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Application of Overall Index of Pollution (OIP) for the Evaluating of the Water Quality in Al-Gharraf River southern of Iraq

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Abstract

This comprehensive study investigates has been made to assess the water quality of Al-Gharraf River, which considered the main branch of Tigris River south of Iraq using the overall Index of Pollution (OIP), depending on 9 physical, chemical, and biological important parameters of water quality were analyzed: hydrogen ion concentration (pH), turbidity (NTU), total dissolved solid (TDS), dissolved oxygen (DO), biological oxygen demand (BOD5) , total hardness (TH), sulfate (SO4), nitrate (NO3),and fecal coliform (FC), which measured monthly at twenty one stations on the river during 2016-2017. Water quality deterioration has occurred in the last ten stations, consequently, the health status of the river has changed from acceptable to heavily polluted, and the fecal coliform bacteria (FC) was the major factor that affects the quality of the wter river. In this paper concluded that the Al-Gharraf River was in class poor and the Al-Gharraf River water is relatively not suitable for direct public usage in all seasons.

Keywords: Overall Index of Pollution (OIP);Al-Gharraf River, Water Quality, WQI.

تطبيق دليل التلوث الشامل (OIP) لتقيم نوعية المياه السطحية في نهر الغراف جنوب العراق

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الخلاصة

تم أجراء دراسة شاملة لتقييم نوعية مياه نهر الغراف الذي يعتبر الفرع الرئيسي لنهر دجلة جنوب العراق باستخدام المؤشر العام للتلوث (OIP) اعتمادا على 9 من المعايير الفيزيائية ، الكيميائية والبيولوجية لنوعية المياه وهي : الرقم الهيدروجني (pH)، العكورة (NTU)، مجموع المواد الصلبة الذائبة (TDS)، الأوكسجن الذائب (DO) والمتطلب الحيوي للأكسجين (BOD_5) ، العسرة الكلية (TH)، الكبريتات (SO_4)، النترات (NO_3)، والبكتريا البرازية (FC)، هذا المعايير تم قياسها شهريا في احدى وعشرون محطة على طول النهر خلال الفترة 2016–2017. وقد حدث تدهور في نوعية المياه في المحطة العشرة الأخيرة، وبالتالي تغيرت الحالة البيئية للنهر من مقبولة إلى شديدة التلوث، وكانت بكتيريا القولون البرازية هي العامل الرئيسي الذي يؤثر على نوعية مياه النهر.

Introduction

Water quality of rivers, lakes and reservoirs can be classified into various degrees indicating the beneficial uses to which it can be put to. The degrees are based on the permissible limits of water quality variables or criteria set by various authorities [1, and 2]. Water quality indices (WQIs) are tools

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to determine conditions of water quality and, like any other tool require knowledge about principles and basic concepts of water and related issues. It is a well-known method of expressing water quality that offers a stable and reproducible unit of measure which responds to changes in the principal characteristics of water [3, and 4].

The OIP-WQI is a promising tool and efficient to study the effect of water quality changes along a the river. It is also a very useful tool for communicating the information on overall quality of water to the concerned citizens and policy makers. This could help to assess and solve local and regional surface water quality related problems [5, and 6].

The Al-Gharraf River is of essential importance for domestic, agricultural and industrial uses and its water masses are essential to satisfy requirements of Wasit and Dhi-Qar provinces. However, no published work was found to assess water quality of the Al-Gharraf River by using OIP-WQIs. Their study aimed at using nine ecological parameters in evaluating the quality of the Al-Gharraf River for public usage during four seasons.

Material and Methods

Study Area.

Tigris is one of the two main rivers feeding Iraq with essential quantities of freshwater. It splits, before passing Kut Dam into two major branches, the first branch called Al-Dijella River and the other branch Al-Gharraf River is penetrating Dhi- Qar governorate and directed towards Shatra town. The coordinates of Al-Gharraf are lies between the north latitude (32° 27′ to 31° 2′ N) and east longitude (45° 45′ to 46° 4′ E). Its basin populated by more than 2 million people using about 432000 m³/year of refined water and passing through an agricultural area of about 215019 h in the south west of Iraq within the sediment plain [7].

