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Original Research Article

Evaluation of Tigris River Quality for Irrigation Purposes within Salah Al-Din province/Iraq

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Abstract: In arid and semi-arid regions around the world, water quality is essential in agricultural systems. The present study was evaluated Tigris River for suitability irrigation in Salah Al-Din province. Water samples were collected and analyzed for various Hydro-chemical parameters like EC, TDS, pH, total hardness (TH), Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, Na^+, and K^+, with different Irrigation indices such as Sodium percentage (Na%), Sodium adsorption ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Kelly's Ratio (KR), Potential salinity (PS) and Hardness were also calculated. The Na%, SAR, RSC, PI, KR, PS and total hardness varied from 2.26 to 10.06 (mmol. l^{-1})$^{1/2}$, 0.01 to 6.10 0 meq. l^{l-}, 8.83 to 77.10%, 0.19 to 1.19 meq. l^{l}, 1.00 to 15.16 meq. l^{l} and 49.3 to 197.1 mg. L^{-1}, respectively. Hence, the various parameters and indices results were concluded that the Tigris River quality was suitable to be used as a water source for irrigation. A strategic plan and regular monitoring are required to limit or reduce the pollution of the river water in order to improve the water quality in its natural condition.

Keywords: Water quality, Irrigation index, Tigris River.

INTRODUCTION

Water is a necessary component for survival of life on Earth. Minerals found in it are essential for human health as well as the health of plants, aquatic life and in producing nanoparticles (Delleur, 1999; Alrawi *et al*., 2022). The management of natural resources has a significant impact on the stability and security of the global food supply (Bagherzadeh & Paymard, 2015).

The quality of irrigation water is a significant environmental issue for both the agricultural sector and every agricultural application, from irrigation to livestock watering, from safe home drinking water on farms, etc. The chemistry of surface waters. is determined by hydro-chemical factors, understanding of different types of water, various geochemical processes and water classifications (Gibbsm 1970; Zhang *et al.*, 2019). Today, the majority of surface and groundwater bodies are unfortunately contaminated and under significant environmental stress from growing urbanization, population, and overuse of chemicals (Radaideh, 2022).

River water quality is strongly influenced by the surrounding community environment. Various human activities, including industrial, agricultural, and settlement operations along the riverfront, has a significant negative impact on the water quality (Pullanikkatil *et al*., 2015).

Agricultural water sources may have poor quality due to natural reasons, contamination or both, and they frequently need to be treated before they are suitable for a particular use (Ayers & Westcotm, 1985). Agricultural methods, vegetative cover, and other management practices all have a direct impact on the river's water quality (Bhattaria *et al.,* 2008). Therefore, the present study aims to determine Tigris River suitability for irrigation at the study area.

MATERIALS AND METHODS

Study area

The study area is located in Salah Al-Din province is northern Iraq lies at 34°55′47″N and 43°29′35″E, the study area covers four sites along Tigris River, as shown in Fig 1. The geographical nature of the area surrounded by agricultural land, and their soil consisted of either mixed sandy, clayey soils, or clay-sandy soil (Twaisan, 2021).

