International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 14S, 2025
https://www.theaspd.com/ijes.php

Using the Irrigation Water Quality Index to Assess the Suitability of the Tigris River Water for Irrigation Purposes Between Al-Shirqat and Tikrit Sections in Salah al-Din Governorate

Maab Noaman Laheeb[1], Mohammed Muthanna Noaman[2]

Department of Environmental Engineering, University of Tikrit, Iraq
mab.numan@st.tu.edu.iq,mohammed.m.numaan@tu.edu.iq

Abstract
The Tigris River water is subject to significant changes in its physical, chemical, and biological properties, most notably due to several factors, most notably the construction of dams in Turkey and successive climate changes. Therefore, the current study aims to monitor and evaluate temporal and spatial changes in water quality in four sections (Sharqat, Zab, Baiji, and Tikrit) located on the Tigris River in Salah al-Din Governorate for irrigation purposes, using the Irrigation Water Quality Index (IWQI) technique. The study period extended from January to July 2024. During this period, five variables were selected and studied: electrical conductivity (EC), sodium adsorption ratio, chloride, sodium, and bicarbonate, due to their direct impact on the suitability of river water as a source of irrigation water.
The study showed that both the north and south of the study area had high values for electrical conductivity (EC), chloride (Cl-), and sodium (Na+) concentrations. The results also revealed that all sectors fall into the second category (76.02-80) when using IWQI, therefore, using river water for irrigation could increase the soil salinity problem if a drainage system is not provided in Salah al-Din Governorate.
Keywords: Surface water, Irrigation Water Quality Index, Salah al-Din, Iraq, Sustainable water management

1.1 INTRODUCTION

The Tigris River is considered one of the most important sources of surface water in Iraq due to its long course within Iraq and its numerous tributaries. As a result, many civilizations and nations established various activities on its banks. These activities, such as factories and cities, discharged various pollutants directly into the river without treatment, exposing it to the risk of pollution. Therefore, this river has been the subject of numerous studies examining its quality and characteristics. These studies indicated the presence of pollution in some parts of the river and its unsuitability for certain uses. This was demonstrated by observing variations in the concentrations of various river characteristics and comparing them with permissible limits (Numaan, 2008a) (Sheet et al., 2014). Therefore, it was necessary to find a more efficient method that collects data and consolidates it into a numerical coefficient that reflects the integrated impact of all factors that play an important role in the qualitative classification process of the river. Through the use of these methods, it is possible to conduct continuous qualitative monitoring of the river's quality, identify its state of pollution, and determine its suitability for various activities within specific categories within an organized system. Hence, the importance of this study to apply the water quality factor, which is one of the aforementioned means, for the purpose of evaluating the quality of Tigris River water for irrigation purposes in Salah al-Din Governorate.

1.2 The Importance of Water Quality Factors:

The nature of studies conducted to determine the water quality of any body of water required several physical, chemical, and biological tests. These studies relied on the concentrations of pollutants in assessing the quality of a body of water. When the concentration of a pollutant exceeds the permissible limits according to the specifications and standards for the type of use, it becomes the primary factor in classifying water quality in terms of its use and pollution (Mohammad Fadhil Alimam et al., 2013).

The water quality factor is the preferred method for solving this problem because it uses several qualitative determinants involved in water assessment and formulates them mathematically, resulting in a number that includes the integrated effect of these determinants.

Since Horton proposed a water quality factor in 1965, several other factors have emerged, most notably the general water quality factor, which includes the most important determinants for classifying river water, determining the nature of its use, and the possibility of treating its water. In addition to the general water quality index, many researchers have devised new indexes related to specific activities, such as drinking water treatment plants, aquatic life, recreation, industry, irrigation, and others. Furthermore, these pollution indexes indicate the nature of water pollution and the possibility of controlling it (Horton, 1965). From the above, it is clear that water quality indexes play an effective role in developing water quality control and strategic management processes, enabling water to be classified qualitatively for various activities within specific categories in a simple and useful manner.

1.3 Research Objectives:

1 .To measure the concentrations of certain elements and compounds, temporally and spatially, in the Tigris River waters of the Sharqat, Zab, Baiji, and Tikrit sections within Salah al-Din Governorate, for the period from January to June 2024.

2 .To evaluate the suitability of the river as a source of irrigation water by determining the value of the water quality index for irrigation purposes for the selected sections in Salah al-Din Governorate.

3 .To classify the suitability of water quality for irrigation purposes.

2- LITRITURE RIVEW

2.1 The Importance of Water Quality Index

The nature of studies conducted to determine the water quality of any body of water required numerous physical, chemical, and biological tests. These studies relied on the concentrations of pollutants in assessing the quality of a body of water. When the concentration of a pollutant exceeds the permissible limits according to the specifications and standards for the type of use, it becomes the primary factor in classifying water quality in terms of its use and pollution.