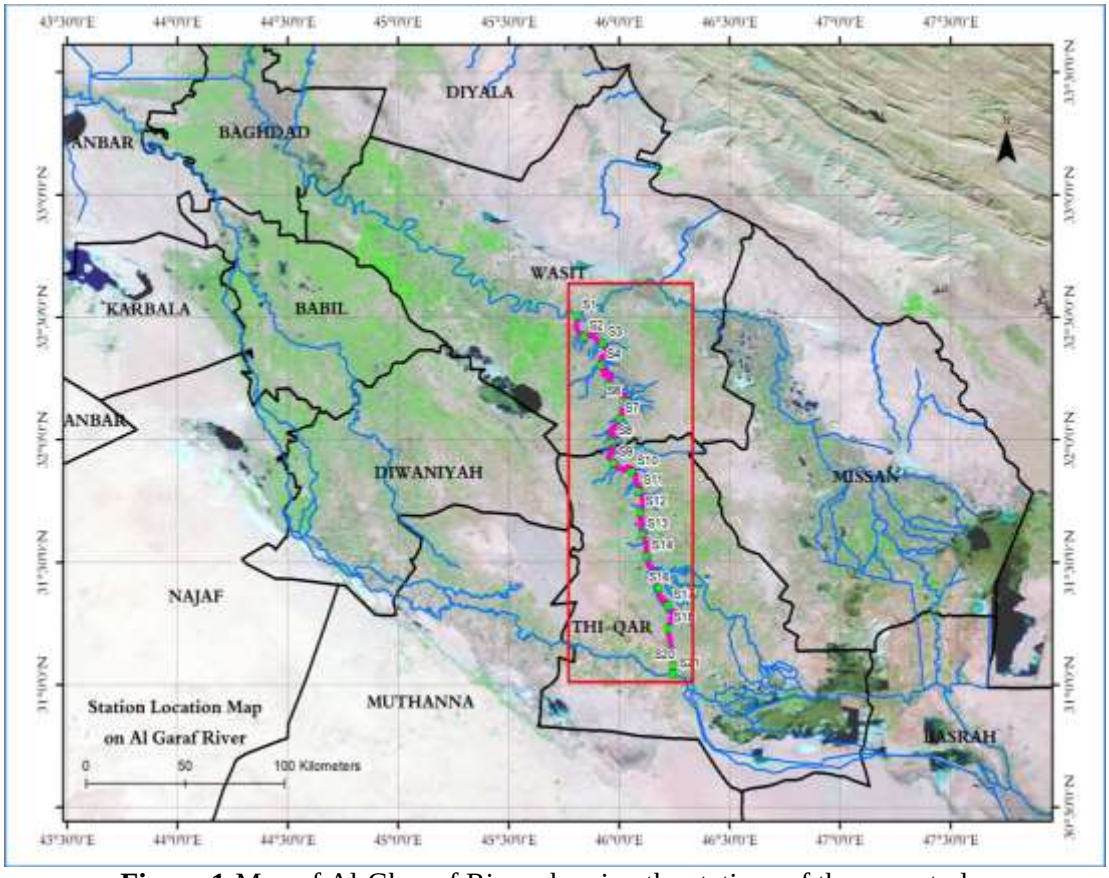

Figure 1-Map of Al-Gharraf River showing the stations of the case study.

Field Sampling and Analytical Procedures

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. Samples were preserved and analyzed according to American Public Health Association [8]. Physical and chemical parameters

including water turbidity (NTU), total dissolved solid (TDS), dissolved oxygen (DO), and pH were measured in situ using a WTW multi-meter model Multi 340i. Biological oxygen demand (BOD_5) measured by winkler method. Total hardness (TH) was measured by Na_2EDTA complex metric titration. Sulphate (SO_4) and nitrate (NO_3) concentration was determined spectrophotometric-ally method. Fecal coliform bacteria (FC) were determined by the most probable number (MPN) method.

Estimating the OIP-WQIs

The OIP-WQI was developed to use as a tool for simplifying and define the water quality data [9]. OIP creates a score to evaluate the surface water quality of Indian rivers based on measurements and classification of pH, BOD_5, dissolved oxygen, turbidity, total hardness, total dissolved solids, sulphate, nitrate and total coliforms. The model classified the river water to five categories as Excellent (pristine), Acceptable (requires disinfection), Slightly Polluted (requires filtration and disinfection), Polluted (requires special treatment and disinfection), and Heavily Polluted (cannot be used), according to Indian standards or WHO standard as presented in Table -1.

Table 1- Water quality classification according to OIP methods

Classification	Excellent	Acceptable	Slightly pollution	Polluted	Heavily polluted
Class score	C1	C2	C3	C4	C5
Parameters	Concentration range				
pH	6.5–7.5	6–6.5 AND 7.5-8	5 – 6 AND 8 - 9	4.5–5 AND 9-9.5	<4.5 AND > 9.5
Turbidity NTU	5	10	100	250	>250
TDS mg/l	10	150	300	600	1200
DO %	88-112	75 - 125	50 - 150	20 - 200	<20 AND >200
BOD_5 mg/l	1.5	3	6	12	24
TH mg/l	75	150	300	500	>500
SO_4 mg/l	150	250	400	1000	>1000
NO_3 mg/l	20	45	50	100	200
FC cfu	50	500	5000	10000	15000

Finally, the mathematical expression of this OIP method [9] is given by:

$$OIP = \sum_{i=1}^{n} \frac{Pi}{n}$$

Where:

Pi = pollution index for ith parameter can be obtained from mathematical expressions for each of the parameter concentration levels as show in Table-2.

n = number of parameters.

Table 2-Mathematical equations for value function curves.

Parameters	Values	Mathematical equations
pH	≤7	x = exp ((7 − y)/ (1.082), y < 7
	>7	x = exp ((y − 7.0)/ (1.082), y > 7
Turbidity NTU	5-10	x= (y/5)
	10-500	x = (y + 43.9)/ 34.5
TDS mg/l	≤500	x = 1
	500–1500	x = exp((y − 500)/ 721.5
DO%	<50	x=exp(-(y-98.33)/36.067)
	50-100	x=-(y-107.58)/14.667
	100≥	x=(y-79.543)/19.054
BOD_5 mg/l	<2	x = 1
	2-30	x = y/1.5
TH mg/l	75–500	x = exp(y + 42.5)/ 205.58

