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Application of water quality index [CCME WQI] to assess surface water quality: A case study of Khosar and Tigris rivers in Mosul, Iraq

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ABSTRACT

Sixty-six samples of water collectedmonthly from five stations on Khosar river and two stations on Tigris riverduring the period from Jan. to Oct. was assessedfor drinking purposes using CCME WQI model, which applied for thirteen water quality parameter (TDS, Cl^-, pH, T.H, T.A, TPC, F. Colif., DO, Na^+, K^+, SO_4^{-2}, PO_4^{-3} andNO_3^-). Based on the results obtained from the CCME WQI values of Khosar River ranged between (29.8-32), which indicate that the river has the poorest quality due to the effect of various wastewater discharge on it. Tigris river values ranged between (37.1-37.8), which indicate that the water poor quality categoriesfor drinkingpurposes, because of most of the studied parameters within the permissible level recommended by the WHO and CCME for drinking water.

Key words: CCMEWQI, Water quality of Khosar and Tigris rivers.

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INTRODUCTION

Humanitarian activities lead to the discharge of various pollutants into the aquatic environment which threatens the health of the mankind population by making water inappropriate [1]. It has been said that this leads to disease and death in various parts of the Widespread in the world and that his accident kills and causes death more than 13,000 people a day[2]. Surface water pollution threatens humans, animals, and ecosystems[3]. Research has shown that 80% of all life-threatening diseases in third world countries are directly related to poor drinking water quality. Also, studies have shown that Iraq faces serious problems in surface water, through the over-exploitation and unequal distribution of water resources, as well as the significant pollution of water in major rivers[4,5,6]. The major reasons for water pollution due to the increase in the discharge of non- treatment municipal wastewater, industrial practices, urbanization, and agriculture activities on the surface water in most Iraqi areas[7,8,9].

Water quality models are an easy way to evaluate the quality of water for different uses as it reflects the effect of interference on different water standards and giving one value instead of the huge amount of data which is understood by the specialist and non-specialist. In our current study, (CCME WQI) was used to assess the quality of river water as one of the most widespread models in the world[10-17], many researchers studied the quality of surface water for different purposes. Ewaid and Abed (2017)[18] used water quality index to evaluate Al-Gharraf River in southern Iraq. Ali et al., (2017)[19] applied CCME WQI for Massab river Al-Nassiryia city, Iraq and which indicated that the river has poor quality for irrigation. Ranjbar et al., (2016)[20] assessed the suitability of surface water quality for Karun River, Iran andAl-Saffawi (2018)[21], assessed the water quality of the Tigris River in Nineveh governorate for aquatic life by using the CCME WQI model. Therefore, the present study is aimed at assessing the water quality of Khosar River and identifying the environmental reality of the river water and its effect on the Tigris River after meeting.

MATERIAL AND METHODS

Description of study stations:

The Khosar River is located in the northern Nineveh Plain in Iraq and on the administrative border between the of Sheikhan distract and Al-Qush sub district. The water sources of Al-Khosar are located in the foothills of the highlands of Bqsiqasub district and Makloub mount, Many small eyes water at the middle of the mainstream of and the basin. The river passes through several villages, including Bahzany, Talsakuf, Samaakia, etc. and many quartersin Mosul city before it metwith Tigris river near Nineveh bridge,which are used to discharge different types of wastewater through several estuaries scattered on both sides of the river, which increases the pollution problems of Khosar river water, especially in dry periods, which adversely effect on the water of Tigris river in the study area. The discharge rate of the Khosar river is estimated at (5682) m^3/h.

METHODOLOGY

Sixty-six samples were taken from seven stations, five of them on Khosar River and two stations on the Tigris River in order to collect water samples through the period from Jan. to Oct. using clean polyethylene bottles as shown in (Table 1) and (Figure 1),for each sample 13 parameters

Table (1): The coordinates of the study area

No.	stations	Coordinates	
		N	E
1	K1	$36^0 42' 54''$	$43^0 19' 93''$
2	K2	$36^0 38' 25''$	$43^0 17' 05''$
3	K3	$36^0 37' 34''$	$43^0 17' 73''$
4	K4	$36^0 35' 47''$	$43^0 15' 13''$
5	K5	$36^0 34' 73''$	$43^0 14' 10''$
6	T6	$36^0 34' 61''$	$43^0 13' 83''$
7	T7	$36^0 34' 19''$	$43,14' 37''$

K: Khosar river, T: Tigris river

were measured which include: pH, Dissolved Oxygen (DO), Biochemical Oxygen demand (BOD_5),Total Hardness (T.H), Total Alkaline (T.A), NO_3^-, PO_4^{-3}, SO_4^{-2}, Cl^{-1}, Na^{+1}, K^{+1}, TDS, Total Plate Count (TPC) and Fecal Coliform (FC), by employing standard method presented by APHA (2017)[22].