Therefore, scientists and researchers have found a solution to this problem by using a mathematical model called the Water Quality Index (WQI). This index is preferred by many researchers in the field of studying and evaluating water quality, as it utilizes many of the qualitative determinants involved in water assessment and formulates them mathematically, resulting in a number that includes the integrated effect of these determinants (Al-Hussein, 1998). Since this factor was proposed in 1965 by Horton to assess water quality, many other factors have emerged. The most prominent of these is the general water quality factor, which includes the most important determinants for classifying river water, determining its use, and the possibility of treating it. Other factors are related to a specific activity and focus on studying the factors of drinking water preparation, aquatic life, recreation, industry, irrigation, and others. In addition to the above, there are pollution factors, which indicate the nature of river pollution and the possibility of controlling it. It is clear from the above that water quality factors play an effective role in developing water quality control and strategic management processes, enabling water to be qualitatively classified for various activities within specific categories in a simple and useful manner.

2.2 General Water Quality Index (General WQI):

Horton proposed the Water Quality Index (WQI) in an attempt to classify water. He selected eight physical and chemical variables to indicate the degree of deterioration or improvement in water quality. He concluded that some rivers have excellent water quality, while others have acceptable or poor water quality. He also explained that the WQI provides a method for measuring existing pollution because it allows comparing river conditions at any given time with desired or planned conditions for the future. Therefore, this index is useful for management purposes and a useful and expressive tool (Tavassoli & Mohammadi, 2017). Abdul-Razak et al. (Asiedu, 2009) conducted a study to investigate changes in the water quality of the Oti River in Ghana using the Canadian Water Quality Index (CCME WQI), which includes four water quality variables (turbidity, fecal coliform, total coliform, and total iron). Water samples were taken semi-monthly from several locations along the river over a six-month period, from December to May 2005. The study results indicated that the river's water quality was poor throughout the study period, classified as Poor, a category five on the index scale. This was attributed to the impact of urban and agricultural waste discharged directly into the river without treatment. A number of researchers also conducted a study to assess the water quality of the Karun River, located in southwestern Iran, using two water quality indices: the CCME WQI and the NSF WQI. The data used to calculate both indices were collected over varying periods from 2002 to 2008 and from nine monitoring stations along the river. The results of the study showed that the Karun River was classified as Medium using the NSF WQI, while it was classified as Marginal and Poor using the CCME WQI (Mojahedi & Attari, 2009).

In the US state of Oregon (Samadi, et al.,2015) evaluated the water quality of the Moradbeik River using the Water Quality Index (WQI) for a period of 12 months. The WQI included nine biological, physical, and chemical tests. The study concluded that the average WQI ranged from acceptable to poor.

2.3 Pollution Index:

This study focused on studying the impact of pollution resulting from various pollutants that reach the river during the discharge of industrial, municipal, agricultural, and other wastes, which affect the condition of the river, causing pollution and altering its characteristics.

Researchers (Pesce & Wunderlin, 2000) used the water quality index to assess the negative impacts resulting from the discharge of sewage from the city of Cordoba on the water quality of the Suquia River in Argentina. Sampling continued for three years from 1996 to 1998 at eight selected stations along the river course. The results of the study showed that water quality was good at stations located upstream (before the river entered the city section), while water quality was poor at stations located downstream and close to urban sewage discharge points.

In India (Chougule, et al. 2009) used the water quality index to monitor pollution resulting from the discharge of industrial, agricultural, and urban waste into the Panchganga River. The study period extended over a full year, from January 2007 to December 2007. The researchers concluded that the index values were very low during the summer months are due to the low water levels at this time of year, which leads to an increase in the concentration of pollutants in the river, while the river's values begin to improve during the autumn and winter months due to the increased water discharge from the upper river.

2.4 Water Quality Index for Different Activities:

Evaluating water quality for different activities and determining the suitability of river water based on the Water Quality Index has become essential because it demonstrates the integrated impact of the concentrations of variables appropriate for each activity, as well as determining the importance of each variable associated with the use of the water resource. Deininger and Maciunas (Deininger & Maciunas, 1971) conducted a study on the drinking water quality index. This index was developed using the DELPHI method (Linstone and Turoff, 1975) to select variables and relative weights associated with this activity. The weighted geometric mean formula was used to calculate this index. Shrivastava et al. (2022) conducted a study on the water quality index to assess the quality of the Netravathi River in India for drinking purposes. They used the Bhargava index and the harmonic mean index. Eight transects along the river were selected. Six parameters were chosen: pH, dissolved oxygen, biochemical oxygen demand, turbidity, dissolved solids, and total microbial count. They concluded that the water quality ranged from excellent to acceptable when using the Bhargava index, but that the harmonic mean index indicated that the water quality of the river ranged from excellent to poor.