	>500	x = (y + 500)/125
SO_4 mg/l	≤150	x = 1
	150–2000	x =((y/50) + (0.375)/ 2.5121
NO_3 mg/l	≤20	x = 1
	20–50	x = exp ((y − 145.16)/ 76.28)
FC cfu	50–5000	x = (y/50)* 0.3010
	5000–15000	x = ((y/50) − (50)/16.071
	>15000	x=(y/15000)+6

Table 3-Summary of the water quality data of Al-Gharraf River over one year (December, 2016, to November, 2017

Seasons \ Parameters		Turb. NTU	pH	TDS mg/l	DO %	BOD_5 mg/l	TH mg/l	SO_4 mg/l	NO_3 mg/l	FC CFU
Winter	**Min**	27	6.97	808.10	50	8.11	307.6	234.33	5.53	346
	Max	87	7.35	4000.8	83	10.4	536	371.43	13.31	112100
	Mean	55.47	7.11	1153.9	66.65	9.39	418.1	312.23	9.41	34937.1
Spring	**Min**	17.33	6.99	584.53	50	0.94	253.5	148.83	5.6766	223.33
	Max	88.1	8.13	871.1	75	7.17	508.6	353.26	15.52	61000
	Mean	44.73	7.51	746.3	61.52	4.47	376.8	241.03	9.293	15631.59
Summer	**Min**	13.83	7.177	464.42	48	2.066	243.3	121.6	3.26	200
	Max	58.16	8.203	672.21	70	8.953	416.3	319.66	12.07	26700
	Mean	34.94	7.8	556.66	59.23	5.46	333.5	224.26	7.41	10365.22
Autumn	**Min**	26	6.517	788.48	50	2.23	321.3	253.66	7.51	236.6667
	Max	156	7.217	1045.1	71	8.35	667.4	457	27.83	63833.33
	Mean	76.92	7.002	912.4	61.3	5.23	481.5	351.60	14.88	31625.07

Result and Discussion

The calculated sub-index values for each parameters, and OIP-WQI and categorization are listed in Tabular [4, 5,6 and 7]. Four different seasons data were used to understand the seasonal variations in water quality of the Al-Gharraf River. All the OIP were computed for all the stations of the river. The major important parameters in this index model were pH, TDS, DO, BOD_5, SO_4, NO_3, turbidity, hardness, and fecal coliform.

Table 4-The calculate OIP-WQI of AL-Gharraf River during Winter (December,2016, January, February,2017).

ID	Name of Station	Individual parameter indices									OIP-WQI values
		Turb. NTU	pH	TDS mg/l	DO %	BOD_5 mg/l	TH mg/l	SO_4 mg/l	NO_3 mg/l	FC CFU	
S1	**Ent. Kut**	2.055	1.37	1.539	1.744	1	4.341	2.084	1	2.107	1.915
S2	**End Kut**	2.693	1.15	1.708	2.494	1.367	2.115	2.82	1	14.45	3.31
S3	**Ent. Al-Muwaffaqiyah**	2.171	1.36	1.568	1.676	1	5.372	2.365	1	5.719	2.47
S4	**End Al-Muwaffaqiyah**	2.896	1.11	1.722	2.017	1.727	5.461	2.845	1	19.26	4.226
S5	**Ent. Al-Hayy**	2.287	1.3	1.58	1.676	1	1.065	2.474	1	9.15	2.392
S6	**Mid Al-Hayy**	3.388	1.07	1.885	3.244	2.667	8.176	3.031	1	47.69	8.016
S7	**End Al-Hayy**	2.49	1.27	1.614	2.221	1.58	9.034	2.522	1	12.82	3.839

S8	**Ent. Al-Fajr**	2.403	1.3	1.589	2.63	1.353	4.297	2.353	1	9.334	2.917
S9	**End Al-Fajr**	3.417	1.12	1.829	3.039	2.633	4.383	2.824	1	17.87	4.235
S10	**Ent. Qalat Sukar**	2.78	1.24	1.62	1.949	1.613	5.667	2.609	1	17.2	3.964
S11	**End Qalat Sukar**	3.446	1.05	1.899	3.38	3.167	8.184	3.019	1	47.81	8.106
S12	**Ent. Al-Rifai**	2.751	1.23	1.728	2.767	2.14	1.689	2.673	1	17.37	3.704
S13	**End Al-Rifai**	3.186	1.09	1.877	3.039	2.653	8.152	2.927	1	19.13	4.784
S14	**Ent. Al-Naser**	2.925	1.09	1.756	3.244	3.033	1.48	2.928	1	19.28	4.081
S15	**End Al-Naser**	3.533	1.05	1.909	3.517	3.053	8.36	3.058	1	50.22	8.411
S16	**Ent. Al-Shatrah**	2.809	1.18	1.75	2.699	1.953	5.901	2.707	1	17.2	4.133
S17	**Mid Al-Shatrah**	4.084	1.01	0.501	3.926	3.967	8.664	3.241	1	63.54	9.992
S18	**End Al-Shatrah**	3.591	1.09	1.811	3.312	2.853	8.624	2.968	1	18.75	4.888
S19	**Ent. Al-Gharraf**	3.388	1.13	1.789	3.108	2.753	2.38	2.713	1	17.99	4.027
S20	**Mid Al-Gharraf**	3.852	1.02	1.929	3.585	3.84	8.4208	3.12	1	53.21	8.886
S21	**End Al-Gharraf**	3.475	1.11	1.834	3.312	2.76	5.203	2.75	1	18.53	4.442

Table 5-The calculate OIP-WQI of AL-Gharraf River during Spring(March, April, May,2017).

