

# Assessment of Surface Water Quality for Irrigation using WQI model; A Case Study of Khosar and Tigris Rivers

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## ABSTRACT

The current study was aimed to assess the water quality of Khosar and Tigris rivers for irrigation by using arithmetic water quality index (WQI). Sixty-six water samples were collected monthly from seven sampling stations from the two rivers during Jan. to Oct., to determine their physiochemical and bacteriological properties such as (pH, EC,  $\text{HCO}_3^-$ ,  $\text{NO}_3^-$ , Cl, Na% and F. Coliform) by using Universal Standard method and calculated some irrigation parameters like (SAR, RSC, MAR, PI and KR). From these data, water quality model was applied to assess surface water for irrigation uses. The results of the water quality index of the Khosar river were poor for station 1 while stations 2, 3, 4 and 5 were unsuitable water quality categories for irrigation purposes. The water quality index for the Tigris river was good for station 6, but station 7 was very poor and WQI values ranged between (196-6830) and (78-284) respectively.

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## INTRODUCTION

Water is vital to the existence of all living organisms especially human's life, instead, this valued resource is increasingly being threatened in Iraq because the water resources have suffered remarkable stress in terms of water quantity. As a consequence building dams on the Tigris and Euphrates rivers because the riparian countries, decrease the annual precipitation average and unsuitable planning of water uses inside Iraq and the climatic changes<sup>[1,2,3]</sup>. One of the important procedures which should be taken to get the maximum benefit of the available quantity of water is the assessment of its quality in order to keep our awareness and understanding of our environment and to take the required steps to stop any spoilage in the quality of available water or rather improve it. nonetheless, the ability to properly track progress toward minimizing impacts on natural environments and improving access of humans to safe water depends on the availability of data that document trends in both space and time. furthermore, on going monitoring of water quality in both surface and groundwater resources is a necessary activity at all governing levels locally and nationally<sup>[4]</sup>.

Estimation of water quality has been one of the important subjects in the field of management and control of environmental. Many types of research have been conducted on the surface water quality of the Rivers about the world. Al-Dabbas and Maiws<sup>[5]</sup> studied about the monthly changes that occurred on some chemical and physical properties of Al-Dujaila River, showed that the Dujaila river water suitable for irrigation purposes and that is done by evaluating using the Sodium Absorption Ratio (SAR) values to determine its suitability. Alsaffawi<sup>[6]</sup> studied the quality of the Tigris river in Mosul city by using (CCME) water quality index, The results revealed that some studied parameters were increased in Tigris river during flowing through the study area, which could be mainly due to the increasing wastewater discharges into the river, which give negative reflect to the values of WQI for the quality was Tigris river is classified as "Good water quality". Berhe<sup>[7]</sup> (2015) studied irrigation water quality of surface and groundwater in the

kütahya plain, Turkey, and Keraga<sup>[8]</sup> (2017) used CCME WQI model for assessment of Awash River quality in Ethiopia for irrigation uses.

## MATERIAL AND METHODS

### Study area description:

The study area included seven stations on Khosar and Tigris rivers in Mosul city, Iraq. The first station located before entering the Khosar river in Mosul city, specifically in Abbasiyah village (between lat. 36°42'54"N and long. 43°19'93"E) and far from the second station approximately (10) km in Al-Sukar quarter after entering the Khosar river in Mosul city (between lat. 36°38'25"N and long. 43°17'05"E). The third station located in Al-Zohur quarter (between lat. 36°37'34"N and long. 43°17'73"E), whereas the fourth station near Swies bridge (between lat. 36°35'47"N and long. 43°15'13"E). The fifth station located in Faisaliah quarter before the Khosar river flows into the Tigris river (between lat. 36°34'73"N and long. 43°14'10"E). The sixth station located near Nineveh bridge before it met with Tigris river (between lat. 36°34'61"N and long. 43°13'83"E), and the seventh station after it met (between lat. 36°34'19"N and long. 43°14'37"E), as shown in (Fig. 1).

