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RESEARCH ARTICLE

Evaluation of Water Quality Using Water Quality Index (WQI) Method and GIS in Al-Gharraf River Southren of Iraq

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Abstract: The present study describes the application of Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for for twenty-one stations along the Al-Gharraf River from Kut Dam when the river branching from Tigris to its end in the northern of Nassiria city. Sixteen water quality parameters under investigation were as follows: WT (9–33°C), pH (6.51–8.25), NTU (11–157), EC (700–1652 µS/cm), TDS (448–1057.23 mg/l), TSS (23–194 mg/l), DO (3.42–10.8 mg/l), BOD5 (0.79–9.07 mg/l), TH (218–689 mg/l), CL (87–381.3 mg/l), SO4 (111.8–469 mg/l), NO3 (3.01–33 mg/l), PO4 (0.107–0.964 mg/l), Pb (0.007–0.242 ppm), FC (180–97000 cfu/100ml) and CHL-a (0.033–9.534 mg/l). were used during the period from December, 2016 to November, 2017.Based on the results of this application, the general surface water quality in the Al-Gharraf River is found to be not suitable for use as drinking water without elaborate treatment, poor for aquatic life protection and fair for irrigation.

Keywords: *CCME WQI, GIS , Water quality, Al-Gharraf River.*

Introduction

Rivers have always been the most important fresh water resources, and most developmental activities are still dependent upon them. Rivers play a major role in assimilating or carrying industrial and municipal waste water, manure discharge and runoff which are responsible for water river pollution (1). The degree of pollution is generally assessed by studying physical and chemical characteristics of the water bodies (2).

Iraqi inland waters witness tremendous impacts through discharges of manufacturers, agricultural and domestic sewage (3). Quite few studies were performed on Tigris River (4) (5) (6) and(7).But, no published work was found to assess water quality of the Al-Gharraf River by using WQIs with GIS. Their study aimed at using sixteen ecological parameters in evaluating the quality of the Al-Gharraf River for for drinking, irrigation, and living aquatic uses during four seasons.

Methodlogy

Study Area

Al- Gharraf River is one of two branches of the Tigris River at Kut City, 225 km south of Baghdad City (Fig. 1). After branching from the Tigris, the Garaff flows southeast toward Al-Haay City (study area) within Wasit Province, 220 km southwest of Baghdad City. The river is 230 km in length with a variable depth of 18 m at its branching point from the Tigris to 10 m at its junction with the Euphrates River at the marsh area near ThiQarProvince.

