

ASSESSMENT OF WATER QUALITY FOR IRRIGATION USING THE SUB-INDEX MODEL: ACASE STUDY OF TIGRIS RIVER WATER IN MOSUL CITY, IRAQ

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DOI: 10.47750/pnr.2022.13.S06.136

Abstract

The purpose of this research was to use mathematical models to evaluate Tigris River water quality in the metropolitan area of Mosul (WQI). Starting in November 2021 and continuing through March 2022, researchers will collect 120 water samples from six different locations along the Mosul River before it enters the city of Mosul at Badush Kasbah, north-east of the city, all the way down to the Yarmajeh area, south of Mosul (at a rate of two repeats per month for each site) in order to conduct physical and chemical analyses. In addition, the water quality for irrigation was assessed using the (Sub-index-WQI) model and the Kelly Index, K.R., both of which adhere to internationally accepted standard techniques.

According to the results of the study, majority of the standards utilized fell within the acceptable range for Irrigation as defined by (WHO, 2004), as shown by the values of the sub-index index falling somewhere in the (44.82-46.12). Because of this, the Tigris River in Mosul City has a high enough quality to be used for irrigation.

Keywords: Tigris River, IWQI, Assessment of water quality for Irrigation, Iraq.

INTRODUCTION

God has blessed humanity immensely by providing water, one of the most fundamental need for all forms of life on Earth. All of man's vital activities, from breathing to digesting, rely on water in some way. Since prehistoric times, humans have pondered a variety of questions related to water, including how to best use it, how it is formed, and how it is most commonly used. Water pollution and its effects on water quality have emerged as one of the world's most pressing problems, necessitating the utmost seriousness in addressing the issue (Al-Taee, 2021).

There is growing concern that environmental concerns, which have been exacerbated by a lack of and inability to adequately regulate human activities, could soon approach their breaking point. Because of Iraq's reliance on the Tigris and Euphrates rivers as primary sources of potable water, as well as Water utilized for civil, industrial, and Irrigation reasons, the research of these concerns must be seriously addressed to give all requirements to combat and control them. Water quality of the Tigris River has declined in recent years due to a combination of factors, including the discharge of civil, industrial, and agricultural pollutants during the river's flow and the lack of rain in recent years, which has reduced the river's discharge (Talat and Al-Saffawi, 2018). The fields and farms along the Tigris river are irrigated with the river's waters.

Many reports have been written about the Tigris River and the pollution of its waters and their potential for human consumption. But there have been few attempts to far to assess the Tigris River's water quality using mathematical models. The amount of wastewater discharged from Mosul city to the Tigris river is estimated at more than 6598 m³, adding to the river's existing difficulties caused by the increased discharge of diverse pollutants without treatment. Hour-1 (Al-Saffawi, 2007), it is vital to perform routine inspections of the Water Quality. An assessment of the river's condition and the implementation of necessary

measures to slow the rate at which its quality is deteriorating are necessary to head off potential future water shortages caused by pollution as Iraq's population and economic, agricultural, and social infrastructure continue to expand.

Therefore, it is important to conduct a qualitative assessment of river water before using it for various purposes (including Irrigation) Using WQI water quality models is a good way to paint a picture of the quality of Water for various uses; as these models give a single value that reflects the various interactions of the qualitative characteristics of Water, rather than the copious amounts of data typically collected (Al-Saffawi and Talat, 2019; Al-Saffawi et al, 2018). Researchers around the world have found that the salinity problem has repercussions for both water quality and soil; Water with high levels of salt for Irrigation with the restricted use of scientific and modern methods of Irrigation has hastened the formation of agricultural problems that are believed to reach critical limits as significant sections of agricultural land deteriorate around the world (Hasanuzzaman et al., 2018;). Several variables influence the quality of irrigation water (Gabr et al., 2020), the first of which is the salinity risk.

Second, the potential for infiltration and permeation.

Ionic toxicity, third.

Fourth, other effects.

WQI Water Quality Models were first introduced in 1965 by Horton and refined in 1970 by Brown; since then, numerous more models have been proposed to help with water quality judgments (Devojee et al., 2018; Zotou et al., 2020). In Iraq, their use has grown rapidly over the past decade. Numerous studies have been conducted to evaluate surface and ground water for various goals (Al-Ridah et al, 2020; Al-Sudani, 2021; Qaseem et al, 2022a). In light of this, the present research assessed the sub-index (IWQI) model quality of Tigris river water in Mosul city for irrigation purposes.