ID	**Name of Station**	**Individual parameter indices**									**OIP-WQI values**
		Turb. NTU	**pH**	**TDS mg/l**	**DO %**	**BOD_5 mg/l**	**TH mg/l**	**SO_4 mg/l**	**NO_3 mg/l**	**FC CFU**	
S1	**Ent. Kut**	1.852	2.895	1.141	2.221	1	1.849	1.419	1	1.565	1.66
S2	**End Kut**	2.345	1.807	1.327	2.767	2.153	3.759	2.187	1	16.53	3.764
S3	**Ent. Al-Muwaffaqiyah**	1s.983	2.79	1.193	2.358	1.453	3.666	1.614	1	5.9	2.44
S4	**End Al-Muwaffaqiyah**	2.803	1.558	1.52	2.903	2.373	2.199	2.285	1	19.75	4.044
S5	**Ent. Al-Hayy**	2.13	2.738	1.211	2.63	1.54	6.612	1.708	1	6.02	2.843
S6	**Mid Al-Hayy**	3.33	1.725	1.482	3.38	4.727	5.084	2.597	1	35.67	6.555
S7	**End Al-Hayy**	3.339	1.295	1.617	3.244	3.82	1.039	2.402	1	17.03	3.866
S8	**Ent. Al-Fajr**	2.171	2.688	1.314	2.699	1.747	5.428	1.608	1	14.45	3.678
S9	**End Al-Fajr**	3.446	1.17	1.65	3.585	4.173	1.855	2.418	1	29.33	5.403
S10	**Ent. Qalat Sukar**	3.099	1.382	1.591	3.039	3.833	6.388	2.339	1	10.58	3.694
S11	**End Qalat Sukar**	2.664	2	1.596	3.449	3.213	9.482	2.45	1	43.11	7.663
S12	**Ent. Al-Rifai**	2.322	2.615	1.327	3.176	2.593	1.056	1.722	1	7.591	2.60
S13	**End Al-Rifai**	2.678	2.276	1.528	3.449	4.047	2.9	2.378	1	34.62	6.097
S14	**Ent. Al-Naser**	2.417	2.451	1.357	3.244	2.92	5.901	1.976	1	8.338	3.289
S15	**End Al-Naser**	2.658	2.474	1.36	2.835	2.74	4.08	1.884	1	52.33	7.929
S16	**Ent. Al-Shatrah**	3.293	1.128	1.63	3.585	4.193	1.01	2.585	1	17.89	4.035
S17	**Mid Al-Shatrah**	4.122	1.047	1.708	3.926	4.9	8.214	3.038	1	58.67	9.625
S18	**End Al-Shatrah**	3.258	1.709	1.526	3.449	4.48	4.304	2.364	1	27.33	5.491
S19	**Ent. Al-Gharraf**	3.417	1.307	1.58	3.517	4.56	2.537	2.617	1	17.6	4.237
S20	**Mid Al-Gharraf**	2.301	2.543	1.335	2.903	1.967	7.891	1.781	1	55.27	8.555
S21	**End Al-Gharraf**	3.748	1.138	1.65	3.721	4.767	3.303	2.729	1	18.07	4.458

Table 6-The calculate OIP-WQI of AL-Gharraf River during Summer (June, July, August,2017).

ID	Name of Station	Individual parameter indices									OIP-WQI value
		Turb. NTU	pH	TDS mg/l	DO %	BOD_5 mg/l	TH mg/l	SO_4 mg/l	NO_3 mg/l	FC CFU	
S1	**Ent. Kut**	1.751	3.17	1	2.562	1.713	8.505	1	1	1.324	2.448
S2	**End Kut**	1.82	3	1.002	2.562	1.447	8.288	1.427	1	15.88	4.048
S3	**Ent. Al-Muwaffaqiyah**	2.055	2.79	1.013	2.767	2.153	3.666	1.699	1	5.71	2.539
S4	**End Al-Muwaffaqiyah**	2.461	2.64	1.098	3.108	2.9	1.171	2.211	1	23.84	4.492
S5	**Ent. Al-Hayy**	2.113	2.84	1.077	2.835	3.293	1.907	1.819	1	7.826	2.746
S6	**Mid Al-Hayy**	3.214	2.08	1.18	3.721	5.3	1.32	2.394	1	40.69	6.766
S7	**End Al-Hayy**	2.983	2.21	1.176	3.449	5.127	3.007	2.308	1	10.58	3.538
S8	**Ent. Al-Fajr**	2.113	3	1.01	2.903	1.987	1.214	1.708	1	7.826	2.529
S9	**End Al-Fajr**	2.968	2.54	1.125	3.176	4.9	1.646	2.315	1	32.93	5.845
S10	**Ent. Qalat Sukar**	2.49	2.82	1.04	2.971	3.207	1.769	1.781	1	5.6	2.519
S11	**End Qalat Sukar**	2.586	2.64	1.136	3.517	4.34	8.988	2.434	1	45.81	8.05
S12	**Ent. Al-Rifai**	2.417	2.74	1.088	3.244	3.387	4.187	1.598	1	3.36	2.558
S13	**End Al-Rifai**	2.606	2.5	1.116	3.449	3.48	3.062	2.02	1	39.55	6.531
S14	**Ent. Al-Naser**	2.461	2.74	1.103	3.312	4.153	2.376	1.964	1	16.97	4.008
S15	**End Al-Naser**	2.875	2.43	1.123	3.926	4.08	5.623	2.275	1	52.11	8.382
S16	**Ent. Al-Shatrah**	2.223	2.84	1.025	3.039	2.027	8.857	1.781	1	35.24	6.448
S17	**Mid Al-Shatrah**	3.577	1.38	1.319	4.037	6.047	8.306	2.872	1	61.97	10.06
S18	**End Al-Shatrah**	2.823	1.95	1.189	3.926	5.373	2.38	2.485	1	47.49	7.623
S19	**Ent. Al-Gharraf**	2.948	2.28	1.148	3.858	4.553	2.228	2.393	1	37.33	6.115
S20	**Mid Al-Gharraf**	3.125	1.62	1.202	7.335	5.713	5.316	2.691	1	58.61	9.623
S21	**End Al-Gharraf**	2.954	2.06	1.153	3.517	4.16	6.056	2.49	1	37.32	6.745