The National Water Quality Index (NSF WQI) was also used as a tool to assess the quality of water from a group of wells and a water treatment plant in terms of its suitability for supplying drinking water to some areas in Delhi, India. Five variables were selected to calculate the index: pH, nitrate, TDS, turbidity, and temperature. Samples were collected monthly from a group of wells located in Nehru Camp (Site 1) and Sanjay Gandhi (Site 2) and from a raw water treatment plant in Haiderpur (Site 3) from December 2006 to August 2007. The index value indicated that the water quality of the plants studied ranged from good to average. The water quality of the treatment plant (Site 3) was acceptable for supplying drinking water, while the water from the other two plants required treatment before being used for supplying drinking water (Chaturvedi & Bassin, 2010). On the Arab world level, the National Water Research Center in Egypt (Abdel-Gewad and Khalil, 2003) used the Water Quality Index (WQI) developed by the Canadian Council of Ministers for the Environment (CCME WQI) to implement an advanced continuous monitoring system to assess the water quality of the Nile River and some of its main tributaries and to determine the suitability of this water for various activities (drinking, irrigation, recreation, and aquatic life). Fixed monitoring stations were deployed along the Nile River, some of its main tributaries, and Lake Nasser. These stations operate automatically to measure certain water quality variables (Temp., pH, DO, EC, turbidity, ammonium, and nitrate) at regular intervals. The primary objective of this project is to develop Egypt's environmental management capacity to monitor changes in the quantity and quality of Nile River water in record time, allowing rapid response and treatment of any emerging water quality threats.

In Tunisia, a number of researchers used the Canadian Medium Water Quality Index (CCME WQI) to conduct long-term monitoring of temporal and spatial changes in the water quality of the Sejnane reservoir, located in northeastern Tunisia. This reservoir is the primary source of drinking and irrigation water in the region. The study period spanned ten years, from 1995 to 2006, with samples collected monthly at nine monitoring stations. The results of the study showed that the quality of the reservoir water ranged from good to excellent throughout the study period, confirming its suitability for drinking, irrigation, recreation, and aquatic life (Zouabi Aloui & Gueddari, 2009).

In Iraq, (Shihab and Al-Rawi, 1994) conducted a study on the water quality index of the Tigris River in Mosul, within a 20-km distance from the city, selecting nine sample sites. The researchers relied on the geometric mean formula previously used in Baghdad, India, and Vietnam, using a sensitivity function between (0 – 1) and using the index to classify the Tigris River within the study area for various activities. The results indicated that the quality of the river's water falls within the excellent category for irrigation and the first and second categories for aquatic life. For human and industrial uses, it falls within the second category. (Al-Hussein, 1998) studied the water quality of the Tigris River from the north of Mosul to Hammam al-Alil. The area was divided into 17 sections, and the study period extended over six months, from the beginning of January to the end of June 1998. The researcher used four formulas for the water quality index (weighted arithmetic mean, weighted adjusted arithmetic mean, weighted geometric mean, and harmonic mean). She concluded that the Tigris River water within Mosul falls within the first and second categories for irrigation purposes, the second category for industrial uses, and the third category for human uses, except for some sections at the outlets of wastewater drains in some residential areas, which fall within the fourth category. Comparing the four formulas she used, she found that the weighted geometric formula was suitable for industrial and irrigation uses, while the harmonic formula was suitable for drinking purposes.

ISSN: 2229-7359
Vol. 11 No. 14S, 2025
https://www.theaspd.com/ijes.php

A study was conducted on the Water Quality Index (WQI) to evaluate the quality of Tigris River water for various uses (public, drinking, irrigation, and industrial) in the area extending from Sharqat district to Albu Ajil village, located south of Tikrit city in Salah al-Din Governorate. The study lasted eight months, starting from November 2007 until the end of June 2008. Seventeen variables affecting river water quality were selected, with one sample per month. The WQI values showed that the water quality was classified as "Very poor" and "Very good" for public water use, while for drinking it was classified as "Polluted" and "Very poor." For industrial use, it was classified as "Very good" and "Polluted," while for irrigation it was classified as "Excellent" and "Acceptable" (Numaan, 2008).

3-Materials and Methods

3.1 Study Area:

The study area encompassed a section of the Tigris River within Salah al-Din Governorate, starting from the city of Sharqat in the north to the city of Tikrit in the south, between latitudes (35.538 - 34.27) north and longitudes (43.257 - 43.241) east. Water quality was selected and studied in four sections located along the Tigris River: (Sharqat - Zab - Baiji - Tikrit). The study area contains agricultural lands and drains distributed along both banks of the river, in addition to a number of diverse industrial activities, such as the northern/Baiji oil refineries, gravel and sand quarries, and other activities. There are also several urban wastewater outlets distributed along both sides of the river, which discharge their waste into the Tigris River, suggesting the presence of various pollution hazards, as illustrated in Figure (3-1), which shows the areas covered by the study.

Figure (1-3): Map of the study area and the studied sites.

Table (1-3): Coordinates of sample taking sites.