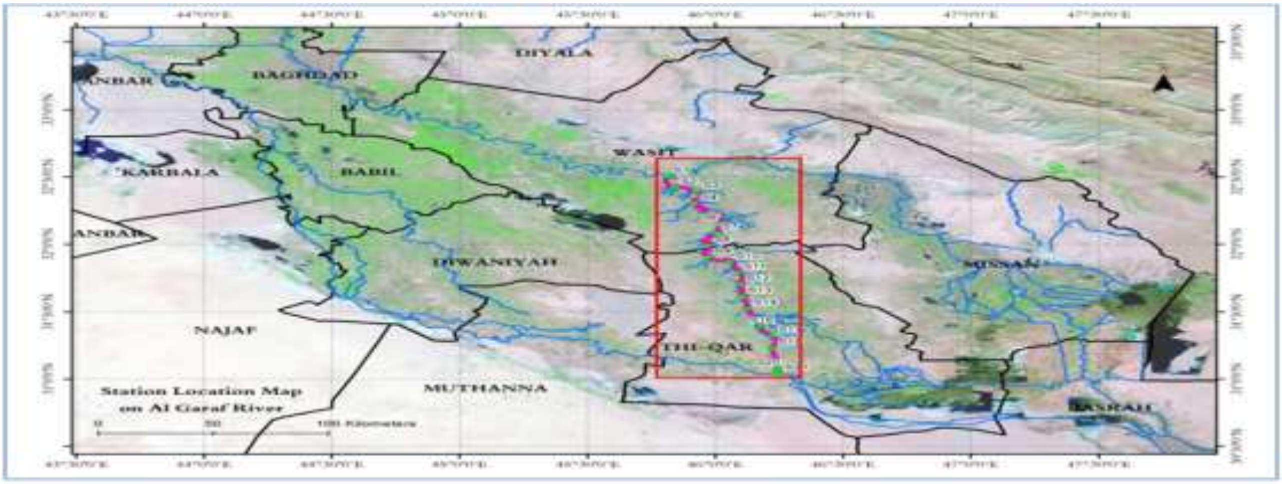

Figure 1: Digital map of Al-Gharraf River showing the stations of the case study

Analytical Procedure

In the study, water samples were collected monthly during four seasons from December 2016 to November 2017, at twenty one stations along the Al-Gharraf River (Figure 1). Water samples were collected for physiochemical analysis using pre-washed polyethylene bottle by water sample twice before filling.The studied physic-chemical and biological parameters including temperature, turbidity, EC, TDS, TSS, pH, DO, BOD_5, SO_4, Cl, NO_3, PO_4, Pb ,total hardness, chlorophyll-a and fecal Coliforms were preserved and analyzed according to American Public Health Association (8).

Estimating the Canadian Water Quality Index (CCME-WQI)

The CCME WQI model was developed to use as a tool for facilitate and definition the water quality data (9). Three measures were selected to calculating index as follow:

- Find F1 (Scope). This factor evaluate the extent of water quality guideline non-compliance over the time period of interest.

$$F1 = \frac{number\ of\ failed\ variables}{total\ number\ of\ variables} \times 100 \qquad \text{Eq.(2.6)}$$

- Find F2 (Frequency). This factor represents the percentage of individual tests that do not meet objectives (failed tests).

$$F2 = \frac{number\ of\ failed\ tests}{total\ number\ of\ tests} \times 100 \qquad \text{Eq.(2.7)}$$

- Find F3 (Amplitude). This factor represents the percentage of individual tests that do not meet objectives (failed tests). This calculated in three steps:

In the first step, the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an excursion and is expressed as follows. When the test value must not exceed the objective:

$$ecrosion = \left(\frac{failed\ test\ valuesi}{objectivej}\right) - 1 \qquad \text{Eq.(2.8)}$$

When the test value must not fall below the objective:

$$ecrsion = \left(\frac{objectivej}{failed\ test\ valuesj}\right) - 1 \qquad \text{Eq.(2.9)}$$

- In the second step, the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).This variable, referred to as the normalized sum of excursions, or **nse**, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} \text{excursioni}}{numer\ of\ tests} \qquad \text{Eq.(2.10)}$$

- In three step, the F3 (*Amplitude*) is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F3 = \left(\frac{nse}{0.01\,nse + 0.01}\right) \qquad \text{Eq.(2.11)}$$

Finally, the water quality index was calculated by using this expression:

$$\text{CWQI} = 100 - \left(\frac{\sqrt{F_1{}^2 + F_2{}^2 + F_3{}^2}}{1.732}\right) \qquad \text{Eq.(2.12)}$$

The CWQI ranks water quality in the following 5 categories according to CCME, (2001).

Table 1: The Canadian Water Quality Index scale

CCME WQI values	Rating	Class
0– 44	Poor	I
45–59	Marginal	II
60–79	Fair	III
80–94	Good	IV
95–100	Excellent	V

Result and Discussion

The CCME-WQI is a tool implemented by Canadian Council of Ministers of the Environment (CCME) to convey the water quality information for both management and the public in Canada, and should not be applied with less than four parameters and four sampling times per year (10).

The critical parameters chosen to evaluate the CCEM-WQI were temperature, turbidity, EC, TDS, TSS, pH, DO, BOD_5, SO_4, Cl, NO_3, PO_4, Pb ,total hardness, chlorophyll-a and fecal coliforms. The parameters are used to classify the Al-Gharrafriver according to the usage. The calculated factors, resulting CCME-WQI and the categorization are listed in Tabular (2, 3,4 &5). It is seen that the Candian WQI for the first five stations of the Al-Gharraf River was classified as Good (80 – 94, less than 85) and Fair (60 – 79) except for End Kut station during April and November which was classified as Marginal (CCME-WQI =57) and Poor (CCME-WQI =39) because of high increasing of CHL-a concentration at this station (3.62 mg/l) at April and fecal coliform bacteria (5400 CFU) at November. The same reason of increasing of CHL-a concentration and fecal coliform bacteria made the water quality index low at station End Muwaffaqiah during April (CCME-WQI = 51), and November (CCME-WQI=33).