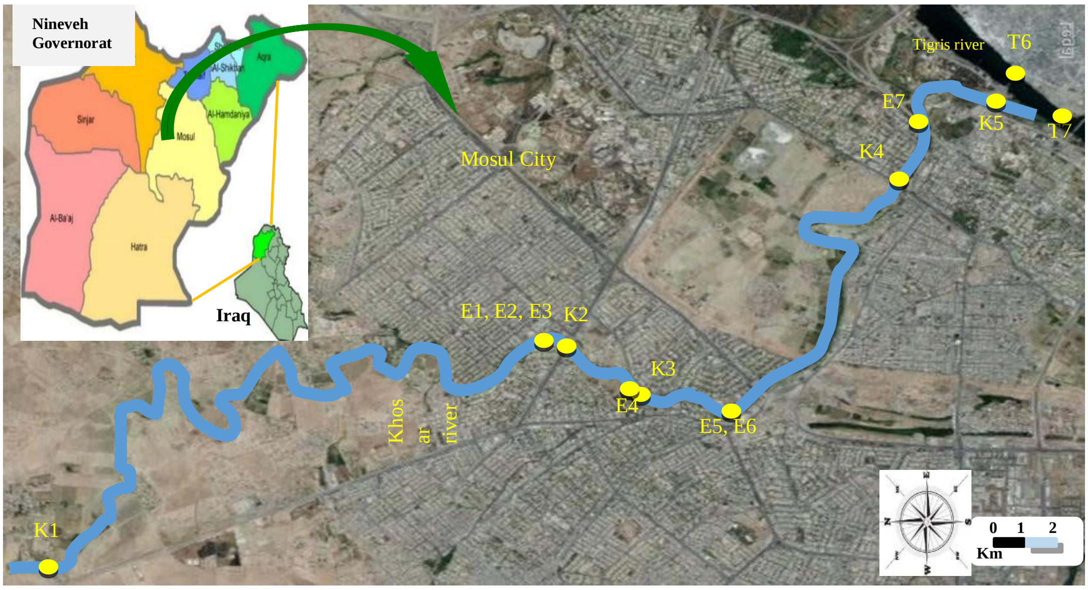

Figure 1: Khosar and Tigris rivers map in Mosul city, Iraq

Calculation of CCME WQI

In this paper, the Canadian Council of Ministry of the Environment model of water quality index(CCME WQI) model was used to identify the degree of water pollution and to communicate information in an easy and simplified way by finding one value for the effect of the different interactions of the studied properties for each site rather than the large numbers of data that are understood by everyone. In this model, three factors F_1, F_2, and F_3 are calculated, as follows[13,21,23]:

F_1:The number of criteria that fail to achieve their goal during the indicator period.
F_2: Percentage of samples that fail to achieve their objectives during the indicator period.
F_3: fails during indicator period.

$$\text{Factor 1: } F_1 = \frac{\text{number of failed variables}}{\text{total number of failed variables}} \times 100$$

$$\text{Factor 2: } F_2 = \frac{\text{number of failed test}}{\text{total number of failed test}} \times 100$$

$$\text{Factor 3: } F_3 = \frac{\text{nse}}{0.01\ \text{nse} + 0.01}$$

$$\text{nse} = \frac{\sum \text{excursion}}{\text{number of test}}$$

$$\text{Excursion} = \frac{\text{failed test value}}{\text{objective}} - 1$$

If the exceeded check value is higher than the standard value.

$$\text{Excursion} = \frac{\text{objective}}{\text{failed test value}} - 1$$

If the exceeded check value is below the standard value.

These factors are combined to give a comprehensive estimate associated with common specifications.

$$\text{CCME} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right]$$

Water quality is classified by linking it to one of the following categories as shown in (Table 2).