Coordinates		Section	Symbol
35°53′06.0″N	43°14′04.1″ E	Sharqat	1
35°16′25.1″N	43°21′51.2″E	Zab	2
34°56′14.2″N	43°30′22.0″E	Baiji	3

34°38′02.5″N	43°40′59.2″E	Tikrit	4

Calcareous or gypsum soils predominate in the study area, and they are the most common type of soil, as they are found in most of the administrative units of Salah al-Din Governorate. They consist of a mixture of sand, gypsum, and lime, and are characterized by high salinity levels, in addition to their lack of organic matter.

3.2 Application of the Water Quality Index

After completing the first stage, which consists of obtaining the values and concentrations of variables and representing them in time and space graphically, the second stage begins, which is calculating the Irrigation Water Quality Index (IWQI) based on the following five water quality factors: electrical conductivity (EC), sodium absorption ratio (SAR), sodium ion concentration (Na^+), chloride ion concentration (Cl^-), and bicarbonate ion concentration (HCO_3^-). The IWQI calculation process is carried out through three main stages:

1. Unit conversion: At this stage, the ion concentration unit is converted from [mg/L] to [mEq/L].
2. Calculating the values of the water quality subfactors (qi) and their cumulative observations (Wi): The values of the water quality subfactors (qi) and their weights (Wi) are calculated based on Table (3-2), which summarizes the ranges of these subfactors (qi) and their proposed limits.

q_i	EC (µS/cm)	SAR $(meq/L)^{1/2}$	Na^+ (meq/L)	Cl^- (meq/L)	HCO_3^- (meq/L)
85–100	200–750	<3	2–3	<4	1–1.5
60–85	750–1500	3–6	3–6	4–7	1.5–4.5
35–60	1500–3000	6–12	6–9	7–10	4.5–8.5
0–35	<200 or >3000	>12	<2 or >9	>10	<1 or >8.5

Table (2-3): Sub-factors of irrigation water quality qi and proposed limits for each category. (Abbasnia et al., 2018).

Then the values of the five water quality parameters qi (qEC, qSAR, qNa+, qCl-, qHCO3) are determined using the equation below :

$$q_i = q_{\max} - \left(\frac{\left[\left(x_{ij} - x_{\inf} \right) \times q_{imap} \right]}{x_{amp}} \right) \quad \text{........................ (1 – 3)}$$

Whe

q_{max}: ponding to qi.

X_{ij}: The actual value obtained for each variable.

X_{inf}: The lower bound value for each variable, as indicated in Table.(1-3)

q_{imap}: The class range.

X_{imap}: The range of values corresponding to each class.

1. Calculating the values of the water quality index for irrigation purposes (IWQI): This stage is done by multiplying the qi values obtained from equation (1-3) by the corresponding weight indicated in table (3-3), using the following relationship:

$$IWQI = \sum_{1}^{n} q_i w_i \quad (2 –$$

Where:

n represents the number of variables used in calculating the index value. In this study, the value of n is 5.

The qi values obtained from Equation (1-3) are multiplied by the corresponding weight, wi, for each variable, as shown in Table.(3-3)

Parameters	w_i
EC	0.211
Na^+	0.204
HCO_3	0.202
Cl^-	0.194
SAR	0.189
Total	1.000

Table (3-3): Weights of water quality parameters for irrigation purposes IWQI (Meireles et al., 2010).

After obtaining the final value of the Irrigation Water Quality Index (IWQI), this obtained value is compared with Table (3-5) to determine the suitability of this water as a source for irrigating crops and the extent of its impact on the quality of agricultural soil.

Table (5-3) Characteristics of the water quality index (Meireles et al., 2010).

Recommendations for crops and agricultural soils		
Soil	Plant Types	IWQI Values
The water can be used for all soil types due to the low risk of soil salinity and sodicity.	Non-toxic	and Type of Limitation
The water can be used for light soils with high sand content and medium to high permeability.	Avoid using it to water salt-sensitive plants	85-100
The water can be used for soils with medium to high permeability, provided that moderate soil leaching is performed.	Moderately salt-tolerant plants	(No Limitation)
The water can be used for permeable soils without compacted layers, taking into account the high frequency of irrigation water tables with characteristics of EC >2000 µS/cm and SAR >7.	Moderately tolerant to salt	70-85
The water cannot be used for soil irrigation under normal conditions.	Moderately tolerant to salt	(Low Limitation)

4-RESULTS AND DISCUSSION

4.1 Evaluation of the five groups' hazards:

4.1.1 Salinity Hazard

The highest electrical conductivity value in the Tigris River water was recorded in the Zawiya section (February) (530) microsiemens/cm, while the lowest value was recorded in the Baiji section (June) (389) microsiemens/cm), as shown in Figure (3-2). All sections witnessed a significant decrease in electrical conductivity values during May and June as a result of the rising water levels of the Tigris River due to the melting snow and rains that occurred in the Kurdistan Region and Turkey, which led to a reduction in salt concentrations in the riverbed.