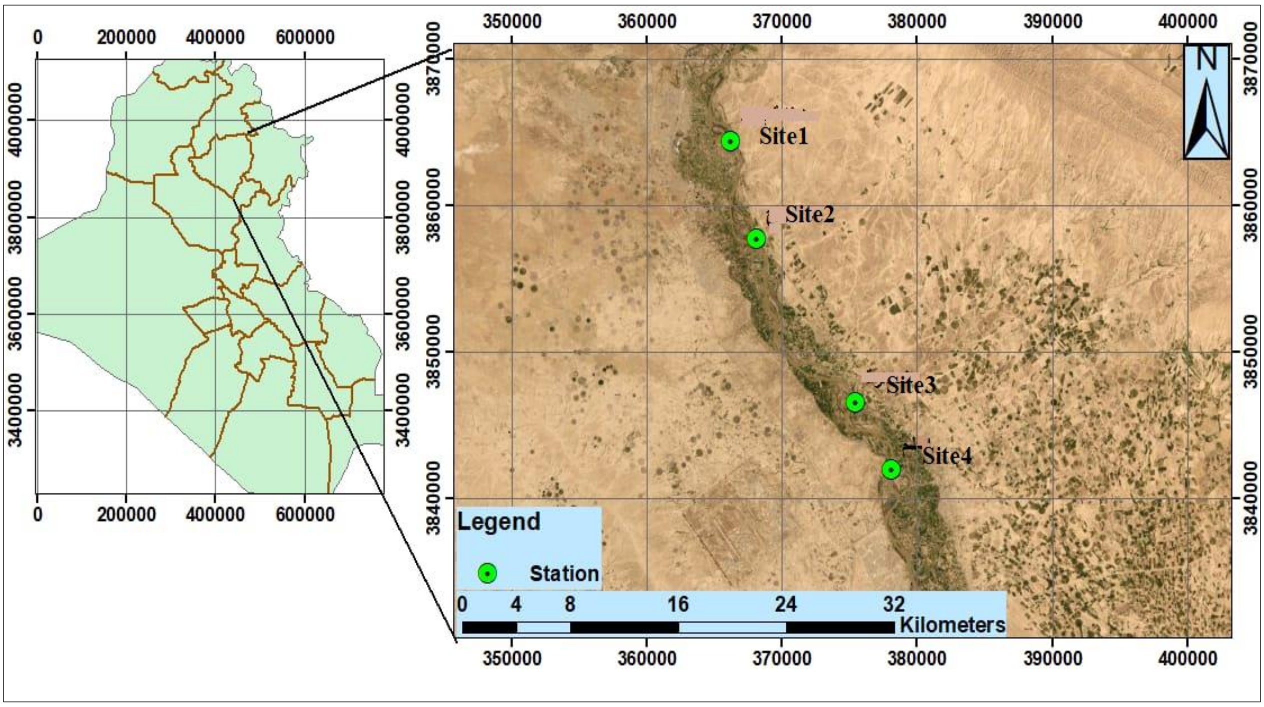

Figure 1: Map of the study sites on Tigris River (Allawi & Ali, 2023)

Sampling and Analytical procedure

Water sampling were collected from four sites on Tigris River during 6 months (December 2022 to May 2023), the sampling was analyzed followed by APHA (2005) as described in Table 1. The samples were transported to the Ecological Laboratory of Biology department/ college of Science/ Tikrit university for analysis.

Table 1: Summarized parameters and analysis methods in this study

NO.	Parameter	Methods
1	Electrical conductivity EC (μs.cm^{-1})	Conductivity multimeter
2	Total Dissolved Solids TDS (mg. L^{-1})	Conductivity multimeter
3	pH	pH meter
4	Calcium ion mg $CaCO_3$.L^{-1}	Titration with Na_2EDTA
5	Magnesium ion mg$CaCO_3$.L^{-1}	Calculation Method
6	Chlorides Cl^{-1} (mg. L^{-1})	Titration with AgNO3
7	Sulphate SO_4^{-2} (mg. L^{-1})	Spectrophotometer (420 nm)
8	Sodium ions mg.L^{-1}	Flame photometer at wavelength (589nm)
11	Potassium ions mg.L^{-1}	Flame photometer at wavelength (766.5 nm)

River water appropriability for irrigation was calculated based on the referenced irrigation quality indices including the Na%, SAR, RSC, PI, KR, , PS and Total hardness values (Table 2), with respect to the measured water parameters.

Table 2: Irrigation quality indices, formula and references

Water Quality	Formula	References
Sodium Percentage (Na%)	$Na\% = [(Na^+ + K^+)/(Ca^{2+} + Mg^{2+} + Na+ + K+)] \times 100$	
Sodium Absorption Ratio (SAR)	$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$	(Ayers and Westcot 1976)
Permeability Index	$= \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100$	(Doneen, 1964)

Water Quality	Formula	References
Kelley ratio	Kelly′s ratio = $Na^+/(Ca^{2+} + Mg^{2+})$	(Kelly, 1963)
Residual Sodium Carbonate	RSC = $[(CO_3^{2-}+HCO_3^-) - (Ca2+ + Mg2+)]$	(Eaton 1950)
Potential Salinity	PS= Cl^- +1/2 $SO4^{2-}$	Doneen (1964)
Total hardness	Total hardness as CaCO3= 2.5$[Ca^{2+}]$ +4.1 $[Mg^{2+}]$	(*Todd & Mays 2005*)

Statistical Analysis

The SPSS 20.0 program is utilized in the current study to analyze the findings, and two methods are used: Mean and Standards Error.