Table (2): Canadian Water Quality Index categorization[24]

Rating	CCME Values
Excellent	95 - 100
Good	80 – 94
Fair	60 - 79
Marginal	45 – 59
Poor	0 - 44

RESULTS AND DISCUSSION

In the aquatic ecosystems, pH has a direct effect on the water chemistry, the fluctuation in values is due to the biological activities[25].

The results (Table 3) indicate that the lowest value of Khosar river was (6.70). This decrease may be due to the presence of CO_2 gas, sulphate salts, nitrates and chlorides with acidic effect[26], as well as the processes of biological degradation and Oxidation of organic matter resulting from discharge of wastewater to the river, especially in the anaerobic conditions, Consequently leads to the formation of many compounds and carboxylic acids, H_2S can be oxidized to the formation of sulphuric acid as shown in the following equations[27]:

$CH_3H_7O_2NS + 8H_2O \longrightarrow 4CH_3COOH + 4NH_3 + 4H_2S$ ……….1
$4CH_3COOH + 8H \longrightarrow 5CH_4 + 3CO_2 + 2H_2O$ ………..2
$H_2S + 3O_2 \longrightarrow 2SO_2 + 2H_2O$ …………3
$H_2SO_3 + O_2 \longrightarrow 2H_2SO_4$ ………...4

These reactions explain to us the emission of the unpleasant odours from the river, the highest value of the water of the river was (8.3) at station K1, which is due to the effect of photosynthesis of hydrophytes and the consumption of CO_2 gas at the light period of the day, which leads to an increase in the composition of alkaline compounds in the aquatic environment as in the following equations[28]:
$2HCO_3^- \rightarrow CO_3^= + CO_2 + H_2O$
$CO_3^= + H_2O \rightarrow CO_2 + 2OH^-$

Table (3): Variations of the physiochemical and bacterial analysis results of Khosar and Tigris Rivers water (mg. l^{-1})

Sta. No.		pH	T.A	T.H	TPC*	F.Colif.**	TDS	Cl
K1	Min.	7.29	132	268	0.014	0.004	362	21
	Max.	8.3	184	1088	4.900	11.00	1123	72
	Mean	7.81	167	713	1.020	2.37	802	45.33
	SD±	0.38	19	263	2.171	4.39	281	16.87
K2	Min.	6.70	180	372	0.300	0.90	456	21
	Max.	7.96	325	580	105.6	93.00	1028	59
	Mean	7.22	228	462	33.60	31.74	715	46.5
	SD±	0.33	57	84	38.06	24.77	180	10.38
K3	Min.	6.76	176	352	0.500	0.900	456	31
	Max.	7.95	344	512	104.8	150.0	1068	69
	Mean	7.14	231	450	36.51	64.29	718	53.1
	SD±	0.33	60	93	33.09	48.66	179	9.62
K4	Min.	6.79	168	356	0.800	0.400	466	27
	Max.	7.95	324	624	1000	240.0	1088	54
	Mean	7.14	226	441	207.95	44.97	698	47
	SD±	0.32	54	83	509.50	92.33	168	7.95
K5	Min.	6.89	164	356	1.760	3.000	514	35
	Max.	7.33	234	580	1000	460.0	1088	56
	Mean	7.08	224	477	290.1	97.90	723	46.1
	SD±	0.14	53	93	390.5	91.53	96	6.85
T6	Min.	6.81	108	176	0.007	0.004	218	12
	Max.	7.85	236	256	7.200	3.000	453	28
	Mean	7.54	136	213	1.020	0.770	310	16.1
	SD±	0.31	40	26	2.191	1.222	80	5.108
T7	Min.	6.55	116	220	0.920	0.030	307	14
	Max.	7.75	280	300	88.00	11.00	548	32
	Mean	7.29	158	259	23.37	3.720	396	22.8
	SD±	0.36	51	26	33.46	4.700	79	5.00
Stand. Limits		6.5-8.5	150	500	10.00	0.000	900	250

* x 10^6; ** x10^5

The relative decrease of pH along the river pathway continues to affect the water quality of the increased at station K1 and then decreases after the river enters the residential quarters of Mosul city due to the effect of the organic-rich sewage,which consumes it for biodegradation, especially in high temperature periods[29], this confirms the organic pollution values (BOD_5) which reached to (96) mg. l^{-1} at a station (K2), due to the discharge of sewage water, where the values of wastewater reached between (50-87) mg. l^{-1}, as shown in (Tables 4,5). In general, the water quality of Khosar River is very polluted according to (BOD_5) by classification of Hynes[30].

