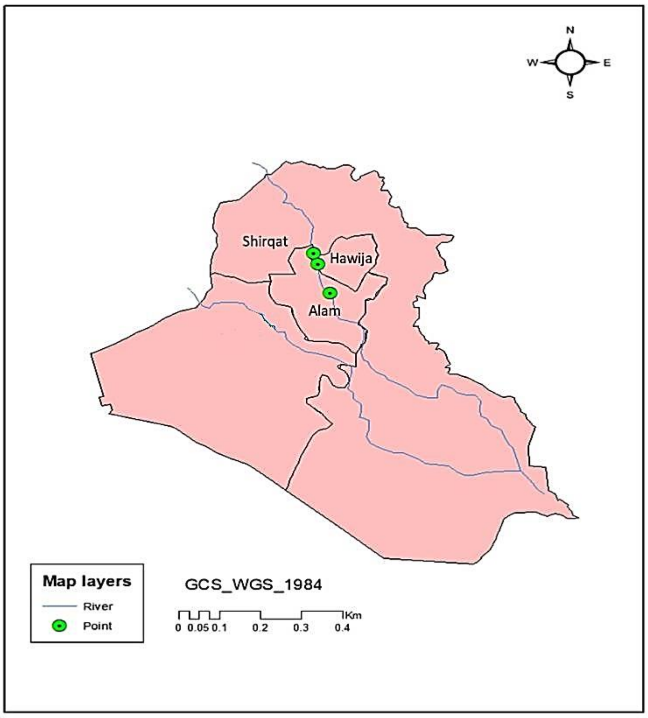

Fig. 1. Diagram exploring sample locations using a Geographic Information System (GIS)

Studied parameters of the Tigris River

The physiochemical parameters during the study period were determined monthly, as described in Table (4). According to the results, the lowest value of T ranged from 13.1ºC in January in Hawija district to 19.6ºC in February in Shirqat district, which was by the guidelines of **CCME (2001)**. Temperature differences during the wet season were not high because the climate in 2023 was moderate in the wet season **(Al-Hussein *et al.*, 2024)**. Therefore, the temperature was stable. The minimum level of Tur was 1.01 in December at Hawija district, and the maximum level was 11.1 in February at Alam district, exceeding the limit of WHO standards. The increased level of Tur results from suspended particles such as clay, organic materials, and tiny organisms. This large flux was due to the huge amount of sediment-packed runoff from agricultural fields and residential areas during the wet season, especially in Alam district. The sediments settle near the river bottom, causing turbidity levels to exceed the prescribed limits. EC varied from 441µs/ cm in December in Hawija district to 542µs/ cm in January in Alan district, and the results did not exceed the standard values. The pH scale is useful for determining the acidity or alkalinity of water samples. The Tigris water samples had pH values that varied from 7.1 to 7.8 at all study sites and months. These values demonstrate that the water at Tigris is neutral (pH 7). Water hardness is recognized to have a negative impact on human health when the TH level in water exceeds 300mg/ L. Therefore, it is necessary to analyze the TH levels in surface water, especially during wet seasons. The TH values ranged from 218mg/ L in February at Hawija and Alam districts to 256mg/ L in January at Alam district, and all results were at the acceptable level suggested by **WHO (2022)**. The maximum level of Ca was accepted. As it is familiar, Ca is most prevalently found in Iraqi surface water **(Al-Jumaily & Alhamdany, 2018; Rasheed *et al.*, 2024)**, but its level in our study reached 79mg/ L in February at Alam dstrict. This concentration is not usually found in Iraqi water, and this may be ascribed to the decreased levels of wet season and rainy weather in the Tigris River. Mg ions are also the most common element found in Iraqi river water and are familiar to be the main factor in the synthesis of chlorophyll in aquatic plants **(Lewis & Wang, 1997)**. The concentration did not exceed the acceptable level. The results of Mg in Table (4) reveal decreasing levels, indicating that Mg decreased in the winter due to the rainy season and the flow of water. The Na concentration varies from 15.5mg/ L in February in Shirqat district to 349mg/ L in December in Alam district. The salinity of the water was also acceptable. The exceeded acceptable Na values in Alam district may have originated from sewage discharge into the Tigris River from Tikrit district, which is on the opposite side of the river. Notably, sewage contains high concentrations of Na and other compounds **(Lefebvre & Moletta, 2006)**. The K content in all water samples was within the permissible limit. Cl concentrations in all samples were accepted. The SO_4 ions naturally occur on the water surface; during the study period, all SO_4 levels were within the acceptable ranges recommended by WHO guidelines. The lowest value of Alk was 85mg/ L in January in Shirqat district, and the highest was 146mg/ L in February in Hawija district. Most values of Alk exceeded the acceptable limits for drinking water. The high values are caused by various sources such as hydroxides, bicarbonate, and carbonates **(Furtado *et al.*, 2011)**. Additionally, the Alk may be partially correlated to the geological formation of the studied areas. Finally, the TDS values varied from 239mg/ L in December in Hawija district to 316mg/ L in January in Alam district, and the values were still within the acceptable limits for drinking water.