MATERIAL AND METHODS

Description of the study area:

The current study covered the area along the Tigris River in Mosul, beginning in the Badoush district and ending in the Yarmoja district. This area is known for its many farms and orchards, especially in the Badoush and Yarmoja districts, and the widespread fields on both sides of the river, where the river's waters are used for irrigation. Sewage from Mosul and the surrounding stalactites is dumped directly into the Tigris via a network of natural troughs and regular estuaries on both sides of the river. Table (1) and Figure 1 display the results of utilizing the GPS in Google Earth to determine the locations of the points of interest (1).

Table (1) shows the characteristics and coordinates of the sites for collecting water models in the city of Mosul

Sites	Longitude (N)	latitude (E)	Usage
1	36°37'63"	43°16'73"	For domestic purposes, irrigation, livestock and poultry watering etc.
2	36°37'92"	43°16'50"	
3	36°37'37"	43°16'31"	
4	36°37'66"	43°16'56"	
5	36°37'98"	43°18'84"	
6	36°38'16"	43°18'52"	

Methodology:

Starting in October 2021 AD and continuing through March 2022 AD (at a rate of two repeats per month), water samples from the Tigris River were collected at six sites from the Badoush area, north of Mosul, to the Yamja area, south of the city, using clean polyethylene bottles and washed between each collection. Repeatedly rinsing the sample with water before filling it with water, and then storing it in a dark cooler box until it can be transported to a lab where it can be tested for electrical conductivity, pH, positive ions (Ca, Mg, Na, K), and negative ions (Cl, SO₄, HCO₃) using internationally accepted procedures

(APHA, 1998, 2017). Using the aforementioned equations (Emenu and & Nwankwoala, 2005), we also determined the irrigation parameters (%Na, SAR, RSC, MH, RK, PI, and P. S).