Fluctuation in the discharges of the good quality water from the Tigris River which were mixed with the water of Al-Gharraf River at Mid Al-Hayy station made the water quality classification fluctuated too from fair, CCME-WQI (60-79, less than 63), during February to marginal, CCME-WQI (45-59), during March and May , then fair during July to marginal during June, and to poor, CCME-WQI (0-40), during other months of year, 2016-2017. This results conceded by Lumb, *et al.* (11), Mahagamagea&Managea,(12), Salman *et al.* (13), and Sehnaz*et al.* (14).

Table 2: Sensitivity of WQPsthat used to calculate CCME-WQI for Winter (December,2016, January,February,2017)

ID	Name of Station	F1	F2	F3	CCME WQI	CCME WQI scale	Water Quality Rating
S1	Ent. Kut	13.33	11.11	31.31	79.33	60–79	Fair
S2	End Kut	40	22.22	32.2	67.69	60–79	Fair
S3	Ent. Al-Muwaffaqiyah	40	20	22.89	70.99	60–79	Fair
S4	End Al-Muwaffaqiyah	40	26.66	28.04	67.86	60–79	Fair
S5	Ent. Al-Hayy	40	24.44	26.59	68.88	60–79	Fair
S6	Mid Al-Hayy	53.33	40	85.81	37.26	0–44	Poor
S7	End Al-Hayy	40	24.44	61.61	55.3	45–59	Marginal
S8	Ent. Al-Fajr	40	24.44	60.14	55.97	45–59	Marginal
S9	End Al-Fajr	46.66	31.11	83.30	42.02	0–44	Poor
S10	Ent. QalatSukar	40	26.66	67.42	52.19	45–59	Marginal
S11	End QalatSukar	60	44.44	85.95	34.26	0–44	Poor
S12	Ent. Al-Rifai	46.66	31.11	69.23	48.55	45–59	Marginal
S13	End Al-Rifai	53.33	42.22	83.18	37.96	0–44	Poor
S14	Ent. Al-Naser	46.66	33.33	67.11	49.03	45–59	Marginal
S15	End Al-Naser	66.66	46.66	86.64	31.37	0–44	Poor
S16	Ent. Al-Shatrah	46.66	40	75.84	43.63	0–44	Poor
S17	Mid Al-Shatrah	73.33	57.77	89.98	25.14	0–44	Poor
S18	End Al-Shatrah	60	42.22	81.54	36.67	0–44	Poor
S19	Ent. Al-Gharraf	53.33	40	78.40	40.58	0–44	Poor
S20	Mid Al-Gharraf	66.66	48.88	87.5	30.5	0–44	Poor
S21	End Al-Gharraf	53.33	42.22	79.25	39.7	0–44	Poor

Table 3: Sensitivity of WQPsthat used to calculate CCME-WQI for Spring (March, April,2017, May,2017).

ID	Name of Station	F1	F2	F3	CCME WQI	CCME WQI scale	Water Quality Rating
S1	Ent. Kut	20	8.88	30.55	78.3	60–79	Fair
S2	End Kut	40	20	42.95	64.19	60–79	Fair
S3	Ent. Al-Muwaffaqiyah	26.66	15.55	38.72	71.41	60–79	Fair
S4	End Al-Muwaffaqiyah	40	24.44	50.37	60.27	60–79	Fair
S5	Ent. Al-Hayy	33.33	17.77	37.65	69.2	60–79	Fair
S6	Mid Al-Hayy	46.66	33.33	78.26	43.98	0–44	Poor
S7	End Al-Hayy	33.33	24.44	60.15	57.86	45–59	Marginal
S8	Ent. Al-Fajr	33.33	22.22	54.54	60.92	60–79	Fair
S9	End Al-Fajr	46	33.33	76.79	44.85	0–44	Poor
S10	Ent. QalatSukar	40	24.44	60.62	55.75	45–59	Marginal
S11	End QalatSukar	53.33	35.55	79.63	40.98	0–44	Poor
S12	Ent. Al-Rifai	40	24.44	68.25	52.19	45–59	Marginal
S13	End Al-Rifai	46.66	28.88	77.11	45.35	60–79	Fair
S14	Ent. Al-Naser	40	26.66	70.58	50.69	45–59	Marginal
S15	End Al-Naser	53.33	37.77	83.02	38.99	0–44	Poor
S16	Ent. Al-Shatrah	46.66	31.11	76.9	45.04	45–59	Marginal
S17	Mid Al-Shatrah	60	46.66	86.46	33.53	0–44	Poor
S18	End Al-Shatrah	46.66	40	81.78	40.93	0–44	Poor
S19	Ent. Al-Gharraf	46.66	33.33	77.27	44.44	0–44	Poor
S20	Mid Al-Gharraf	53.33	40	84.39	37.9	0–44	Poor
S21	End Al-Gharraf	40	33.33	79.91	44.93	0–44	Poor