Table 7-The calculate OIP-WQI of AL-Gharraf River during Autumn (September, October, November, 2017).

ID	Name of Station	Individual parameter indices									OIP-WQI value
		Turb. NTU	pH	TDS mg/l	DO %	BOD_5 mg/l	TH mg/l	SO_4 mg/l	NO_3 mg/l	FC CFU	
S1	**Ent. Kut**	2.171	1.272	1.525	2.494	1.687	6.377	2.299	1	4.107	2.548
S2	**End Kut**	2.8957	1.107	1.867	3.108	2.473	5.31	3.22	1	15.38	4.04
S3	**Ent. Al-Muwaffaqiyah**	2.258	1.295	1.573	2.562	1.967	3.015	2.307	1	10.58	2.951
S4	**End Al-Muwaffaqiyah**	3.2435	1.087	1.885	3.039	2.74	8.16	3.31	1	16.05	4.502
S5	**Ent. Al-Hayy**	2.3159	1.272	1.626	2.63	1.987	2.714	2.34	1	11.2	3.009
S6	**Mid Al-Hayy**	4.0841	1.019	1.95	3.244	4.847	8.712	3.469	1	85.25	12.62
S7	**End Al-Hayy**	2.7507	1.214	1.678	3.039	2.593	2.938	2.496	1	23.02	4.526
S8	**Ent. Al-Fajr**	2.5478	1.283	1.623	2.835	2.427	1.852	2.45	1	19.04	3.895
S9	**End Al-Fajr**	3.9391	1.038	1.91	2.971	4.74	8.5232	3.424	1	64.09	10.18
S10	**Ent. Qalat Sukar**	2.9826	1.149	1.668	2.767	2.7	2.611	2.817	1	20.53	4.248
S11	**End Qalat Sukar**	5.2435	1.019	1.981	3.312	5.213	9.0008	3.541	0.195	93.96	13.72
S12	**Ent. Al-Rifai**	3.2435	1.181	1.674	3.108	3.407	1.24	2.955	1	36.71	6.058
S13	**End Al-Rifai**	3.9971	1.057	1.792	3.244	4.487	8.312	3.406	1	70.31	10.85

S14	**Ent. Al-Naser**	3.2145	1.159	1.739	3.039	3.233	4.141	3.143	1	31.24	5.767
S15	**End Al-Naser**	4.8957	1.077	1.965	3.38	5.313	8.96	3.588	0.199	97.69	14.12
S16	**Ent. Al-Shatrah**	3.8232	1.149	1.773	3.244	3.527	1.983	3.136	1	37.33	6.33
S17	**Mid Al-Shatrah**	6.3739	1.558	2.165	3.926	5.833	9.512	3.883	0.23	117.6	16.79
S18	**End Al-Shatrah**	5.0116	1.128	1.823	3.653	4.193	8.3024	3.206	0.195	90.22	13.08
S19	**Ent. Al-Gharraf**	4.7507	1.181	1.758	3.312	3.547	8.1256	3.019	1	44.54	7.917
S20	**Mid Al-Gharraf**	5.5623	1.488	2.029	3.721	5.307	8.8016	3.671	0.214	114.9	16.18
S21	**End Al-Gharraf**	4.9536	1.149	1.86	3.517	4.053	8.228	3.187	0.196	108	15.02

It was noticed, from tables above, that the OIP-WQI for the first ten stations of the Al-Gharraf River (Entrance Kut, End Kut, Entrance Al-Muwaffaqiyah, End Al-Muwaffaqiyh, Entrance Al-Hayy, End Al-Hayy, Entrance Fajir, End Fajer) were fluctuated in their classifications between Acceptable, (1 – 2) and polluted , (4 – 8), except in End Fajer station during October, (OIP = 12) and November (OIP = 9) which was classified as heavily polluted, (8–16). The reason for this fluctuations in the water quality index at these stations was the fluctuation in fecal coliform bacteria (more than 59000 CFU), total hardness (more than 560 mg/l), sulphate (more than 420 mg/l), and nitrate (more than 19.5 mg/l), as a result of direct domestic and industrial effluents.