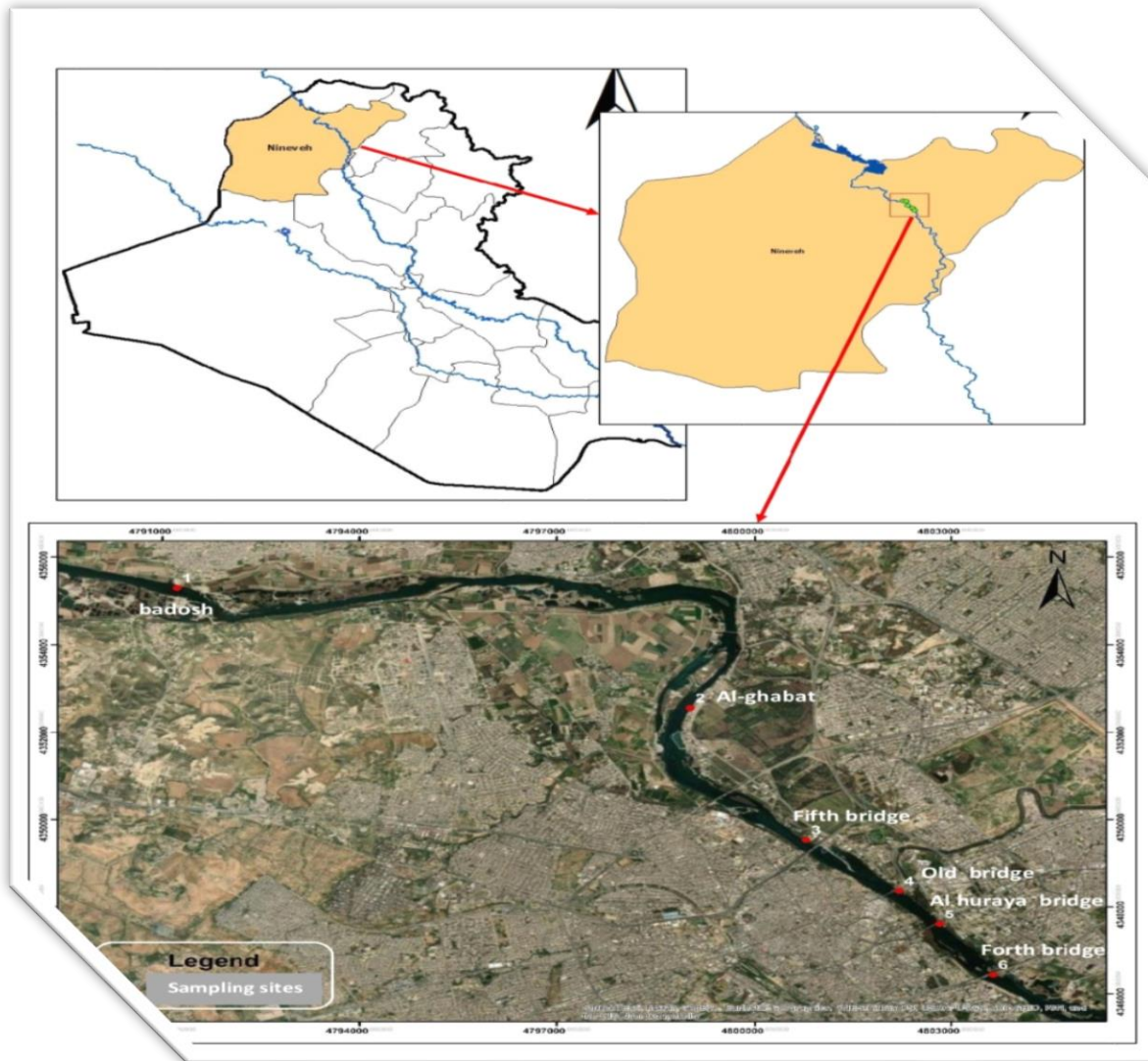


Figure (1): A space map showing the study area and sample collection sites.

2018; Tomaz et al, 2020; Yasmin et al, 2019;. Devojee et al,2018; Balamurugan et al, 2020 Qaseem et al, 2022a):

$$P. \text{ Salinity meq. l}^{-1} = \text{Cl} + \frac{1}{2} \text{SO}_4$$

$$\% \text{ Na} = \text{Na} \times 100 / \text{Na} + \text{K} + \text{Ca} + \text{Mg}$$

$$\text{RSC meq. l}^{-1} = [(\text{HCO}_3^- + \text{CO}_3^-) - (\text{Ca}^{+2} + \text{Mg}^{+2})]$$

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\text{Ca} + \text{Mg}/2}}$$

$$\text{PI} = [\text{Na} + \sqrt{\text{HCO}_3} / (\text{Na} + \text{Ca} + \text{Mg})] \times 100$$

$$\text{KR or KI} = \text{Na} / \text{Ca} + \text{Mg}$$

$$\text{MAR} = \text{Mg} \times 100 / \text{Ca} + \text{Mg}$$

Assessment of water quality using (IWQI):

The use of mathematical models to assess the quality of Water for different purposes is one of the important means used globally to give a single value that expresses the quality of Water, which is the result of different interventions between the qualitative parameters used and the huge amount of data that confuses the reader, as the specialist and the non-specialist understand it—the results of mathematical models in providing data and information for future studies. The first sports model was proposed in the sixties of the last decade by Horton (Al-Saffawi and Al-Barzangi 2020). Several models were developed and developed with time, such as the CCMEWQI, NSFQI, OWQI, and WPij models, etc. (Al-Shanona et al., 2020; Givi et al., 2021; Al-Saffawi 2019; Mother. and Al-Saffawi, 2022a). In this study, the sub-index model referred to by Al-Shanona, et al. (2020), Nsabimana et al. (2021), Adimalla et al. (2018), Chegbeleh et al., (2020), Sunitha and Reddy (2022). We was determined for each parameter according to its relative importance. For example, weight was given to 5 for electrical conductivity and Potential salinity due to its effect on soil and plants. In contrast, potassium was given a weight of 1 for its low concentration in river water in all studied sites compared to the global determinants approved for Irrigation (Yasmin et al., 2019) shown in table (2), The irrigation water quality index (IWQI) is also calculated from the following five stages.

Table (2) Standard limits, characteristic weight, and relative weight used to calculate (IWQI) for Irrigation.