### Methodology

Water samples were monthly collected from Khosar and Tigris rivers during the study period from February to October by using cleaned polyethylene bottles after rinsing it with water sample before it is filled. Each of sample was analysed for chemical, bacteriological and physical properties like (pH, EC, Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, Ca<sup>+</sup>, Mg<sup>+</sup> and F. Coliform) were determined using standard methods<sup>[9]</sup>. Irrigation parameters likesodium percentage (Na%), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), residual sodium carbonate (RCS), Kelley's ratio (KR) and permeability index (PI) Calculated from the following equations<sup>[10-14]</sup>:

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

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

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

$$\text{RSC} = (\text{CO}_3 + \text{HCO}_3) - (\text{Ca} + \text{Mg})$$

$$\text{KR} = \frac{\text{Na}}{\text{Ca} + \text{Mg}}$$

$$\text{PI} = \frac{\text{Na} + \sqrt{\text{HCO}_3}}{\text{Ca} + \text{Mg} + \text{Na}} \times 100$$

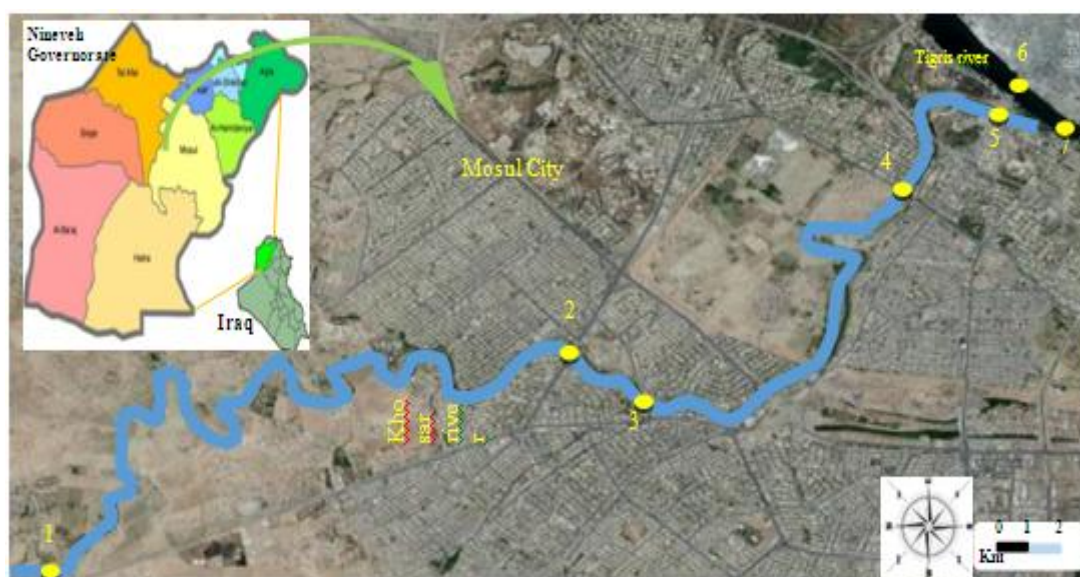


Figure (1): Khosar and Tigris rivers map in Mosul city, Iraq

### CALCULATION OF THE WQI

The use of these models was widespread after the mathematical model was proposed by Horton in 1965 and developed by Brown in 1970. Over time, a number of mathematical models were developed to assess water quality for different purposes<sup>[15]</sup>. The use of the water quality index (WQI) facilitates the process of assessing the surface water quality for irrigation purpose, due to the ability of the index to give the single value that reflects the interference between the large number of data and characteristics of irrigation water, which are understood by the specialist and non-specialist<sup>[16]</sup>.

The WQI for the rivers was calculated from twelve parameters for seven sampling stations to assess the suitability of Khosar and Tigris Rivers water for irrigation purposes. In the first step, each of the twelve parameters has been assigned a weight ( $w_i$ ) according to its relative importance in the overall quality of water for irrigation uses (Table 1). The maximum weight of 5 has been assigned to the parameter SAR. due to its major importance in water quality assessment.  $\text{NO}_3^-$  which is given the minimum weight of 2 as  $\text{NO}_3^-$  by itself may not be harmful.

In the second step, the relative weight ( $W_i$ ) is calculated from the following equation:

$$W_i = \frac{w_i}{\sum w_i}$$

Where,  $W_i$  is the relative weight,  $w_i$  is the weight of each parameter and number of parameters.