RESULTS AND DISCUSSION

The development of river water quality and their suitability for irrigation were impacted by the hydro-chemical processes and their control mechanisms. The result of hydro-chemical analyses of water samples of the study sites are given in Table 3.

Table 3: Hydro-chemical parameters of the study area (mean and Standard Error)

Parameters	Sites No.				Standard limits
	St.1	St.2	St.3	St.4	
EC (µs.cm^{-1})	151-404 290.3±48.83	91-559 322.8±69.56	103-457 308.6±58.123	140-465 321.5±55.53	2250
pH	7.1-7.6 7.41±0.07	7.2-7.9 7.46±0.108	7.2-7.8 7.6±0.10	7.2-7.9 7.70±0.106	8.5-6.5
Ca^{+2} mg. L^{-1}	16.03-64.12 44.08±7.09	24.05-56.11 43.15±6.14	16.03-64.13 40.74±8.43	16.03-56.11 37.67±7.15	<200
Mg+2 mg. L^{-1}	2.24-11.2 7.09±1.57	2.69-14.56 7.35±1.68	2.24-13.44 7.09±2.27	2.24-15.68 7.46±2.05	150
CO_3^{-2} mg.L^{-1}	60 80.0±12.64	60 80.0±12.64	60-120 80.0±12.64	60-180 70.0±10.0	< 50
HCO_3^{-1} mg.L^{-1}	122-305.1 264.4±60.32	122-305.1 294.9±36.65	244.1-427.1 213.6±20.83	61-305.1 213.5±34.34	< 120
Chloride mg.L^{-1}	44.3-79.1 66.8±11.98	35.5-76.7 58.12±7.63	35.5-71.4 52.21±6.68	35.5-85 53.33±7.60	< 140
Sodium mg.L^{-1}	13-34 25.21±3.08	19-38 26.1±3.07	11-31 20.91±3.19	9-38 20.83±4.08	200
Potassium mg.L^{-1}	1.3-2.2 1.76±0.14	0.9-2 1.51±0.19	1.1-2.2 1.66±0.14	1.1-2.5 1.66±0.207	12
Sulphate mg.L^{-1}	160-290 198.3±18.87	160-260 188.3±15.36	150-280 186.6±19.60	160-230 185.0±10.24	200

Water salinity hazard was the most important water quality standard for crop yield. Water with a high EC may be the result of a plant's inability to compete with ions in the soil solution for water, which will have an impact on plant output. In the study sites, EC values ranged from 91 µS.cm^{-1} to 559 µS.cm^{-1} in site2 (Table 3), which indicated a freshwater type and were in the optimal level for agriculture purposes. The rapid soil-water ion exchange, insoluble geologic rocks and mineral formations, and minimal solute solubility may all contribute to the low EC values. These values within the Higher Agricultural Council (1978) in Iraq.

pH ranged from 7.1 to 7.9, it indicating the water is alkalinity which means that these waters are validated for irrigation uses according to Ayers and Westcot (1985), as shown in Table3.

Ca^{2+} and Mg^{2+} ions were ranged between (16.03-64.12) mg. L^{-1} and (2.24-15.65) mg. L-1 respectively may have resulted from the dissolution of anhydrite minerals, dolomite and gypsum in surface water. The exchange of cations can also increase the surface water of Ca^{2+} concentration as well as rainwater runoff (Subrahmanyam & Yadaiah, 2001; Allawi & Ali, 2023). In present study, the Ca^{2+} and Mg^{2+} concentration within the permissible limit of the Ayers & Westcot (1985) for irrigation water.

Water containing excessive amount of HCO_3^- and CO_3^{-2}, react with Ca^{2+} and Mg^{2+} in soil solution and will precipitate them as calcite and magnesite (Todd & Mays 2005). The carbonate CO_3^{-2} and bicarbonate HCO_3^- values (60-180) mg. L^{-1} and (61-427.1) mg. L^{-1} respectively, and were higher than the permissible level by Ayers & Westcot (1985) for irrigation water expect site 4 in February. This will allow sodium to be adsorbed into the clay surfaces, improving exchangeability Na% of soil.