	Sti	wi	RWi
pH	6.5-8.5	4	0.0930
EC₂₅ $\mu\text{s.cm}^{-1}$	2000	5	0.1162
Cl meq. l^{-1}	10.0	3	0.0697
HCO₃ meq. l^{-1}	8.5	3	0.0697
RSC meq. l^{-1}	2.25	2	0.0465
P.S meq. l^{-1}	7.00	5	0.1162
%Na	60.0	4	0.0930
SAR	18.0	5	0.1162
MAR	50.0	4	0.0930
P. Index	75.0	5	0.1162
K. Index	1.00	3	0.0697
Σ		43	0.9994

The first step is to determine the relative weight. After determining the Quality rating (qi), the third step involves determining the Subindex (SLi), and the fourth step involves determining the WQI using the following equations (Oyewumi et al., 2019;

$$\text{Maskooni et al., 2020): } W_i = \frac{w_i}{\sum_{i=1}^n w_i}$$

$$q_i = \frac{C_i}{S_i} \times 100.$$

$$SL_i = W_i \times q_i.$$

$$WQI = \sum SL_i.$$

Where: W_i : relative weight., w_i : property weight., Q_i : quality rating., C_i : the value of the measured characteristic, S_i : the standard concentration of the characteristic, according to international classifications.

Finally, the effective value, % Ev, is calculated for the purpose of knowing the effect of each parameter on the WQI sub-index value, as in the following equation: (Ibrahim, 2019)

$$E_{wi} = \frac{SL_i}{WQI} \times 100$$

After finding the value of the WQI sub-index, the water quality is categorized as:

If $IWQI \leq 50$: the quality is Excellent., $51 \geq IWQI \leq 100$: Good quality., $101 \geq IWQI \leq 200$: Poor quality., $201 \geq IWQI \leq 300$: Very poor quality., $IWQI > 300$: Unsuitable quality (Maskooni et al, 2020; Qaseem et al, 2022a).

Results and Discussion:

Salinity Hazard: Important indicators of irrigation water quality, such as electrical conductivity and potential salinity (P.S.), are reflected in these numbers. The tables (3) reveal that the values ranged from (0.396 to 0.551) and varied from a low of (0.435 0.024) to a high of (0.501 + 0.034) dS. m-1 and a high of (0.94 to 1.79) at a pace that never went over (1.57 0.25) meq. l-1. Al-Hanoona et al(2020) .s findings, which placed the quality of Tigris River water in Mosul at between (0.405 and 0.566) dS.m-1, are compatible with these figures. The range of (0.427 to 0.506) dS. m-1 found by Mahmood and Saeed, (2022) in their analysis of Tigris River water from Mosul city to the Kayara district is also applicable here. This, however, is lower than the values of 1.19 dS. m-1 and 5.6 meq. l-1 for electrical conductivity and potential salinity that Al-Saffawi and Al-Sangari (2018) measured in the water of the Al-Kharazi valley in Mosul City. The values of the waters of the Tigris River in the city of Baghdad have climbed to 1.273 dS. m-1 and (4.41) meq. l-1, and the values of the water from the Diyala River have increased to reach 3.991.1 dS. m-1 and (17.01) meq. l-1, according to studies. According to research (Oleiwi and Al-Dabbas, 2022) According to the American Salinity Laboratory's (USSL) categorization system, the investigated water falls into the medium salinity class C2, making it suitable for irrigation of all soil types (Moghimi, 2016; Al-Saffawi et al, 2020a).

Table (3): Minimum, upper, mean, and standard deviation (\pm Sd) of the water parameters of the Tigris River for Irrigation. (* in meq. l⁻¹).