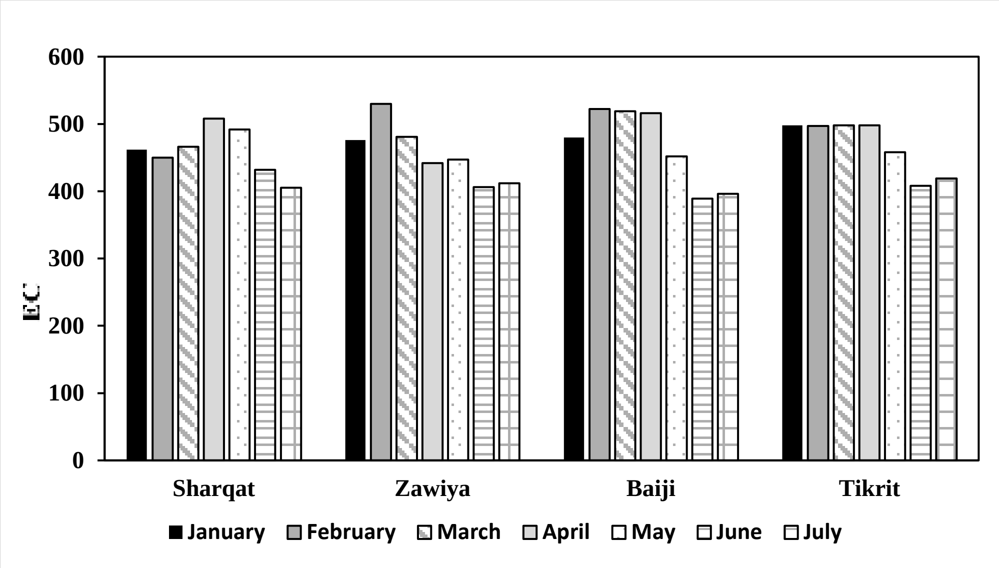

Figure (1-4): Electrical Conductivity Values in the Study Area

On the other hand, electrical conductivity values slightly increased in the center and south of the study area, due to interference with groundwater in the Al-Zawiya and Baiji sections, as well as the impact of thermal pollution from the North Baiji power plant and industrial wastewater from the North Oil Refinery, in addition to the geological formation of the Al-Fath area (Numaan, 2011). As for the south of the study area, agricultural drainage and soil type in this area (gypsum and calcareous soil) all led to increased electrical conductivity values (Mahdi et al., 2022).

4.1.2 Infiltration Hazard

The temporal and spatial variations in the sodium adsorption ratio (SAR) can be observed in Figure 4-2. The results showed an increase in SAR values during the first four months due to the impact of rainfall on the river water level and the accompanying erosion of liquid and solid waste from civil and industrial activities. Furthermore, the rise in the river water level in February and March led to the washing away of the upper soil of agricultural lands and an increase in salt concentrations in the riverbed.

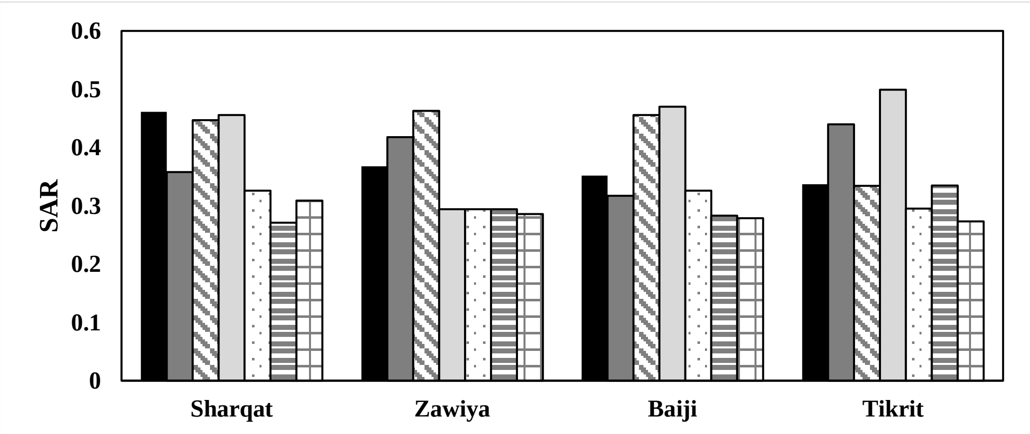

Figure (2-4) shows the sodium adsorption rate in the study area.

4.1.3 Specific Ions Toxicity

Figure (4-3) shows the temporal and spatial variations in sodium ion concentrations at all sections.