Table 4: Sensitivity of WQPsthat used to calculate CCME-WQI for Summer (June,July,August,2017)

ID	Name of Station	F1	F2	F3	CCME WQI	CCME WQI scale	Water Quality Rating
S1	Ent. Kut	33.33	13.33	7.14	78.14	60–79	Fair
S2	End Kut	40	31.11	14.31	69.59	60–79	Fair
S3	Ent. Al-Muwaffaqiyah	26.66	20	15.75	63.13	60–79	Fair
S4	End Al-Muwaffaqiyah	40	31.11	24.31	67.55	60–79	Fair
S5	Ent. Al-Hayy	40	28.88	15.11	70.2	60–79	Fair
S6	Mid Al-Hayy	53.33	42.22	67.76	44.56	0–44	Poor
S7	End Al-Hayy	40	28.88	30.06	66.64	60–79	Fair
S8	Ent. Al-Fajr	33.33	26.66	29.52	70.03	60–79	Fair
S9	End Al-Fajr	53.33	40	63.76	46.73	45–59	Marginal
S10	Ent. QalatSukar	40	31.11	49.035	59.28	45–59	Marginal
S11	End QalatSukar	60	48.88	72.14	38.91	0–44	Poor
S12	Ent. Al-Rifai	40	33.33	50.04	58.3	45–59	Marginal
S13	End Al-Rifai	46.66	40	60.31	50.28	45–59	Marginal
S14	Ent. Al-Naser	40	33.33	56.33	55.71	45–59	Marginal
S15	End Al-Naser	60	51.11	77.22	36.29	0–44	Poor
S16	Ent. Al-Shatrah	40	35.55	74.42	47.07	45–59	Marginal
S17	Mid Al-Shatrah	60	60	84.73	30.76	0–44	Poor
S18	End Al-Shatrah	60	48.88	77.67	36.69	0–44	Poor
S19	Ent. Al-Gharraf	53.33	44.44	74.93	41.02	0–44	Poor
S20	Mid Al-Gharraf	60	55.55	80.91	33.58	0–44	Poor
S21	End Al-Gharraf	53.33	42.22	77.47	40.47	0–44	Poor

Table 5: Sensitivity of WQPs that used to calculate CCME-WQI for Autumn (September,October,November,2017)