**Table 1: weight ( $w_i$ ), Relative weight ( $W_i$ ) of some physicochemical parameters**

Parameters	Standard value	Weight ( $w_i$ )	Relative weight ( $W_i$ )
pH	7.5	4	0.08333333
EC	2255	4	0.08333333
Na%	60	4	0.08333333
$\text{HCO}_3$	8.5	3	0.06250000
$\text{NO}_3$	2.114	2	0.04166667
Cl	10	3	0.06250000
SAR	9.0	5	0.10416667
MAR	50	4	0.08333333
RSC	2.25	4	0.08333333
KR	1.0	5	0.10416667
PI	75	5	0.10416667
F. Colif.	150	5	0.10416667
		$\sum 48$	$\sum 1.00000000$

The third step, a quality rating scale ( $q_i$ ) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in and the result multiplied by 100<sup>[17,18]</sup>:

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

Where  $q_i$  is the quality rating,  $C_i$  is the value of each parameter in each water sample and  $S_i$  is the standards limit for irrigation. For computing the WQI, sub-index ( $Sl_i$ ) is calculated for each parameter and the WQI is then calculated as per the following equations:

$$Sl_i = W_i \times q_i$$

$$WQI = \sum Sl_i$$

Water quality classified into five categories based on WQI values as shown in (Table 2)<sup>[19]</sup>.

**Table 2: Water quality classification based on WQI value**

WQI value	Water quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unsuitable

## RESULTS AND DISCUSSION

The values of the study parameters of seventy water samples are given in (Table 3). pH of water ranged from 6.55 to 8.3. In our research, water was showing alkaline nature. The slight acidic of some surface water samples may be due to the presence of organic acid and dissolved carbon dioxide which is derived from degradation of organic matter which sewage water discharge into the river<sup>[20]</sup>. pH of all surface water samples was within the acceptable limits of irrigation purposes<sup>[17]</sup>.  $EC_{25}$  is an important character for determining salinity damage and water viability for irrigation purposes, and increasing its value leads to deterioration of water quality. The values ranged from 0.34 to 1.76 dS.  $m^{-1}$ , high values due to the discharge of domestic wastewater to the Khosar river. The values of water samples of Khosar river indicate that 93.4% in the range of high salinity hazard (class doubtful quality), whereas 100% of Tigris river samples in the range of medium salinity hazard (class good quality)<sup>[18]</sup>.

High  $Cl^-$  ions affect the growth of plants by increasing the osmotic pressure, which in role reduces crop growth cause lower water availability to plants. Excess  $Cl^-$  ions absorbed in plants tissues accumulate on the leaves also resulting in leaf burns, while the user of the immoderate amount of nitrate reduce the yield and Crops quality, due to it delays the crop ripeness in the current study<sup>[21]</sup>.

**Table 3: Results of physico-chemical analysis of Khosar and Tigris Rivers (maq.  $l^{-1}$ )**

Sta. No.		pH	$EC_{25}^*$	$HCO_3$	$NO_3$	Cl	Ca	Mg
1	Min.	7.29	0.565	2.63	0.0120	0.592	3.2	2.16
	Max.	8.30	1.755	3.67	0.0330	2.031	13.84	7.92
	Mean	7.81	1.252	3.32	0.0180	1.278	8.76	5.50
	SD $\pm$	0.38	0.439	0.37	0.0100	0.475	3.49	2.03
2	Min.	6.70	0.713	3.60	0.0040	0.592	3.76	2.16
	Max.	7.96	1.606	7.03	0.0400	1.664	9.44	5.28
	Mean	7.22	1.116	4.55	0.0170	1.311	5.45	3.79
	SD $\pm$	0.33	0.341	1.13	0.0120	0.292	1.76	0.81
3	Min.	6.76	0.713	3.52	0.0050	0.874	3.92	2.16
	Max.	7.95	1.668	6.88	0.0320	1.946	7.04	6.08
	Mean	7.14	1.121	4.62	0.0180	1.497	5.16	3.83
	SD $\pm$	0.33	0.394	1.19	0.0100	0.271	0.92	1.08
4	Min.	6.79	0.728	3.36	0.0030	0.761	4.32	2.56
	Max.	7.95	1.700	6.47	0.0300	1.523	6.64	5.84
	Mean	7.14	1.089	4.52	0.0160	1.325	4.97	3.82
	SD $\pm$	0.32	0.340	1.07	0.0090	0.224	0.71	1.09
5	Min.	6.89	0.803	3.27	0.0030	0.987	4.32	2.56
	Max.	7.33	1.699	6.47	0.0280	1.579	7.12	5.6
	Mean	7.08	1.129	4.47	0.0160	1.300	5.67	3.87
	SD $\pm$	0.14	0.293	1.06	0.0080	0.193	1.11	1.17
6	Min.	6.81	0.340	2.00	0.0006	0.338	2.4	0.4
	Max.	7.85	0.708	4.72	0.0150	0.789	3.76	2.32
	Mean	7.54	0.484	2.72	0.0080	0.454	3.07	1.18
	SD $\pm$	0.31	0.125	0.80	0.0050	0.144	0.44	0.53
7	Min.	6.55	0.480	2.32	0.0020	0.394	2.88	1.28
	Max.	7.75	0.857	5.60	0.0160	0.902	4.32	2.12
	Mean	7.29	0.618	3.16	0.0100	0.643	3.46	1.75
	SD $\pm$	0.36	0.122	1.02	0.0070	0.141	0.44	0.32