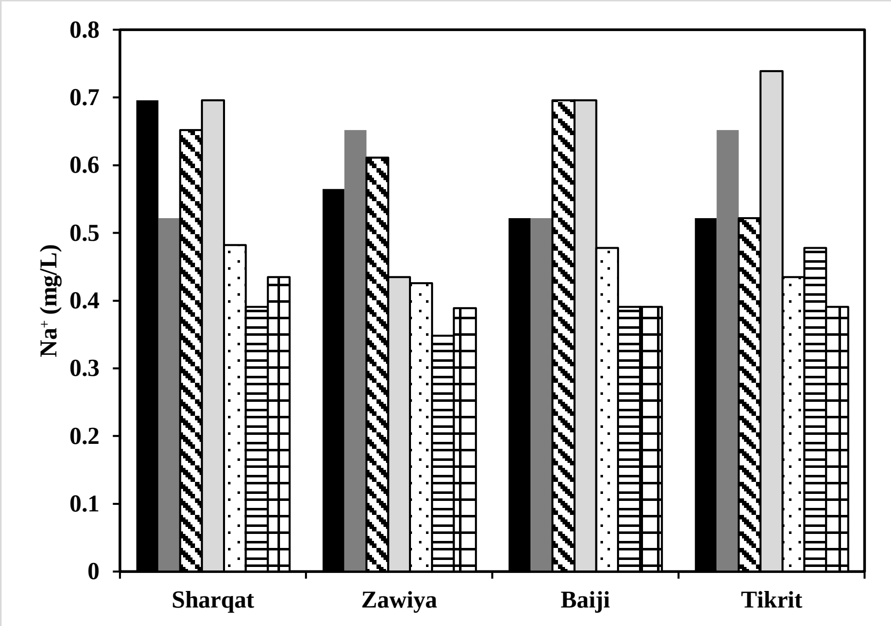

Figure (4-3) Sodium ion concentration in the study area.

The results showed a decrease in sodium ion concentrations in all sections during the last three months due to the rise in river water levels, which led to dilution of the river water, particularly sodium concentrations. However, the first four months witnessed a significant increase in values due to delayed rainfall and increased agricultural, urban, and industrial discharges into the river, which in turn contain high concentrations of sodium ions. This is also due to the dissolution of minerals from the rocky structure, such as halites in the geological formation of the Al-Fatah area and clay minerals (Alattar, 2024). Chloride ions are another criterion whose concentrations must be determined in water sources when used for irrigation. The current study showed an increase in chloride ion concentrations in February compared to other months, as shown in Figure 4-4. The reason for the high ion concentrations is due to rainfall, which in turn washes away sediments present on the banks and at the bottom of the river. Moreover, the geological formation of the Al-Fatah area (halite mineral), the evaporation factor, and the drainage of agricultural areas played a major role in increasing the concentration of chloride ions in the river water.

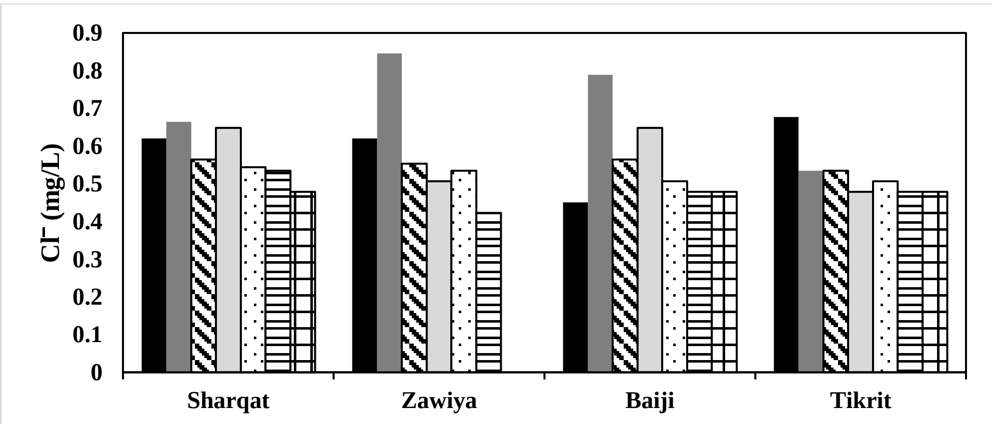

Figure (4-4) Chloride ion concentration in the study area.

4.1.4 Other Miscellaneous Effects

Bicarbonate concentrations increased at all sites in March and April, as shown in Figure 5-4. This increase is attributed to rainfall and rising river water levels, which lead to the dissolution of minerals from the rock structure, such as limestone and dolomite. In addition, the interaction between groundwater, river water, and the geological formation of the Al-Fatah area was the second reason for the increase in ion concentration (Numaan, 2008).