Also, the water quality at Mid Al-Hayy, End Qalat Suker, End Rifai and End Naser stations during year 2017 was polluted, OIP (4 – 8, less than 11), during January, March, April, June, and July while it was slightly polluted, OIP (2 – 4, more than 3), during May, and October, and heavily polluted, OIP (8 – 16, less than 14), during December,2016, February,August, September, and November. According to OIP-WQI values, river water at these stations, clearly appear the unsuitability of water for human consumption. The comparatively high level of turbidity (> 130 NTU), total dissolved solid (> 980 mg/l), hardness (>620 mg/l), and sulfates (>430 mg/l), indicates the water is not suitable for domestic use without elaborate treatment. The Al-Gharraf River can be used for boating or other recreational activities because of the good dissolved oxygen concentration (>5 mg/l).

On the other hand, the water quality at stations of Entrance Qalat Suker, Entrance Rifai, and Entrance Naser, improved during May and July, to be acceptable, (OIP =2). The main reason for this improvement was decreasing of the values of total hardness (320 mg/l), total dissolved solids (528 mg/l), sulfates (205 mg/l), nitrate (6.5 mg/l) and turbidity (42 NTU).

The water quality for stations Mid Al-Shatrah, End Shatrah and Mid Al-Gharraf was classified as heavily polluted (OIP, more than 9) during year 2016-2017, except for End Al-Shatrah during December, 2016 (OIP=7), May,2017 (OIP= 5) and June,2017 (OIP= 7.5), where it was classified as polluted. The increase in OIP-WQI value in the three stations is a reflection of different types of pollutants entering its basin due to natural reasons and various anthropogenic activities such as discharge of untreated domestic sewage and runoff water from agricultural lands near the banks of the Al-Gharraf River.

Furthermore, no studies has been done on OIP-WQI related to Iraqi Rivers, but this the study is coincided with findings of Fulazzaky [10],found the OIP-WQI between 2-15 in Citarum River in Malaysia, which was classified as Acceptable to heavily polluted, Akkoyunlu and Akiner [11], found the OIP-WQI value between 6-17 in Sapanca Lake in Turkey, which was classified as polluted to heavily polluted, Rangeti et al., [12], found the OIP-WQ between 11-18 in Yamuna River in Indi, which was classified as heavily polluted, and Dede et al., [13],found OIP-WQI value between 3-8 in Kirmir River in Turkey, which was classified as Slightly polluted to polluted.

Figures-(2, 3, 4, 5 and 6): display the water quality index (WQI) for public uses according to Overall Index Pollution (OIP-WQI) for the twenty one stations along the Al-Gharraf River during the period from December, 2016 to November, 2017.

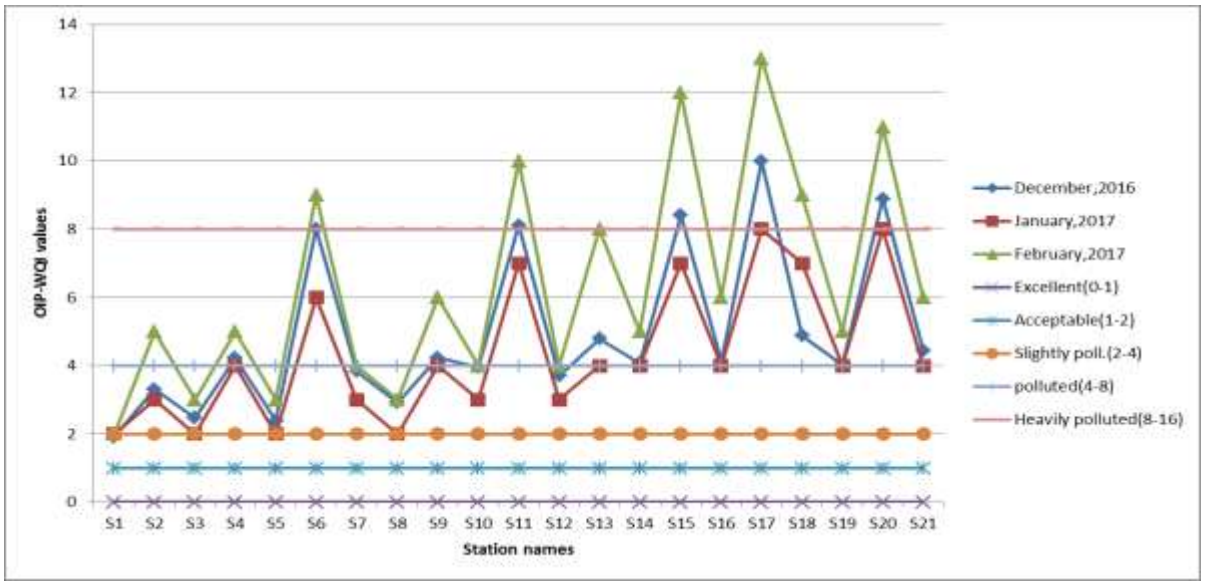

Figure 2-OIP-WQI at twenty one sampling stations on Al-Gharraf River during Winter.