Paramet. Sites		RSC*	P.S*	SAR	%Na	PI	MAR	KR
S1	<i>Min</i>	-0.4	0.94	0.71	21.73	63.19	5.19	0.28
	<i>Max</i>	-0.04	1.28	0.87	25.65	69.09	22.78	0.35
	<i>Mean</i>	-0.24	1.14	0.77	23.38	66.69	10.53	0.31
	\pm Sd	0.15	0.12	0.05	1.23	2.180	5.49	0.02
S2	<i>Min</i>	-0.36	0.99	0.71	20.70	62.27	3.70	0.28
	<i>Max</i>	-0.02	1.38	0.89	24.76	67.86	20.2	0.35
	<i>Mean</i>	-0.22	1.22	0.77	22.35	65.30	8.89	0.30
	\pm Sd	0.16	0.14	0.05	1.16	2.620	5.45	0.02
S3	<i>Min</i>	-0.76	1.05	0.74	21.68	57.57	3.75	0.28
	<i>Max</i>	-0.06	1.53	0.92	25.91	67.47	20.2	0.36
	<i>Mean</i>	-0.29	1.31	0.83	23.64	64.05	9.99	0.32
	\pm Sd	0.23	0.17	0.04	1.28	3.060	5.40	0.03
S4	<i>Min</i>	-0.64	1.12	0.7	19.86	56.54	4.11	0.25
	<i>Max</i>	-0.04	1.68	0.85	23.74	64.95	12.9	0.32
	<i>Mean</i>	-0.20	1.47	0.75	21.45	62.09	6.69	0.28
	\pm Sd	0.19	0.22	0.05	1.29	2.540	3.37	0.02
S5	<i>Min</i>	-0.64	1.02	0.80	21.69	57.06	3.29	0.28
	<i>Max</i>	-0.04	1.75	0.92	25.43	65.70	16.0	0.35
	<i>Mean</i>	-0.29	1.39	0.84	23.15	61.87	7.18	0.31
	\pm Sd	0.21	0.24	0.03	1.10	2.630	4.61	0.02
S6	<i>Min</i>	-0.68	1.06	0.79	21.72	56.32	2.68	0.28
	<i>Max</i>	-0.04	1.79	0.93	24.93	64.41	14.3	0.33
	<i>Mean</i>	-0.26	1.57	0.86	23.18	61.28	6.87	0.31
	\pm Sd	0.25	0.25	0.04	1.15	2.960	4.92	0.02

Infiltration:

Water permeability and infiltration are influenced by a number of soil characteristics, including electrical conductivity and the salt absorption rate (SAR). Table 3 shows that the SAR values varied from (0.71 to 0.93) at a rate of (0.86 0.04) (0.77 0.05). According to the Ayers and Branson categorization, the Tigris River is irrigable because of its high specific absorption rate

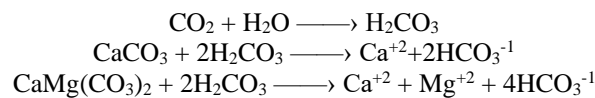
(SAR) and low electrical conductivity values, both of which have a positive impact on soil permeability (Al-Saffawi and Al-Matheedi 2017)

Specific ion toxicity:

High concentrations of sodium ions in irrigation water are harmful to plants because they produce burns and tissue death along the length of the leaf and along its outer edge; this causes the soil's sodium content to grow and expresses sodium damage in a corresponding increase in SAR. Since the values of the analyzed water samples did not exceed (0.93) as shown in Table (3), and since they are within the safe standard limits permitted for Irrigation)3 SAR(, the water under study is suitable for use in irrigation (Al-Taee, 2021). At high concentrations, chloride ions contribute to toxicity by burning the tips and eventually the edges of leaves. Leaves fall off in the later stages. The chloride ion concentration rates varied from (0.707 0.101 to 0.98 0.229), as indicated in Table (4). Because it has a chloride toxicity level that is less than the allowable threshold for the occurrence of toxicity (less than 3.95 meq. l-1), the Water is suitable for Irrigation (Ayers & Westcot, 1985).

Miscellaneous effects:

One such effect is on the pH level, which, as seen in Table 4, is rather near to 7. (6.8 and 8.1). Products of biological breakdown of organic components like carboxylic and mineral acids contribute to the relative decrease in values (Al-Taee, 2021). Due to the high acidity susceptibility (ANC) of the Iraqi environment, however, there is no appreciable drop in readings (Talaat, 2012). It is because of this (ANC) that the aquatic ecosystem wasn't harmed more severely (Al-Saffawi and Al-Sinjari, 2018). The concentration of bicarbonate ions, which play a significant role in the acidity equation or the so-called (ANC), is estimated to be between 2.89 0.14 and 3.44 0.07 meq. l-1 in the studied Water; this increase in concentration is a result of reactions between the Water and sediment and suspended matter, as shown by the following equations (Jaafer and Al-Saffawi, 2020; Al-Hamdani et al., 2021



In general, the Water studied in terms of the effect of bicarbonate is of suitable quality for Irrigation, according to a classification (Ayers & Westcot, 1985).