\*dS.  $m^{-1}$

The mean values of chloride and nitrate reached to 2 and 0.03 meq.  $l^{-1}$  respectively. In our research, (chloride and nitrate) ions concentration within the prescribed limits for irrigation uses, the irrigation indexes such as (SAR, KR, Na%, PI, and MAR) are important parameters for determining the suitability of water for irrigation purposes (Table 4)<sup>[22]</sup>.

The SAR values ranged from 0.01 to 1.99 meq.  $l^{-1}$  and the water from the study area fell into the excellent irrigation quality water quality index. The degree of cation exchange reactions in soil can be indicated by SAR of irrigation water as high SAR is indicative of excess sodium ions in the soil that can replace Magnesium and Calcium ions through cations exchange processes, which lead to damage soils structure (infiltration and aeration)<sup>[23]</sup>, while the Na% Values reached to 29.81, also all values of %Na, KR, PI, and MAR of water in the study area are suitable for irrigation purposes<sup>[18]</sup>.

Hazardous effect of  $\text{HCO}_3$  on the quality of water for irrigation purpose is assessed using residual sodium carbonate (RSC). The value of RSC higher than  $2.25 \text{ meq. l}^{-1}$  is not suitable for irrigation<sup>[24]</sup>. Persistent use of water having RSC higher than  $2.25 \text{ meq. l}^{-1}$  lead to the precipitation of calcium and magnesium ions and thus the predominance of sodium ions in the soil solution which adversely affects the soil characteristics<sup>[25]</sup>. In this research, all RSC values are less than  $2.25 \text{ meq. l}^{-1}$ , therefore its suitable for irrigation uses.

Other irrigation parameters like F. Coliform which related to human health the result revealed that Khosar and Tigris Rivers water is suitable for irrigation purposes<sup>[26]</sup>.

The results of the water quality index for the studied stations of the Khosar river shown in (Table 5), which ranged from (196-6830). This indicates the river quality water is between poor to unsuitable for irrigation purposes.

The lower values are especially at the stations 2, 3, 4, and 5 of Khosar River as a result of wastewater discharge to the river while passing through Mosul city, which leads to raising the concentrations of some pollutants and thus increase the values of the sub-index (Sli) of those pollutants, which negatively affects the values of WQI (as shown in Table 6). While, the water quality index of the Tigris river was at station 6 good for irrigation uses, but station 7 is very poor because of the due to of the Khosar river on the Tigris river.

In general, the results indicate that there is an obvious effect on the water quality of Khosar river on the water quality of Tigris river at station 7 compared with station 6 (control) to increase the means of some studied parameters such as  $\text{EC}_{25}$ ,  $\text{NO}_3$ , Cl, Na%, MAR and F. Colif. Which reached to (28, 25, 42, 14, 23, 383)% respectively.