As for the values of TDS, T.Hard. , Na^{+1}, $K^{+1}$and Cl^{-1} is observed mostly higher in the first site of the water river because of the emanation of sewage water and the presence of sulphur springs which reached to (1123,1088, 86 and 10.4) mg. l^{-1} and decrease during river runoff due to the decline in the flow rate and the dense growthof aquatic plants and then rise relatively at the K5 station due to the discharge of wastewater of theestuary E7, instead, the values of T.

Alkalinity rise with river flow due to wastewater discharged into the river which reached to 344 mg. l^{-1} at K3[29]. The existence of some parameters is very necessary for vital activities in addition to disease prevention.

Table (4): Variations of the chemical analysis results of the water of Khosar and Tigris Rivers *

Sta. No.		DO	BOD_5	PO_4	NO_3	SO_4	Na	K
K1	Min.	7.4	16	0.17	0.8	203	40	4.0
	Max.	10.3	40	1.87	2.1	729	86	10.1
	Mean	9.3	27	0.77	1.16	374	64	7.4
	SD±	1.0	10	0.83	0.67	254	16	2.2
K2	Min.	0.0	32	0.33	0.28	144	24	4.8
	Max.	8.0	96	7.74	2.49	802	108	8.8
	Mean	2.8	56	3.36	1.09	258	58	7.3
	SD±	3.5	21	2.88	0.76	211	29	1.2
K3	Min.	0.0	32	0.71	0.34	117	33	6.7
	Max.	7.2	72	9.38	2.03	364	99	10.4
	Mean	1.4	51	4.94	1.12	218	60	8.0
	SD±	2.4	12	3.67	0.63	99	28	1.2
K4	Min.	0.0	24	0.51	0.21	113	25	5.3
	Max.	6.8	72	9.93	1.90	214	86	8.4
	Mean	1.4	43	4.46	1.01	171	48	6.4
	SD±	2.3	16	3.68	0.57	38	23	1.0
K5	Min.	0.0	16	0.55	0.22	128	14	3.4
	Max.	4.4	50	7.74	1.74	248	86	10.4
	Mean	1.1	44	3.81	1.00	181	48	7.9
	SD±	1.6	16	2.84	0.55	57	27	2.4
T6	Min.	3.6	1.6	0.09	0.04	14	0.5	0.9
	Max.	11.2	5.6	0.77	0.99	77	30	2.4
	Mean	8.5	3.6	0.29	0.52	33	12	1.8
	SD±	2.5	1.8	0.19	0.36	19	12	0.5
T7	Min.	2.0	3.2	0.28	0.13	29	3.0	2.3
	Max.	10.4	32	2.96	1.02	137	40	4.6
	Mean	6.8	20	1.51	0.67	56	18	3.1
	SD±	3.1	11	1.24	0.45	33.6	13	0.9
Stand. Limits		5.0	5.0	10.0	50.0	400	200	12

*(mg. l^{-1})

Table (5): Mean* result of wastewater estuaries discharged to Khosar river.

Estua. / Param.	E1	E2	E3	E4	E5	E6	E7
Tem. °C	28.7	28.3	27.6	28.2	28.3	28.0	26.0
pH	6.95	6.80	6.93	6.72	6.73	6.90	7.04
TDS	501	525	614	460	447	599	790
T.Hard.	249	326	320	239	546	368	560
T.Alkal.	185	203	228	196	212	257	255
DO	0.80	0.40	0.13	1.13	0.60	0.66	0.00
BOD_5	87	76	50	84	71	72	61
Ca^{+2}	157	169	188	155	163	219	372
Mg^{+2}	92	93	132	84	56	149	188
Cl^{-1}	38	41	52	36	39	48	41
NO_3^{-1}	1.33	1.30	1.31	1.40	1.31	0.81	1.28
SO_4^{-2}	80	114	146	62	49	84	79
PO_4^{-3}	4.44	4.96	8.58	4.47	5.37	3.22	5.88

*Mean of three replicates(mg. l^{-1}).

For instance, the hardness and its causes as it works to prevent diabetes, heart diseases and liver cirrhosis furthermore magnesium ions reduce the risk of cancer[31,32].