The concentrations of chloride ranged (35.5-85) mg. L^{-1} and were found within permissible limits for irrigation (0.0–140) mg. L^{-1} according to FAO (1985) and Higher Agricultural Council (1978) in Iraq. SO_4^{-2} values ranged from 150 mg. L^{-1} to 290 mg. L^{-1} in site 3,1 respectively. It is due to the dissolution of rocks such as gypsum rocks, and anhydrite is the source of sulphates in water (Abdullah & Hussain, 2015). The values did not exceed Higher Agricultural Council (1978) in Iraq.

These ions, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{-2}, Cl^- and SO_4^{2-}, are present in the study sites because of rock-water interactions and environmental variables. Wide ranges of ions in surface water samples show the influence of various sources of recharge, including surface channels, human activities, drainage, and excessive fertilizer and pesticide usage. Major ions are effective tools for determining dissolved sources (Jalali, 2007, Sadiq *et al.*, 2019).

Na^+ and K^+ concentrations ranged between 9-38 mg. L^{-1} and 0.9-2.5 mg. L^{-1} respectively. Sodium and potassium were one of the most common forms found in water and nature (Al-Hamim, 1986), that affect surface water geochemistry, high sodium ions in water affects the permeability of soil and causes infiltration problems as well as other problems to the crop and insufficient nutrient availability for plants (Oster *et al.,* 2016).

For accomplishing maximum crop productivity, the water used for irrigation should be of good quality. Thus, for classification and evaluation of water quality the chemical parameters play a significant role. Therefore, to assess water quality for irrigation, water quality indices such as Na%, SAR, RSC, Permeability index, Kelly's ratio, potentially salinity and Total hardness and were calculated from the chemical properties of water in the study area.

The Na% is often utilized to identify the surface water suitability for agricultural application (Elsayed *et al.*, 2020). In Table 4, it is observed that the sodium percentage values ranged between (17.36-54.89)%. According by Wilcox (1955) classification the Na%, value of <60 in water is suitable for irrigation purposes, as shown in Table 5.

Table 4: The Irrigration quality indices values of the Tigris River for irrigration use

Irrigation quality index	**Sites No.**			
	St.1	**St.2**	**St.3**	**St.4**
Sodium Percentage (Na%)	17.36-45.92 30.3±4.09	22.57-44.51 32.7±3.45	20.11-54.89 33.17±5.58	22.72-37.96 30.61±2.49
Sodium Absorption Ratio (SAR) $(mmol\ l^{-1})^{1/2}$	2.30-7.95 4.48±0.77	3.52-7.04 5.16±0.62	2.69-10.06 5.10±1.07	2.26-6.38 4.70±0.58
Residual Sodium Carbonate (RSC) meq. L^{-1}	0.10-6.10 2.41±0.93	0.10-5.20 1.93±0.81	0.01-2.40 1.20±0.38	0.01-3.10 1.40±0.42
Permeability Index (PI) %	24.69-68.88 43.4±6.94	27.30-76.67 53.01±6.95	28.15-77.10 45.7±6.80	18.83-64.55 47.52±6.74
Kelley Ratio (KR) meq. L^{-1}	0.19-0.83 0.44±0.90	0.28-0.77 0.48±0.07	0.23-1.19 0.53±0.15	0.27-0.58 0.43±0.51
Potential Salinity (PS) meq. L^{-1}	1.25-15.16 9.33±2.61	1.00-10.90 6.31±1.73	1.49-14.54 7.20±2.40	1.00-8.74 4.51±1.52
Total hardness mg. L^{-1} **as CaCO3**	86-197.1 139.3±17.35	78.5-190 138.1±17.32	49.3-215.4 130.9±22.75	67.60-157 124.8±13.60

Table 5: Limits of parameters quality indices for sustainability of irrigation in the study sites

Water Quality Indices	**Ranges**	**Water Class**
Sodium Percentage (Na%)	<20 20–4 40–60 60–80 >80	Excellent Good Permissible Doubtful Unsuitable
Sodium Absorption Ratio (SAR)	<10 10–18 18–26 >26	Excellent Good/safe Doubtful/moderate Unsuitable
Residual Sodium Carbonate (RSC)	<1.25 1.25–2.5 >2.5	Good Doubtful Unsuitable