**Table 4: Results of Khosar and Tigris rivers.**

Sta. No.		Na%	SAR	MAR	RSC	KR	PI	F. Colif.**
1	Min.	10.70	0.79	33.5	-1.68	0.120	17.40	0.004
	Max.	23.47	1.35	48.9	-19.12	0.320	51.38	11.00
	Mean	17.11	1.07	38.9	-10.93	0.214	30.08	2.370
	SD±	4.25	0.18	5.50	-5.57	0.060	11.28	4.390
2	Min.	11.75	0.53	18.6	-0.56	0.137	34.47	0.900
	Max.	29.23	1.99	49.4	-8.00	0.419	44.41	93.00
	Mean	19.38	1.12	41.9	-4.68	0.254	38.99	31.74
	SD±	5.73	0.19	9.1	-2.49	0.080	3.72	24.77
3	Min.	14.64	0.77	30.6	-0.32	0.174	33.34	0.900
	Max.	29.12	1.9	46.3	-9.36	0.418	47.43	150
	Mean	20.76	1.2	42.0	-4.36	0.248	41.10	64.29
	SD±	5.79	0.05	5.5	-2.63	0.090	4.68	48.66
4	Min.	11.02	0.53	34.7	-0.64	0.126	33.13	0.400
	Max.	23.57	1.49	50.8	-8.64	0.314	47.41	240.0
	Mean	17.68	0.97	42.8	-4.28	0.226	38.79	44.97
	SD±	5.19	0.17	5.3	-2.42	0.070	4.46	92.33
5	Min.	7.80	0.32	26.4	-0.64	0.111	30.76	3.000
	Max.	22.46	1.48	49	-8.80	0.295	40.81	460.0
	Mean	16.14	0.91	40.2	-5.07	0.202	35.67	97.90
	SD±	5.85	0.14	7.1	-2.46	0.080	3.05	91.53
6	Min.	0.48	0.01	9.6	-0.32	0.004	36.26	0.004
	Max.	29.81	1.22	45.3	-2.56	0.212	55.75	3.000
	Mean	10.26	0.39	27.3	-1.52	0.129	44.37	0.770
	SD±	10.27	0.41	10.1	-1.10	0.140	6.49	1.222
7	Min.	2.53	0.08	26.2	-0.24	0.026	35.92	0.030
	Max.	23.79	1.04	41.9	-3.12	0.251	45.46	11.00
	Mean	11.76	0.51	33.5	-2.06	0.142	41.52	3.720
	SD±	7.42	0.34	5.3	-1.11	0.090	3.92	4.700

\*\*  $\times 10^5 \text{ cell. ml}^{-1}$



**Table 5: Calculated WQI and their classification of the stations**

Sta. No.	WQI	Classification type
1	196	Poor
2	2237	Unsuitable
3	4499	Unsuitable
4	3155	Unsuitable
5	6830	Unsuitable
6	78	Good
7	284	Very poor

**Table 6: Values  $Sl_i$  and  $qi$  for parameters**

Sta. No.		pH	EC <sub>25</sub>	Na%	HCO <sub>3</sub>	NO <sub>3</sub>	Cl	SAR	MAR	Kr	PI	F. Colif.	RSC
1	$Sl_i$	8.67	4.62	2.36	2.44	0.035	0.79	1.2375	6.48	0.22	4.17	165	0.0
	$qi$	104.13	55.52	28.33	39.14	0.84	12.78	11.88	77.8	2.14	40.10	1580	0.0
2	$Sl_i$	8.02	4.12	2.63	3.345	0.03	0.81	1.29	6.98	0.26	5.55	2204	0.0
	$qi$	96.26	49.49	31.66	53.52	0.79	13.11	12.44	83.82	2.54	53.32	21160	0.0
3	$Sl_i$	7.94	4.14	2.77	3.39	0.035	0.93	1.38	7.01	0.25	5.70	4465	0.0
	$qi$	95.28	49.71	33.33	54.35	0.84	14.97	13.33	84.18	2.48	54.80	42860	0.0
4	$Sl_i$	7.94	4.02	2.36	3.32	0.03	0.82	1.12	7.13	0.23	5.38	3123	0.0
	$qi$	95.28	48.29	28.33	53.17	0.74	13.25	10.77	85.66	.26	51.72	29980	0.0
5	$Sl_i$	7.86	4.17	2.22	3.28	0.03	0.81	1.05	6.71	0.21	4.95	6799	0.0
	$qi$	94.4	50.06	26.66	52.58	0.74	13.00	10.11	80.54	2.02	47.56	65267	0.0
6	$Sl_i$	8.37	1.78	1.38	2	0.01	0.28	0.45	4.56	0.13	6.16	53	0.0
	$qi$	100.53	21.46	16.66	32	0.37	4.54	4.33	54.72	1.29	59.16	513	0.0
7	$Sl_i$	8.1	2.28	1.52	2.32	0.01	0.40	0.58	5.59	0.14	5.76	258	0.0
	$qi$	97.20	27.40	18.33	37.17	0.46	6.43	5.66	67.18	1.42	55.36	2480	0.0

## CONCLUSION

1. 80% of the Khosar river water samples are unsuitable for irrigation purposes by results of (WQI).
2. The results of the study indicate that there is a relative increase of most parameters studied during the passage of the Khosar river inside Mosul city, due to the discharge of sewage directly to it.
3. There is a noticeable effect of the water of the Khosar River on the waters of the Tigris River after meeting (station 7).

Therefore, we recommend to educating the population about the negative effects of randomly discharging waste and pollutants into the environment, and conducting preliminary treatment of wastewater before discharging it into the river with recurrent studies to stand at any emergency to reduce the deterioration of water quality.

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