The values of Sulphate ion for all stations were within the WHO standard for drinking purposes. Except for the K1 and K2 station which reached to 729 and 802 mg. l^{-1} respectively, Because of the presence of sulphur springs in the basin of the river, as well as the processes of anaerobic microbial degradation of the protein, which leads to the formation of different forms of sulphur (H_2S, $S^=$, and SO_4) and this explains to us the emission of bad odour from the river[21].

$$2\{CH_2O\} + SO_4^= \xrightarrow{\text{Anoxic Bact}} 2\,CO_2 + 2H_2O + S^=$$
$$S^= + 2H^+ \rightarrow H_2S$$
$$SO_4 + CH_4 + 2H^+ \rightarrow CO_2 + 2H_2O + H_2S$$

Also, according to chloride and phosphate ions which did not exceed the permissible drinking limits, the highest concentrations reached to (72, 9.38) mg. l^{-1}respectively, as for the nitrate ions, we note from the (Tables 4,5) fluctuation of the values of nitrate ions, which may be due to the self-purification and discharge of wastewater to the river and that the highest concentration reached (2.49) mg. l^{-1} at the station K2 due to the discharge of agricultural wastewater to the river. However, the values did not exceed the limits allowed for drinking. The high concentrations of nitrate ions have serious health problems such as children's blue syndrome, cancers, and thyroid problems. As well as the impact on pregnant women such as abortion and the sudden death of babies and brain tumors[33,34].

As for evidence of bacterial contamination indicators such as Faecal coli form and *E. coli*, they are essential to give a picture of the occurrence of faecal contamination and thus the potential for pathogens existence [35].The results (Tables 3) shown that the total number of bacteria (TPC), Faecal coliform and *E. coli* were increased with the entry of the river Mosul city to reach (1 x 10^9) cell. ml^{-1}, (460 and 460) x 10^5 cell. 100 ml^{-1} respectively, a consequence to the discharge of wastewater to the river through estuaries scattered on its sides. When comparing the results of the present study to the study conducted on the same river in 1994[30], we note that there is a significant increase in the number of bacteria (TPC) to reach the percentage increase to (693)%.

In general, with regard to the impact of Khosar river on the water quality of the Tigris river. The results (Table 3and 4) indicate that most of the parameters studied for Tigris river water have increased at station T7 (200-meter distance from the meeting point) such as Biochemical Oxygen demand BOD_5, (SO_4, PO_4 ions) and TPC of bacteria to reach (460, 70, 421 and 2191)% respectively, also, clearly decrease in pH and DO values compared to the station T6 (control points). Finally, the results of the water quality index (CCME WQI) and the factors (F1, F2, and F3) in the Khosar and Tigris Rivers as shown in (Table 6). The CCME WQI values in Khosar river has ranged between29.8 to 32.0 Thus, the water quality of the river classified asthe Poor water quality category for drinking uses, this deterioration in the water quality due to a large amount of wastewater that is discharged to the river. Also, high concentration of pollutants such as TDS, DO, BOD_5, T.H., SO_4, and bacterial contamination will result in higher of(F1, F2, and F3) values that are inversely correlated with CCMEWQI values.

As for the Tigris river in the study area, the water quality classified as poor (37.8 and 37.1) water quality category in the station (T6, T7), This deterioration in quality is due to the impact of pollutants transferred from Khosar river.

Table (6):Water quality index drinking for the studied stations from Khosar and Tigris rivers

Stations	F_1	F_2	F_3	CCME WQI	Ranking
K-1	50	37.0	99.9	32.0	Poor
K-2	57	38.9	99.9	29.8	Poor
K-3	50	38.2	99.9	31.8	Poor
K-4	50	36.9	99.9	32.0	Poor
K-5	50	39.7	99.9	31.5	Poor
T-6	35.7	18.3	99.9	37.8	Poor
T-7	35.7	24.2	99.9	37.1	Poor

CONCLUSIONS AND RECOMMENDATIONS

The water of the Khosar river was characterized by the highest standards during the period of study, especially the values of TDS, T. H., T. A., DO, BOD_5 and the index of bacterial contamination, which affects the quality of water as a source of drinking, 100% of the quality values were of poor water category.

Wastewater discharged to the river exceeds the maximum allowable limits of wastewater discharged to rivers according to Iraqi specifications, especially the concentration of SO_4, DO, BOD_5 and bacterial contamination(36).

Finally, we recommend educating residents of the city and the villages near the river to prevent the use of the water of Khosar River to drink, as well as to prevent boys and children from swimming in the river and to establish an advanced sewage network and a plant to treat this wastewater before discharging it into the river.

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