As for sulfate ions, no standard criterion for their damage to soil and plants has yet been determined. Still, they contribute to increasing soil salinity (Qaseem et al, 2022a), and it is noted from Table (4) that the relative rise of sulfate ions in the studied Water is Tilg (1.26) meq. l-1, and this increase in concentration is due to the products of the biological decomposition processes of organic materials such as carboxylic and mineral acids, as shown in the equation (Al-Saffawi and Al-Singari, 2018):

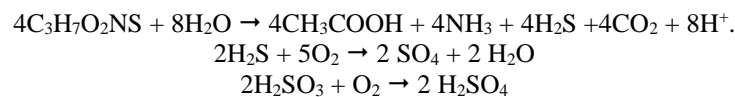


Table (4): Minimum, upper, mean, and standard deviation (±Sd) of the water parameters of the Tigris River for irrigation (meq.l⁻¹., EC₂₅: dS. m⁻¹

parameter sites		pH	Ec ₂₅	Na ⁺	K ⁺	HCO ₃ ⁻	SO ₄ ⁻	Cl ⁻
S1	Min	6.80	0.390	0.869	0.076	2.76	0.84	0.536
	Max	7.50	0.477	1.086	0.128	3.11	0.96	0.817
	Mean	7.20	0.435	0.961	0.140	2.89	0.88	0.707
	±Sd	0.24	0.034	0.66	0.02	0.14	0.06	0.101
S2	Min	7.10	0.404	0.913	0.102	2.88	0.90	0.509
	Max	7.70	0.479	1.043	0.128	3.18	1.01	0.902
	Mean	7.40	0.444	0.975	0.113	3.01	0.95	0.758
	±Sd	0.20	0.026	0.07	0.013	0.12	0.04	0.137

S3	<i>Min</i>	7.00	0.421	0.956	0.76	3.04	0.96	0.565
	<i>Max</i>	7.80	0.503	1.173	0.153	3.36	1.07	1.015
	<i>Mean</i>	7.40	0.459	1.096	0.119	3.16	1.01	0.811
	<i>±Sd</i>	0.20	0.028	0.06	0.024	0.11	0.05	0.154
S4	<i>Min</i>	7.10	0.434	0.956	0.102	3.32	1.02	0.622
	<i>Max</i>	7.90	0.523	1.173	0.153	3.56	1.21	1.099
	<i>Mean</i>	7.50	0.475	1.983	0.139	3.44	1.11	0.927
	<i>±Sd</i>	0.30	0.031	0.15	0.017	0.07	0.07	0.195
S5	<i>Min</i>	7.20	0.448	1.086	0.102	3.24	1.04	0.566
	<i>Max</i>	8.10	0.541	1.217	0.153	3.62	1.25	1.128
	<i>Mean</i>	7.50	0.486	1.158	0.132	3.43	1.15	0.905
	<i>±Sd</i>	0.30	0.030	0.04	0.017	0.14	0.06	0.192
S6	<i>Min</i>	7.20	0.458	1.086	0.128	3.44	1.06	0.537
	<i>Max</i>	8.10	0.551	1.26	0.179	3.72	1.26	1.184
	<i>Mean</i>	7.60	0.501	1.211	0.147	3.61	1.19	0.980
	<i>±Sd</i>	0.30	0.034	0.05	0.016	0.08	0.06	0.229

This will be reflected in the potential salinity values (PS), which amounted to (1.79) meq. l-1 as shown in Table (4), as well as the dissolved sodium percentage (% Na) and permeability index (PI), which were within the appropriate limits for Irrigation. Also, no concentration of residual sodium carbonate RSC was recorded in the waters of the Tigris river due to the high concentration of calcium and magnesium ions compared to the concentration of bicarbonate ions. The relative decrease in KR values is also observed due to the high levels of calcium and magnesium ions compared to the concentration of sodium ions (Qaseem et al, 2022a). Table (5): Results of Qi and Sli values for Tigris River water for Irrigation in the city of Mosul.

Assessment of water quality for Irrigation:

The Sub-index Model was applied to eleven criteria for evaluating the studied river water for Irrigation, as shown in Table (1). The results shown in Table (5) indicate that the IWQI values ranged between (44.28-46.12). When compared with Table (2) to classify the water quality, all the studied water samples in the study sites were of the excellent water quality for Irrigation. Concentrations of all the studied parameters (Ci) for the upper limits allowed for Irrigation and were approved in the study.