ID	Name of Station	F1	F2	F3	CCME WQI	CCME WQI scale	Water Quality Rating
S1	Ent. Kut	40	17.77	11.42	73.88	60–79	Fair
S2	End Kut	66.66	46.66	55.61	45.09	0–44	Marginal
S3	Ent. Al-Muwaffaqiyah	46.66	31.11	28.57	63.66	60–79	Fair
S4	End Al-Muwaffaqiyah	60	44.44	57.69	45.52	45–59	Marginal
S5	Ent. Al-Hayy	46.66	33.33	49.44	56.28	45–59	Marginal
S6	Mid Al-Hayy	66.66	51.11	84.52	31.2	0–44	Poor
S7	End Al-Hayy	53.33	35.55	72.45	55.84	45–59	Marginal
S8	Ent. Al-Fajr	46.66	33.33	69.96	47.77	45–59	Marginal
S9	End Al-Fajr	66.66	46.66	83.55	32.66	0–44	Poor
S10	Ent. QalatSukar	46.66	35.55	70.05	47.24	45–59	Marginal
S11	End QalatSukar	66.66	51.11	85.46	30.81	0–44	Poor
S12	Ent. Al-Rifai	60	44.44	79.59	36.99	0–44	Poor
S13	End Al-Rifai	66.66	48.88	85.31	31.41	0–44	Poor
S14	Ent. Al-Naser	53.33	46	77.82	39.4	0–44	Poor
S15	End Al-Naser	66.66	57.77	88.43	27.88	0–44	Poor
S16	Ent. Al-Shatrah	53.33	44.44	80.56	38.6	0–44	Poor
S17	Mid Al-Shatrah	73.33	71.11	90.44	21.22	0–44	Poor
S18	End Al-Shatrah	60	51.11	90.24	30.82	0–44	Poor
S19	Ent. Al-Gharraf	60	51.11	86.77	32.31	0–44	Poor
S20	Mid Al-Gharraf	73.33	60	90.02	24.54	0–44	Poor
S21	End Al-Gharraf	60	51.11	84.12	33.44	0–44	Poor

For the same reasons that previously mentioned, the water quality for stations End Fajer, End QalatSuker, End Rifai and End Naser deteriorated more during year 2017 to become poor, CCME-WQI (0 – 44, less than 38), for most months except January and May, where it was classified as marginal, CCME-WQI (45 –59, less than 53). These results agreed withCelalettin&Orhan (15); Noori*et al.* (16); Ozlem*et al.,* (17) and Regmi*et al.,* (18). On the other hand, the water quality at End Al-Hayy, Entrance Fajer and Entrance Rifai, improved strangely during January,June and October to be Fair, CCME-WQI (60-79), because of reducing the values of turbidity (less than 29 NTU),total organic matter (less than 4.5 mg/l), total hardness (less than 315 mg/l), total dissolved solids (less than 480 mg/l), sodium (less than 68 mg/l), nitrate (less than 5.9 mg/l), sulfates (less than 185 mg/l),and cadmium(less than 0.0018 mg/l). It was noticed from Figure (2 to 5), that the last six stations of the Al-Gharraf River were classified as poor water quality for drinking, irrigation, and living aquatic usesfor all months from December, 2016 to November, 2017 except in Entrance Al-Shatrah station during January (CCME-WQI=59), May (CCME-WQI=55), and July (CCME-WQI=53) which was classified as marginal source. The real reasons for deterioration of water quality at these stations is large shortage of water level due to narrow width with low depth of the river, as well as water contains high concentration from organic materials (TOM >11.9 mg/l), plankton, algae and plants (CHL-a >9.53 mg/l) with dark green color (BOD5 >9.07 mg/l), reducing in pH (<6.5)and oxygen(<3.6 mg/l), raising turbidity(>179 NTU), total dissolved solids(>1000 mg/l), sulphate (>460 mg/l) phosphate (>0.964 mg/l) and, fecalcoliform (>97000 CFU), which affecting the overall water quality.