Water Quality Indices	Ranges	Water Class
Permeability Index (PI) %	>75% 25%–75% <25%	Good-Class I Good-Class II Unsuitable-Class III
Kelley Ratio (KR) meq. L^{-1}	<1 >1	Good Unsuitable
Potential Salinity (PS) meq. L^{-1}	1 - 3 3 -15 15-20	Soil of low permeability Soil of medium permeability Soil of high permeability
Total hardness mg. L^{-1} as CaCO3	<75 75-150 150-300 > 300	Soft Moderately Hard Very hard

The SAR is a significant index determining how well irrigated water is suited to sodium hazards (Subramani *et al*., 2005), and it is more closely related to the sodium percentages of exchangeable in soil (Suarez *et al*., 2006). SAR can indicate the degree to which irrigation water tends to participate in cation-exchange processes in the soil. It is dangerous when sodium replaces adsorbed calcium and magnesium because it causes damage to the soil′s structure (Raju, 2007). The SAR values ranged from 2.26 (mmol $l^{-1})^{1/2}$ to 10.06 (mmol $l^{-1})^{1/2}$ and according to the Richards classification of SAR, all sample are excellent for irrigation (SAR < 10) according to the SAR classification (Table 5).

Residual Sodium Carbonate (RSC) which indicates the hazardous impact of HCO_3^- and CO_3^- concentrations on the quality of water for irrigation usage. RSC has been frequently utilized to predict the additional sodium hazard linked to Ca^{2+} and Mg^{2+} precipitate as CO_3 (Eaton 1950). The classification by Eaton 1950 and Wilcox *et al.* (1954) for RSC in Table 5. In the present study area, most of RSC values are within Good to Doubtful category except site 3 in December2022, April and May 2023, and sites 1,2 in May were within Unsuitable for irrigation.

The Permeability Index (PI) is frequently used to evaluate the suitability of the irrigation water, which is altered by exposure over time to irrigation water with a high concentration of Na+, Ca^{2+}, Mg^{2+}, and alkalinity ions (Ravikumar *et al*., 2011). A criterion for assessing the suitability of irrigation water was based on PI water and can be classified as class I, Class II and Class III orders (Doneen, 1964; Raghunath, 1987). In the present study area, the permeability ranged from 18.83% to 77.10% at site 4 and 3 respectively in Table 4; hence, the water quality within Good-Class I and Good-Class II, so it suitable for irrigation.

The Kelley Ratio (KR) revealed an excess in the quantity of sodium in water (Sudhakar & Narsimha, 2013). Therefore, water with a Kelly's ratio below one is appropriate for irrigation, while water with a ratio beyond one is unsuitable. The KR values of this study ranged between (0.19 -1.19) meq. L^{-1}. This indicates that the Tigris River exceed the allowed limit of 1.0 and is considered inappropriate for irrigation uses.

The potential salinity (PS) ranged from 1.5 meq. l^{-1} to 8.6 meq. l^{-1}. It suggests that the potential salinity in the water of the studied area nearly is high, thus, making the water unsuitable for irrigation usage. High values of potential salinity in the area can be attributed to high sulfate concentration derived from the lead mining, the major mineral extracted in the studied area. Doneen (1964) explained that soluble salts do not determine whether water is suitable for irrigation. Because low solubility salts precipitate in the soil and build up after each irrigation, the concentration of highly soluble salts raises the soil salinity.

Water hardness is a practical test for evaluating of the water quality for domestic, agricultural and industrial uses. The hardness of water is generally caused by Ca^{2+} and Mg^{2+} ions (Sappa *et al*., 2014). The total hardness values ranged from 49.3 mg. L^{-1} to 197.1 mg. L^{-1}. The classification of water based on total hardness shows that most of the samples fall between soft and moderately hard except some values very hard in sites 1,2,3 in December2022, January and February 2023 and sites 3,4 in January 2023.

CONCLUSIONS

A straightforward way for the initial identification of river water quality for irrigation is to use irrigation water quality indices. The adoption of a water quality index will not only make it possible to examine how the quality of the water has changed over time and space, but also to assess the success and shortcomings of efforts to safeguard aquatic resources. With only a few exceptions, Tigris River water can generally be categorized as acceptable for irrigation use. A plan for reducing river water pollution is required to improve the water quality in its unaltered state.

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