Table (5): Results of Qi, Sli, and (IWQI) values for Tigris river water for irrigation in Mosul city.

Sites Param.		1	2	3	4	5	6
pH	Qi	88.2	87.1	87.1	88.2	88.2	89.2
	Sli	8.02	8.10	8.10	8.20	8.20	8.22
EC ₂₅	Qi	21.7	22.2	22.9	23.8	24.3	25.0
	Sli	2.52	2.57	2.66	2.76	2.82	2.90
Cl	Qi	7.04	7.55	8.12	9.36	9.19	9.89
	Sli	0.49	0.52	0.56	0.65	0.64	0.68
HCO ₃	Qi	34.0	35.5	37.2	40.5	40.4	42.4
	Sli	2.37	2.47	2.82	2.82	2.81	2.95
RSC	Qi	0.00	0.00	0.00	0.00	0.00	0.00
	Sli	0.00	0.00	0.00	0.00	0.00	0.00
PI	Qi	88.9	87.1	85.4	82.8	82.5	81.7
	Sli	10.3	10.1	9.92	9.61	9.58	9.49
%Na	Qi	39.0	37.3	39.4	35.8	38.6	38.6
	Sli	3.62	3.46	3.66	3.32	3.58	3.59
SAR	Qi	4.27	4.27	4.61	4.16	4.72	4.77
	Sli	0.49	0.49	0.53	0.48	0.54	0.55
MAR	Qi	21.1	17.8	20.0	13.4	14.4	13.7
	Sli	1.95	1.65	1.85	1.24	1.33	1.27

P.S	Qi	16.3	17.4	18.7	21.0.	19.9	22.4
	Sli	1.89	2.02	2.17	2.44	2.30	2.60
KI	Qi	31.1	30.3	31.7	28.0	30.8	30.8
	Sli	2.16	2.11	2.02	1.95	2.14	2.14
WQI	value	34.0	33.5	34.2	33.5	34.0	34.39
	Status	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.

It is also noted from the same Table that the values of the sub-index (Sli) used to calculate the water quality index (WQI) were relatively low for all parameters and for all samples, which made the Water of excellent quality. This confirms the effective Ewi% values on the IWQI values, which were also low, except for the pH values and the permeability index, reaching 25.3 and 29.7, as shown in Table (6).

Conclusions and Recommendations:

The Water of the Tigris River in the city of Mosul is suitable for Irrigation because all the values of: Na%, SAR, RSC, PI, KR, and P.S are within the international standard limits suitable for Irrigation, which was positively reflected in the values of the sub-index Sli and the values of the water quality index (IWQI), which were from the category of

Table (6) % Ewi values of irrigation parameters affecting IWQI values.

Sites Param.	1	2	3	4	5	6
pH	24.1	24.2	25.3	24.5	24.1	23.8
EC₂₅	7.25	7.43	7.53	7.98	8.03	8.14
Cl⁻¹	1.41	1.50	1.58	1.88	1.82	1.91
HCO₃⁻¹	6.82	7.14	7.33	8.15	8.01	8.28
PI	29.7	29.2	28.1	27.8	27.3	26.7
RSC	0.00	0.00	0.00	0.00	0.00	0.00
%Na	10.4	10.1	.104	9.60	10.2	10.1
SAR	1.41	1.42	1.50	1.39	1.53	1.54
MAR	5.61	4.77	5.23	3.59	3.79	3.56
P.S	5.44	5.84	6.14	7.05	6.55	7.30
KI	6.21	6.10	6.23	5.64	6.10	6.01

Excellent water quality for Irrigation. Therefore, we recommend periodic follow-ups to conduct tests on the waters of the Tigris river and limit the dumping of untreated wastewater to it, while following modern scientific methods of Irrigation to maintain soil quality and prevent water wastage.

Acknowledgments

To the Presidency of the University of Mosul, the researchers offer their sincere gratitude and appreciation. Sincere appreciation and thanks go out to all of our colleagues, especially Prof. Dr. Qusay Kamal Al-Din Al-Ahmadi, the Deans of the College of Education for Pure Sciences and the College of Environmental Technologies, and the entire research team.

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