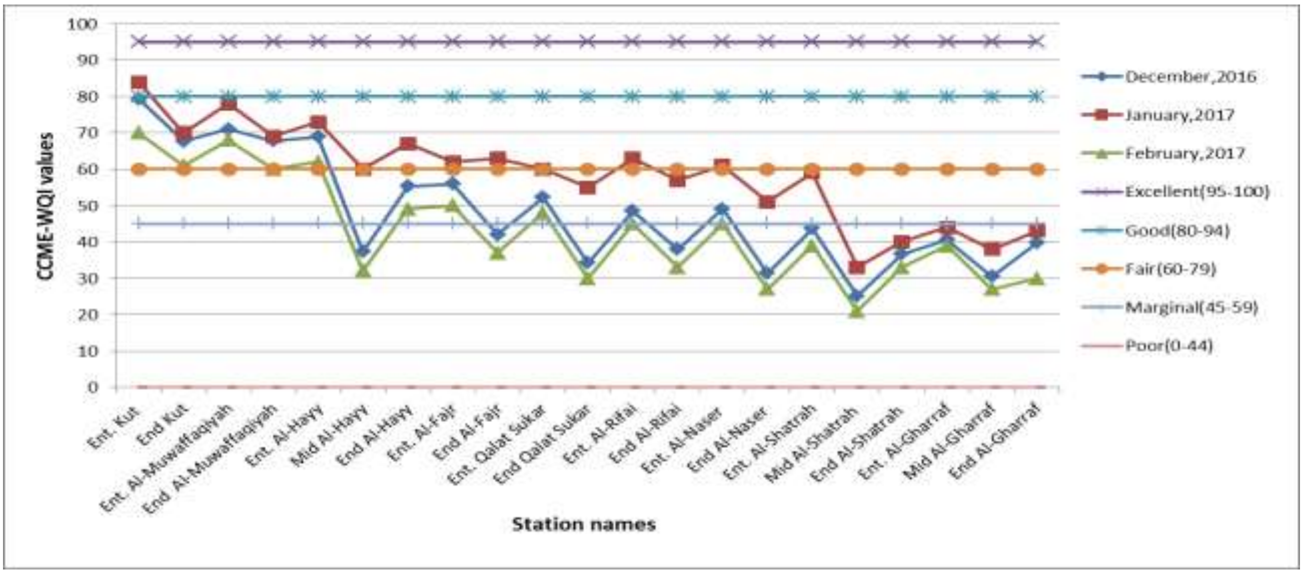

Figure 2: Water quality index (WQI) for drinking, irrigation, and living aquatic uses according to the Canadian method (CCME-WQI) for stations of Al-Gharraf River during December,2016 to February, 2017

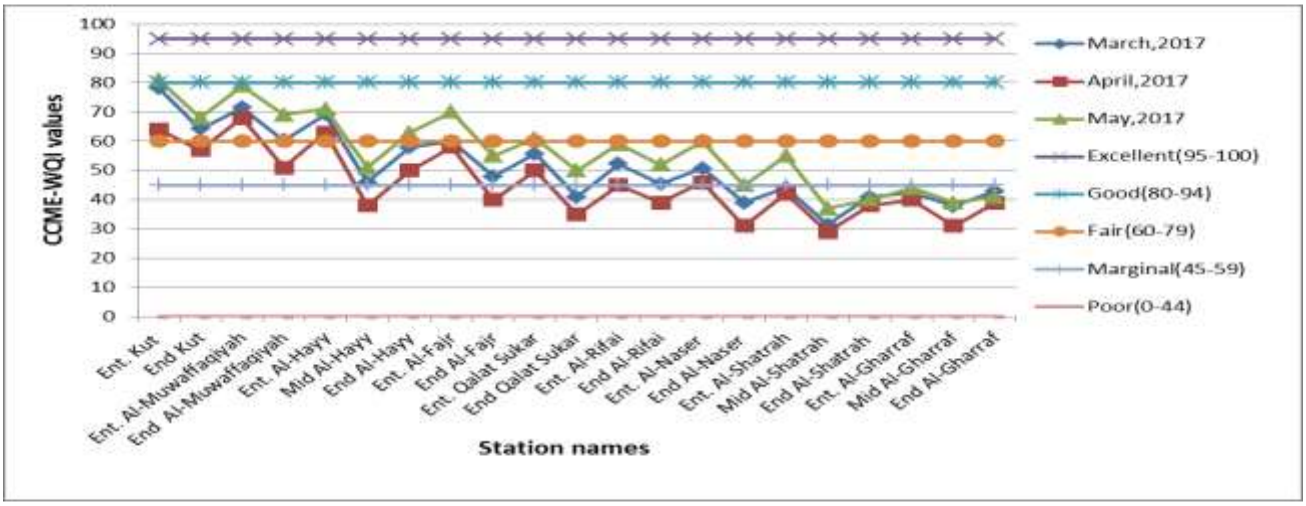

Figure 3: Water quality index (WQI) for drinking, irrigation, and living aquatic uses according to the Canadian method (CCME-WQI) for stations of Al-Gharraf River during March to May, 2017