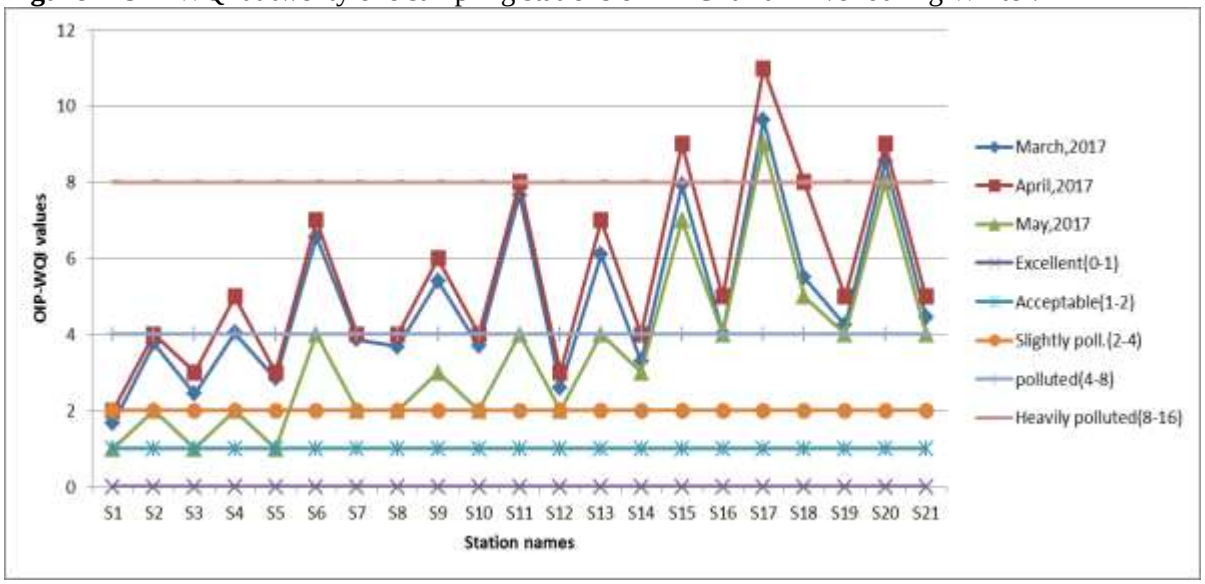

Figure 3- OIP-WQI at twenty one sampling stations on Al-Gharraf River during Sprin
g.

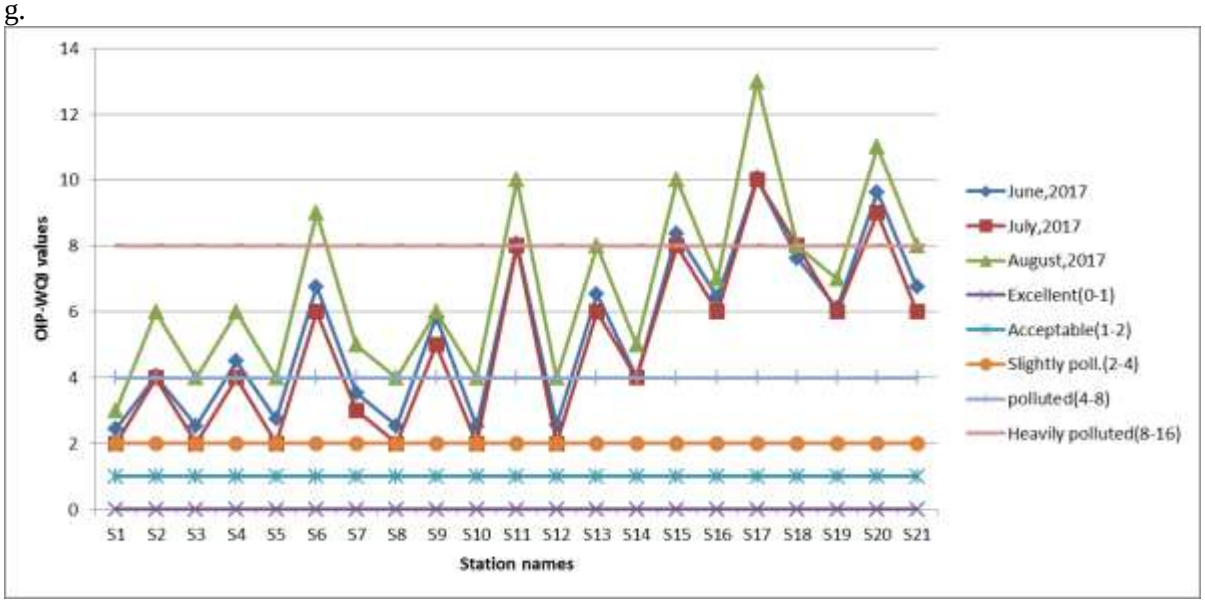

Figure 4- OIP-WQI at twenty one sampling stations on Al-Gharraf River during Summer.