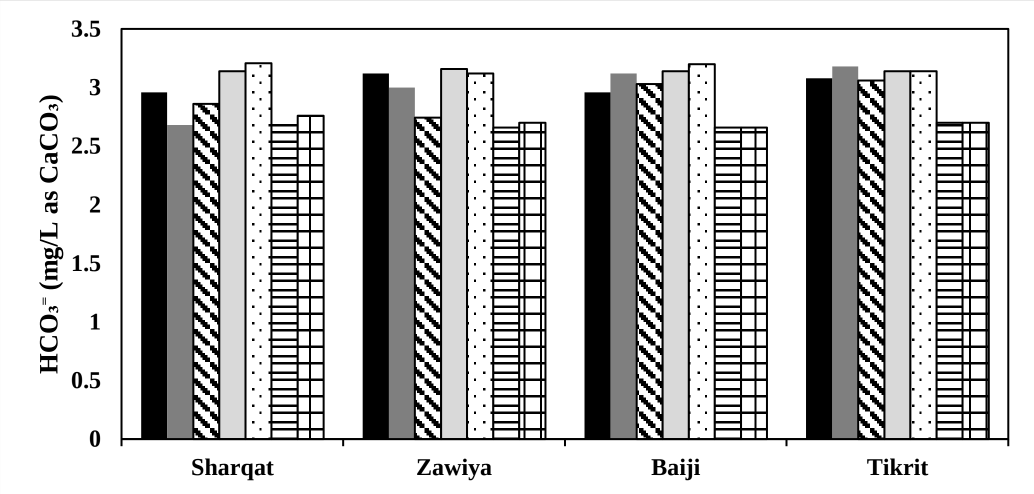

Figure (4-5) shows the concentration of chloride ion in the study area.

4.2 Irrigation Water Quality Index (IWQI)

Figure (6-4) shows the irrigation water quality index (IWQI) values for all studied sections. River water was classified as Category 2 (low-restriction) for irrigation in all sections during the study period. In general, irrigation water quality indicators improved across all sections during the months of May, June, and July, as shown in Figure.(4-6)

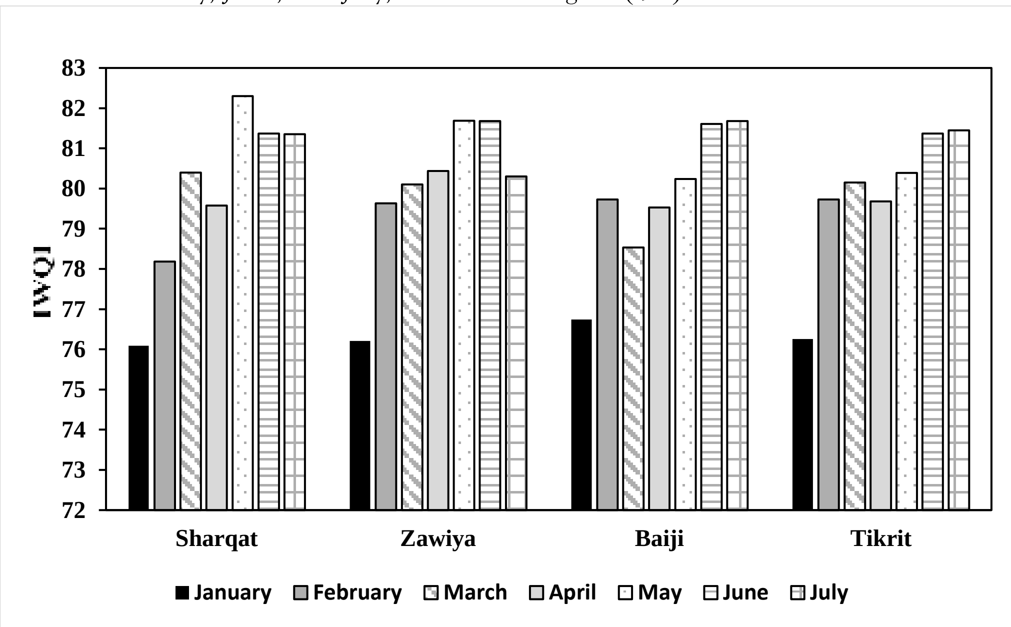

Figure (4-6) Water quality index values for irrigation purposes in the study area.

5--CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

Based on the results obtained from the current study, the following conclusions can be drawn:

1. The months of January, February, March, and April witnessed a significant increase in electrical conductivity and sodium adsorption ratio values for all sections.
2. The geological composition of the Al-Fatha area (the Halatite mineral), the discharge of agricultural, civil, and industrial waste, and interference with groundwater played a major role in increasing the values and concentrations of the five studied factors in the river water.

3. The Tigris River Water Quality Index values for irrigation in the Tikrit section for all months were classified as Category 2, which is characterized by its unsuitability for salinity-sensitive crops.

5.2 Recommendations

1. Adopt water quality parameters for irrigation and geographic information systems as an integrated tool to assess the suitability of water quality for irrigation and the potential problems associated with it on soil and agricultural crops.
2. Conduct an annual assessment of the quality of Tigris River water and groundwater within Salah al-Din Governorate, based on water quality parameters and geographic information systems, to provide a database that can be used by decision-makers.
3. Increase awareness among farmers through audiovisual and written media on the optimal use of agricultural fertilizers, whether organic or chemical, to reduce water pollution from fertilizer waste.