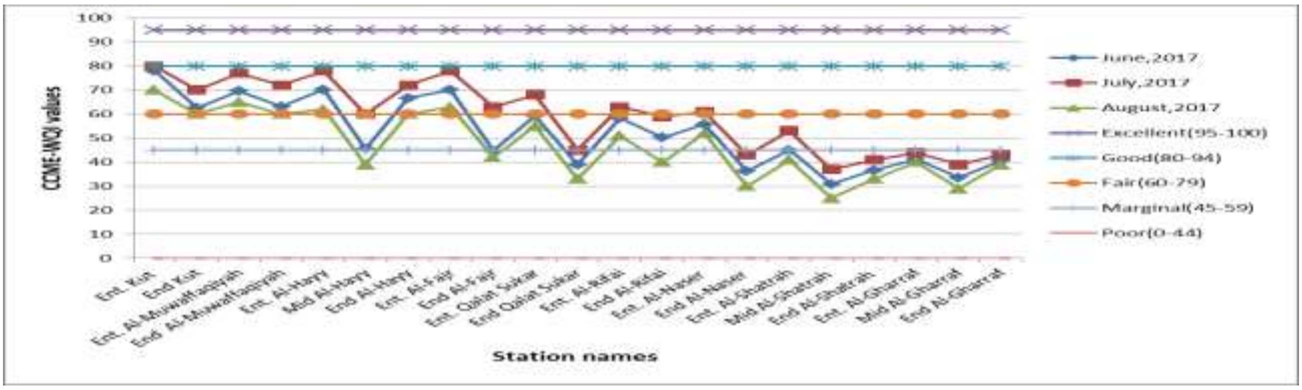

Figure 4: Water quality index (WQI) for drinking, irrigation, and living aquatic uses according to the Canadian method (CCME-WQI) for stations of Al-Gharraf River during June to August, 2017

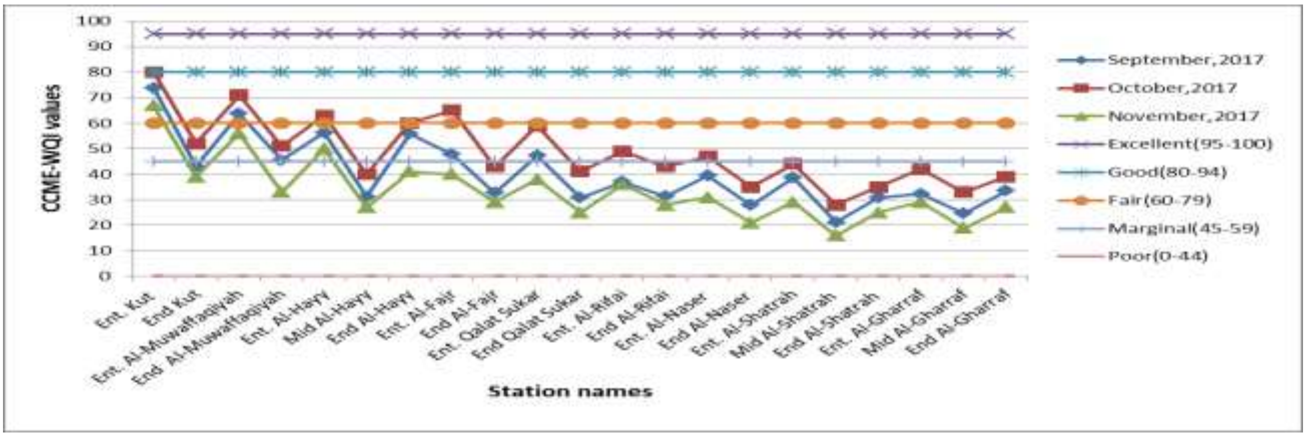

Figure 5: Water quality index (WQI) for drinking, irrigation, and living aquatic uses according to the Canadian method (CCME-WQI) for stations of Al-Gharraf River during September to November, 2017

Furthermore, in this paper, final CCME-WQI maps of the Al-Gharraf river were prepared using Geographic Information System (GIS) techniques and presented in Figure (6).