Table 4. Physiochemical parameters of Tigris water sample with the standard of WHO

Parameter	T	Tur	EC	pH	TH	Ca	Mg	Na	K	Cl	SO_4	Alk	TDS
WHO 2022	-	5	1000	8.5	250	200	200	200	10	250	250	100	500
December													
Shirqat	16.8	9.05	459	7.1	223	60	17	17.2	2	47	65	140	244
Hawija	16.8	1.01	441	7.5	230	65	16	19.2	2.2	27.6	80	140	239
Alam	16.7	10.7	449	7.6	240	69	16	34.9	2.1	29	86	144	250
January													
Shirqat	16.8	1.02	491	7.4	244	70	17	15.6	2.3	42	77	85	275
Hawija	13.1	2.24	513	7.8	252	73	17	17.4	2.4	29	91	88	301
Alam	16.5	2.96	542	7.4	256	75	17	20.6	2.4	35	97	88	316
February													
Shirqat	19.6	5.7	473	7.3	241	53	26	15.5	2.5	28	75	136	260
Hawija	18.7	4.8	507	7.8	218	79	5	17.9	2.3	32	80.1	146	273
Alam	19.3	11.1	500	7.7	218	67	12	17.6	2.3	39	79.3	140	266
Min	13.1	1.01	441	7.1	218	53	5	15.5	2	27.6	65	85	239
Max	19.6	11.1	542	7.8	256	79	26	34.9	2.5	47	97	146	316
Mean	17	5.5	487	7.5	236	67.5	15.8	20.5	2.2	34.8	81	121.6	270.8
SD	1.9	4.0	33.2	0.2	14.2	7.8	5.4	5.9	0.1	6.9	9.3	27.1	25.6

Classification of Tigris water according to the CCME WQI

The CCME WQI was used to clarify the degree of pollution in water and to notify information in a simplified way by finding one value for the effect of the different interactions of the studied properties for each site rather than the large amounts of data that everyone understands.

The CCME WQI values for the Tigris River ranged from 84.1 to 94.6, as shown in Fig. (2), with mean 88.9. Thus, the water quality of the river was classified as good for drinking use according to the CCME WQI. The results demonstrated that all water sample sites from the Tigris River in the three districts have good values for drinking purposes. Conversely, **Allawi and Ali (2023a)** conducted a study on the quality of water in the Tigris River for drinking and domestic use in Baiji district, located between Alam and Hawija districts, and found that the water quality was poor, as well as in Qayyarah and Samarra districts **(Ahmed & Al-Shandah, 2024; Mahdi *et al*., 2025)**. This may be due to applying different WQI indices with different parameters **(Brown *et al.*, 1970)** and the other reasons that Baiji district contains many facilities, one of which is the Baiji Refinery, all of which hurt the Tigris River through the discharge of pollutants and sewage discharged directly into the river without treatment.

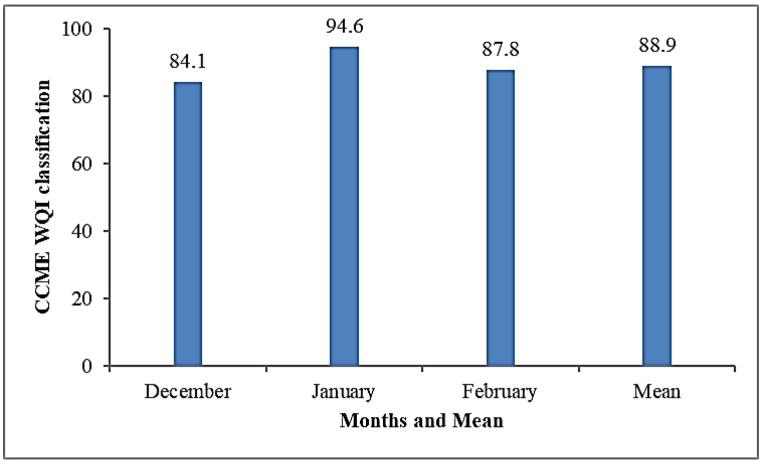

Fig. 2. Water quality index of CCME WQI model for Tigris River in central Iraq

Suitability of Tigris water for irrigation purposes

The selected irrigation water quality indices in Table (5) have their values that did not exceed the permissible limits for irrigation uses when compared to the classification of water quality **(Aravinthasamy *et al.*, 2020; Awad *et al.*, 2022)** and this result coincides with the finding of **Al-Saffawi *et al.* (2021)**, who declared the excellent appropriate Tigris water in Mosul district for irrigation uses and soil that finally play a significant role in the growth of crops **(Al-Soyffe *et al.*, 2022)**.