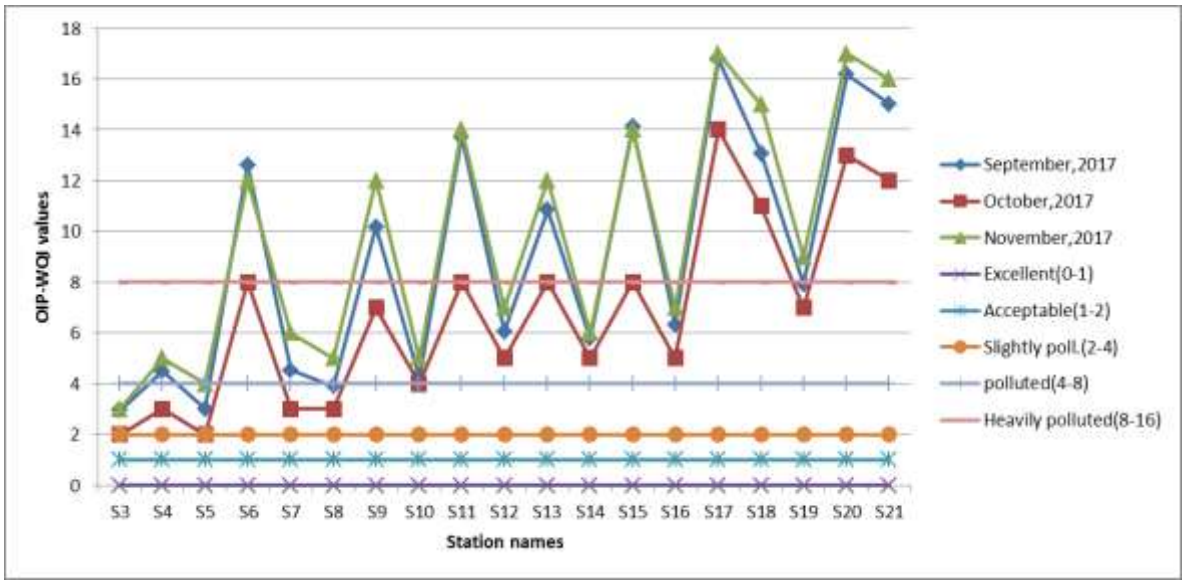

Figure 5- OIP-WQI at twenty one sampling stations on Al-Gharraf River during Autumn.

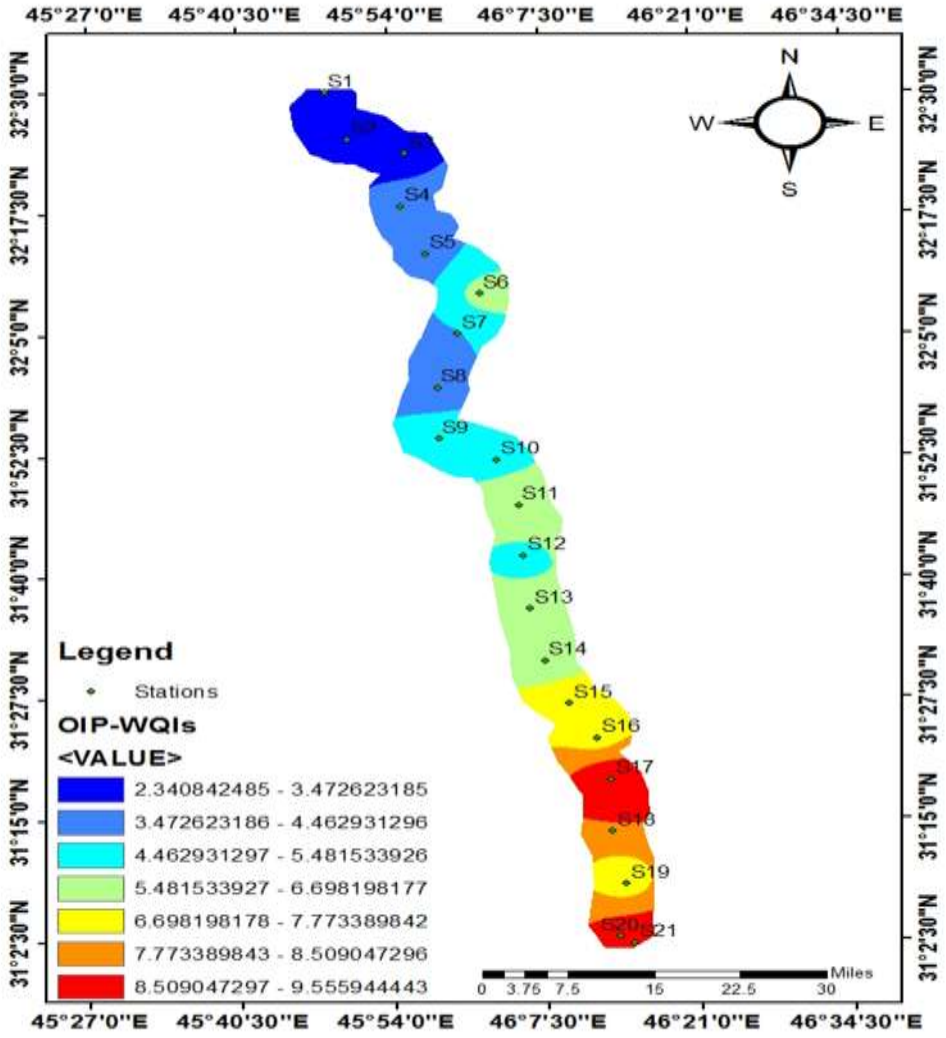

Figure 6-Spatial distribution of OIP-WQI of the Al-Gharraf River during 2016-2017.

Conclusion

The results of the study revealed that the Al-Gharraf river water can be used for public consumption after the elaborate treatment. On other hand, the shortage of water in the river and discharge domestic sewage and runoff water from agricultural have negatively impacted on the quality of water. The study showed that application of OIP is a useful tool in assessing the overall quality of river. Therefore, water quality evaluating using OIP tool could help to assess and solve local and regional water quality related problems along river.

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