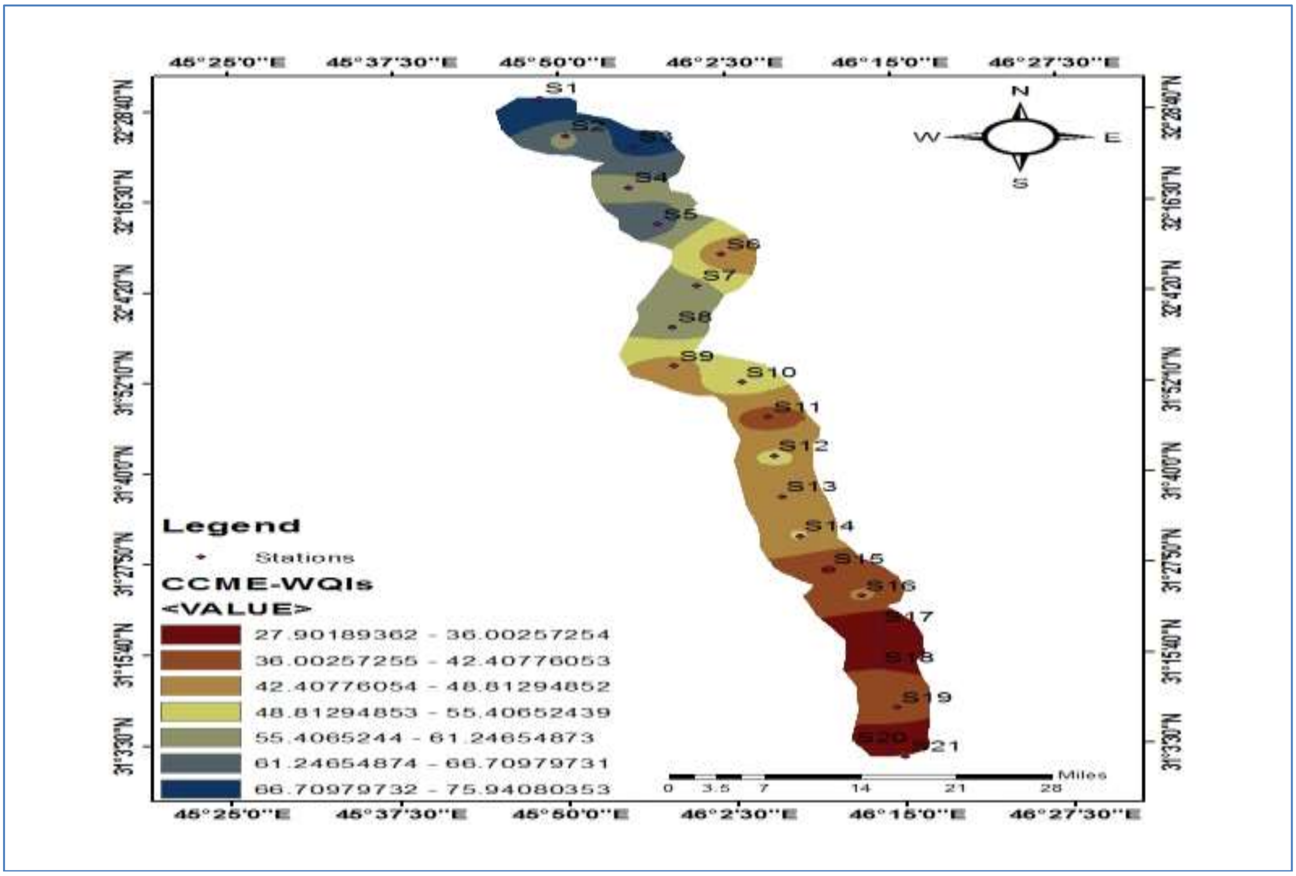

Figure 6: Water quality index (WQI) map for drinking, irrigation, and living aquatic uses according to the Canadian Council of Ministers of the Environment (CCME-WQI) for the twenty one stations of the Al-Gharraf River during 2016-2017

Conclusion and Recommendation

- In this study that CCME-WQI provided realistic results in comparison to the raw data, they are the best approach for the assessment of surface water quality in Al-Gharraf River.
- The results of the study revealed that the river is not suitable for use as drinking water without elaborate treatment, poor for aquatic life protection and fair for irrigation
- The proposed WQIs values integrated with GIS can be directly used to analyse and compare conditions across river area and to detect trends over time.
- We recommende working to find a solution to provide the river inhabitants sources of fresh water for them and their animals and working on reducing the pollution levels in the Iraqi rivers.

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