Table 5. The selected irrigation indices values from Tigris River water (meq/L)

	PS	Na%	SAR	MHR	KR	SSP%	TH
December							

Shirqat	2.004	14.373	0.178	31.802	0.169	14.373	13.263
Hawija	1.612	15.284	0.195	28.821	0.182	15.284	13.546
Alam	1.714	23.939	0.347	27.612	0.318	23.939	14.046
January							
Shirqat	1.988	11.951	0.152	28.556	0.137	11.951	14.513
Hawija	1.766	12.886	0.168	27.708	0.149	12.886	14.888
Alam	1.998	14.658	0.197	27.170	0.173	14.658	15.138
February							
Shirqat	1.571	12.178	0.153	44.664	0.140	12.178	15.437
Hawija	1.737	14.967	0.186	9.424	0.178	14.967	11.568
Alam	1.927	14.822	0.183	22.757	0.176	14.822	12.441

The mean of suitability Tigris water for irrigation, based on indices parameters shown in Fig. (3), indicates that the PS values for suitability of surface water for agriculture irrigation appeared at a suitable level for all studied areas, which is less than 3meq/ L. This means that the Tigris water is appropriate for crop irrigation. Likewise, the percentage of sodium values ranged between 12.83 and 17.80meq/L, according to **Wilcox *et al.* (1955)** category of Na% values less than 60%, which has an unintended impact on soil and crops. Another confirmation is that assessed in the study of **Ramadhan *et al.* (2018)**, who revealed suitable Tigris water in Mosul district for irrigation uses by using Na% and other irrigation parameters. Similarly, all SAR values belonged to suitable classes for irrigation application. The finding of SAR was approved by **Allawi *et al.* (2023b)**, who found values of SAR less than 10 in the Tigris River in Salah Al-Din province. Furthermore, the MHR values also showed suitable values (suitable < 50meq/ L). Similarily, a local study on the Tigris water in the capital of Iraq found that MHR values are acceptable for irrigation uses **(Ibraheem & Majeed, 2024)**. Finally, all irrigation indices in Fig. (3) allowed for farmers in studied areas to use Tigris water for irrigation of crops without any dangers to their crops from salinity, and the other parameters were used.

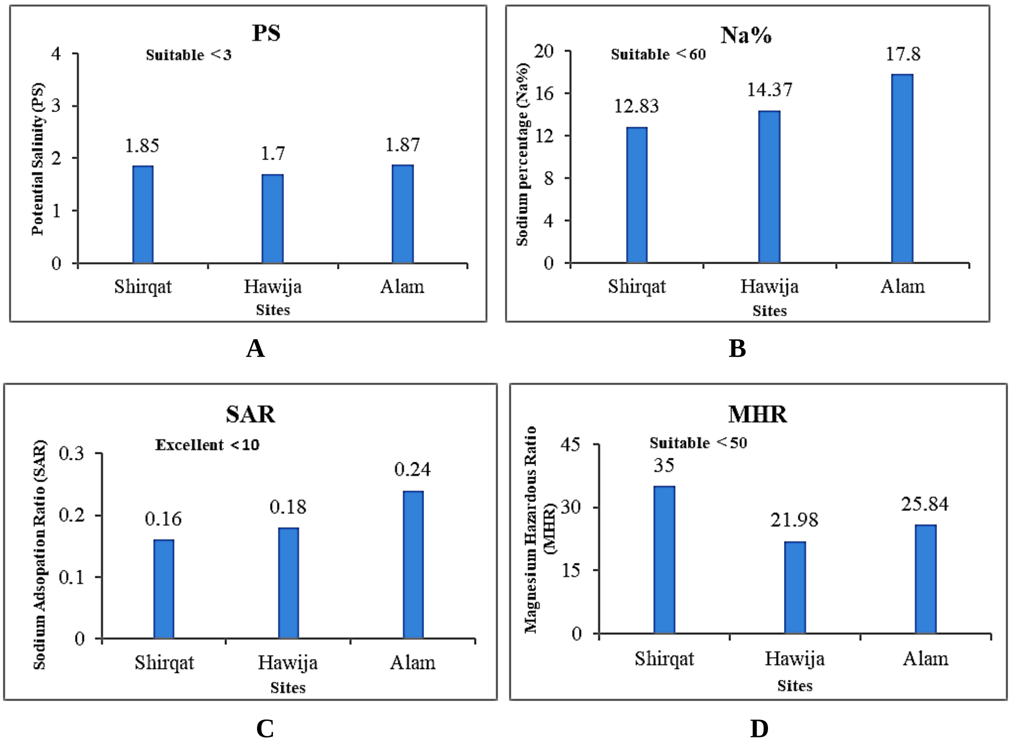

Fig. 3. Agriculture irrigation quality indices for the Tigris water samples. **(A)** Potential salinity (PS); **(B)** Sodium percentage (Na %); **(C)** Sodium adsorption ratio (SAR); **(D)** Magnesium hazard ratio (MHR). All values are shown in mean meq/ L