REFERENCES

- Abbasnia, A., Alimohammadi, M., Mahvi, A. H., Nabizadeh, R., Yousefi, M., Mohammadi, A. A., Pasalari, H., & Mirzabeigi, M. (2018). Assessment of groundwater quality and evaluation of scaling and corrosiveness potential of drinking water samples in villages of Chabahr city, Sistan and Baluchistan province in Iran. *Data in Brief*, *16*, 182–192. https://doi.org/10.1016/j.dib.2017.11.003
- Alattar, M. H. (2024). Mapping groundwater dynamics in Iraq: Integrating multi-data sources for comprehensive analysis. *Modeling Earth Systems and Environment*, *10*(3), 4375–4385. https://doi.org/10.1007/s40808-024-02029-9
- Asiedu, A. B. (2009). *Assessment of the Water Quality of the Oti River in Ghana*.
- Chaturvedi, M. K., & Bassin, J. K. (2010). Assessing the water quality index of water treatment plant and bore wells, in Delhi, India. *Environmental Monitoring and Assessment*, *163*(1–4), 449–453. https://doi.org/10.1007/s10661-009-0848-2
- Chougule, M. B., Wasif, A. I., & Naik, V. R. (2009). Assessment of water quality index (WQI) for monitoring pollution of River Panchganga at Ichalkaranji. *Proceedings of International Conference on Energy and Environment, Chandigarh*, 122–127.
- Deininger, R. A., & Maciunas, J. J. (1971). A water quality index for public water supplies, Department of Environmental and Industrial Health, School of Public Health, University of Michigan. *Ann Arbor, Michigan*.
- Horton, R. K. (1965). An index number system for rating water quality. *J Water Pollut Control Fed*, *37*(3), 300–306.
- Mahdi, M. J., Ibrahem Aldoury, M. M., & Ismaeal, N. N. (2022). Improving Groundwater Quality by Electromagnetic Polarization. *IOP Conference Series: Earth and Environmental Science*, *1120*(1), 012032. https://doi.org/10.1088/1755-1315/1120/1/012032
- Meireles, A. C. M., Andrade, E. M. D., Chaves, L. C. G., Frischkorn, H., & Crisostomo, L. A. (2010). A new proposal of the classification of irrigation water. *Revista Ciência Agronômica*, *41*(3), 349–357. https://doi.org/10.1590/S1806-66902010000300005
- Mohammad Fadhil Alimam, L., Khalil Saleem, M., & AbdulHadi Aliraqi, G. (2013). Statistical analysis of the Tigris River water and drinking water in some locations of Mosul. *JOURNAL OF EDUCATION AND SCIENCE*, *26*(4), 55–73.
- Mojahedi, S. A., & Attari, J. (2009). A comparative study of water quality indices for Karun River. *World Environmental and Water Resources Congress 2009: Great Rivers*, 1–9.
- Numaan, M. M. (2008a). Development of Water Quality Index for Tigris river water between Alsharqat and Alboajeel. *M. Sc. Thesis*.

- Numaan, M. M. (2008b). *Development of Water Quality Index for Tigris river water between Alsharqat and Alboajeel* [PhD Thesis]. M. Sc. Thesis, Engineering Collage, University of Tikrit.
- Numaan, M. M. (2011). *Quality Assessment of Tigris River by using Water Quality Index for Irrigation Purpose*. *57*(1), 15–28.
- Pesce, S. F., & Wunderlin, D. A. (2000). Use of water quality indices to verify the impact of Córdoba City (Argentina) on Suquía River. *Water Research*, *34*(11), 2915–2926.
- Samadi, M. T., Sadeghi, S., Rahmani, A., & Saghi, M. H. (2015). *Survey of Water Quality in Moradbeik River Basis on WQI Index by GIS* (SSRN Scholarly Paper ID 2610038). Social Science Research Network. https://papers.ssrn.com/abstract=2610038
- Sheet, W. M., Numaan, M. M., Sabeeh, N. N., & Basher, T. S. (2014). Evaluating of raw and treated water quality for some water treatment plants in Tikrit by Water Quality Index. *Journal of Environmental Studies*, *13*(1), 107–115.
- Shrivastava, V., Ali, I., Marjub, M. M., Rene, E. R., & Soto, A. M. F. (2022). Wastewater in the food industry: Treatment technologies and reuse potential. *Chemosphere*, 133553.
- Tavassoli, S., & Mohammadi, F. (2017). Groundwater Quality Assessment Based on WQI and Its Vulnerability to Saltwater Intrusion in a Coastal City, Iran. *Journal of Geoscience and Environment Protection*, *5*(06), 86.
- Zouabi Aloui, B., & Gueddari, M. (2009). Long-term water quality monitoring of the Sejnane reservoir in northeast Tunisia. *Bulletin of Engineering Geology and the Environment*, *68*(3), 307–316. https://doi.org/10.1007/s10064-009-0186-1
- . Al-Hussain, Mayada Hazem Mohammed Ali. (1998). Derivation of Water Quality Index for the Tigris River in Mosul City. Master's Thesis, College of Engineering, University of MosuL