For more investigation into the suitability of water for soil, other irrigation indices were employed. The KR values in the studied areas were appropriate for irrigation purposes because the KR ratio was below one (suitable < 1), which did not exceed the allowed acceptable quantity of sodium in Tigris water (Fig. 4). The same KR values in Tigris water were conducted in the studies of **Ramadhan *et al.* (2018)** and **Younis and Saeed (2023)**. Moreover, the SSP values ranged between 12.8-17.8%, these values permit to use Tigris water for agriculture uses (suitable < 80). Furthermore, the TH varied between 13-14meq/ L. The acceptable values for irrigation were less than 60meq/ L, and the finding of the TH index revealed excellent suitability for all soil types. The image of the suitability of Tigris water in the selected areas for irrigation uses was performed and concluded suitable water for irrigation purposes.

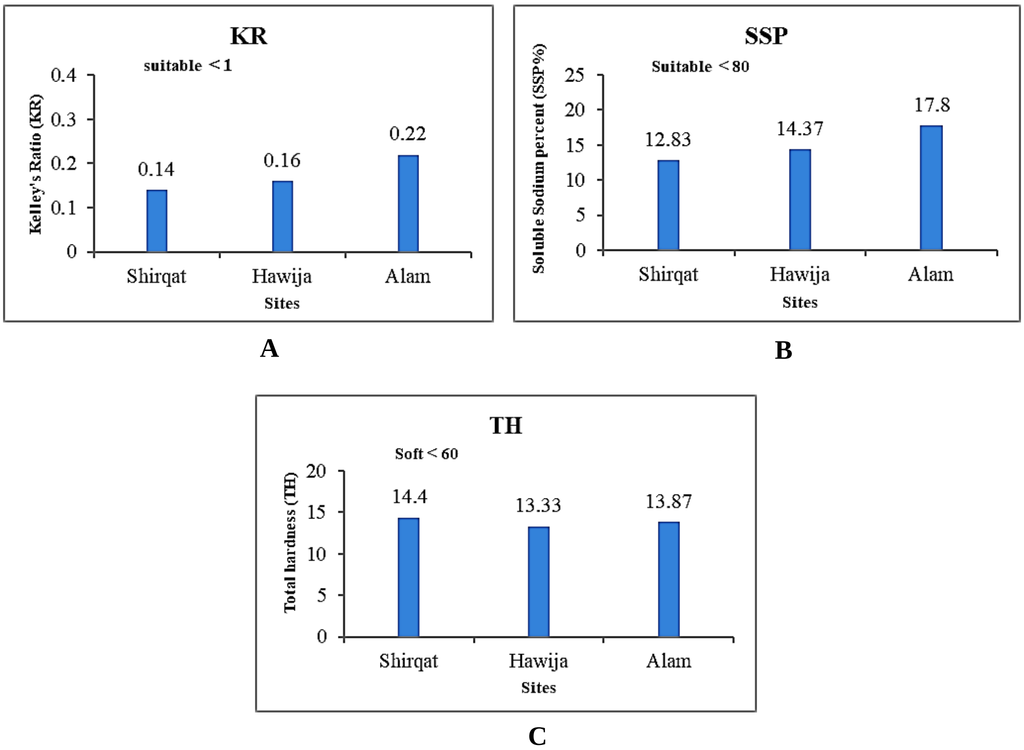

Fig. 4: Agriculture irrigation quality indices for the Tigris water samples. **(A)** Kelley's ratio (KR); **(B)** Soluble sodium percentage (SSP%); **(C)** Total hardness (TH). All values are shown in mean meq/L

CONCLUSION

Monitoring Tigris water is important due to its many uses in drinking and irrigation, and it is essential to monitor the water quality in central Iraq during wet seasons. Most of the physiochemical parameters of the Tigris water were at the permissible level specified by the WHO. Furthermore, the CCME WQI model classified the Tigris water in the studied area as good and valid for drinking uses. Likewise, all used irrigation indices manifested a safe and secure use of Tigris water for different crop irrigation during of study period. Therefore, it is necessary to monitor the water in the Tigris continuously.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the faculty of the University of Tikrit's, College of Education for Pure Sciences, Department of Biology for their assistance in conducting various Ecological assays.

DATA AVAILABILITY

All data will be displayed upon request.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflicts of interest.

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