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STUDY OF THE WATER QUALITY INDEX (WQI) IN NAJAF GOVERNORATE, AL-KUFA AND AL-ABASSIYA RIVERS AS A CASE STUDY

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ABSTRACT

Water Quality Index (WQI) is a practical and distinctive way to gauge the quality of water. It is frequently used to analyse water quality and determine its suitability for various uses by stating the status of the water in plain terms (good or terrible, usable or unusable, etc.). The purpose of the study is to evaluate the water quality index (WQI) in the Euphrates River (Al-kufa and Al-Abassia rivers). The site was monitored and evaluated, then data collection over a two-year from 2022 to 2023 on two station sampling sites, S1 and S2 within the river. Twelve physio-chemical parameters were examined in accordance with the Canadian Council of Ministers of the Environment Water Quality Index methodology (CCME WQI) in order to determine the WQI. These parameters (pH, turbidity (TUR) dissolved oxygen (DO), total dissolved salts (TDS), sulfate ion (SO4-2), Chloride ion (Cl-), nitrate ion (NO3-), Phosphate ion (PO4-3), total hardness (TH), alkalinity (Alk), calcium (Ca2+), and magnesium (Mg+2). All data were within the World Health Organization's allowed limits, with the exception of SO4-2, TUR, and TDS, which all exceeded the WHO's allowable limits at the two stations (S1 and S2) over the study period, as well as chloride (Cl-) concentrations during specific months. At the S1 station, the highest values for the parameters (SO4-2, TDS, and TUR) were (466, 1100, 19.8) and (414, 1218, 20.15) in 2022 and 2023, respectively. At the S2 station, the highest values for the parameters (SO4-2, TDS, and TUR) were (427, 1043, 16.45) and (397, 1151.5, 22.55) in 2022 and 2023, respectively. during the study period the WQI displayed clear fluctuation, with good, fair, and marginal quality, The highest values were (79.12 and 65.81) at the S1 station in 2022 and 2023 and (86.1 and 79.33) at the S2 station in 2022 and 2023, respectively. According to the current study, human activity, agricultural runoff, and the discharge of improperly treated wastewater have all contributed to the pollution of the Euphrates River, rendering it unfit for human consumption unless properly treated.

KEYWORDS

Water quality index (WQI), Canadian Council, Total hardness, Agricultural runoff**.**

1. INTRODUCTION

Access to a sufficient supply of clean water that is suitable, safe, and readily available, as it is essential for survival. Enhancing the availability of potable water can significantly affect people's health. To guarantee that potable water is as safe as possible, every effort should be made (WHO, 2022).

The quality of surface or groundwater influence by natural and human factors, acting either independently or in combination. Natural processes such as the weathering of bedrock minerals, atmospheric contributes including evapotranspiration, wind-driven dust and salt deposition, the natural leaching of organic matter and nutrients from soil, hydrological factors that cause runoff, and biological processes in the aquatic environment that may alter the physical and chemical composition of water would be the only factors influencing water quality in the absence of human intervention. As a result, natural water may contain both dissolved and non-dissolved particles. Because they support the health and vitality of organisms that depend on this ecosystem service, minerals and dissolved salts are crucial elements of high-quality water (Stark, 2000).

Several research and studies have been conducted to evaluate the quality of water for Euphrates River's. Specifically, the water quality of the Euphrates Stream in Najaf Governorate was evaluated using the Bhargava WQI method and the GIS-ANN coordination model. Using water quality standards, evaluation methods and the Nemerow pollution index (NPI), they tested and evaluated the river's quality (Al-Khuzaie et al.,2025; Noori and Mohammed, 2017; Al-Sulaiman et al.,2025).

Water quality management requires the collection and analysis of massive datasets, which can be challenging to analyze and synthesize. A variety of tools for evaluating water quality data have been created, including the Water Quality Index (WQI) model. WQI models use aggregation functions to analyze huge temporally and geographically changing water quality datasets and provide a single value, known as the water quality index, that shows the quality of the waterbody. They are appealing to water management/supply agencies because they are simple to use and translate complex water quality datasets into a single, understandable value metric (Uddin and Olbert, 2021).

This study intends to support communities to manage water resources efficiently, contribute to future water management, and determine the water quality index (WQI) of the Al-Kufa and Al-Abassiya Rivers (branch of the Euphrates River) based on physicochemical criteria.

The WQI will be compared to World Health Organization's (WHO) drinking water standards to assess the suitability of the rivers for human consumption.

2. STUDY AREA AND DATA COLLECTION

Najaf Governorate is one of the governorates of Iraq, located around 100 miles south of the capital city, Baghdad. flat terrain spans from the Euphrates River in the northeast to the Saudi Arabian border in the southwest. The region is sparsely populated, save around the river, in 2014, the governorate covered 28,824 square kilometers and had an estimated population of 1,389,500.

Najaf governorate experiences a typical dry desert environment, summer months are hot and dry, with negligible precipitation during the winter. The Euphrates River, western Asia's longest river, flows through Najaf city. The river starts in Turkey, flows through Syria, enters Iraq from the west, and discharges into Shatt Al-Arab (the confluence of the Tigris and Euphrates rivers). Najaf governorate rapid population growth and industrialization have led to a significant increase in freshwater demand. Pollution in the Euphrates River is caused by uncontrolled discharges from home, industrial, and agricultural sources throughout its downstream reach. Most industrial institutions and companies are located on both sides of the river banks so the drainage of sewage and wastes from institutions and factories directly into the Euphrates River poses an ecological hazard to the Najaf governorate ecology. River water quality monitoring is required for several objectives.

This research relied on data from the Ministry of Water Resources in Iraq for 2022 and 2023, included monthly average values for 12 water parameters (pH, turbidity (TUR) dissolved oxygen (DO), total dissolved salts (TDS), sulfate ion (SO_4^{-2}), Chloride ion (Cl^-), nitrate ion (NO_3^-), Phosphate ion (PO_4^{-3}), total hardness (TH), alkalinity (Alk), calcium (Ca^{+2}), and magnesium (Mg^{2+}).

Samples were collected from two sites along the Euphrates River near Al-Kufa Water Project and Al-Abassiya Water Project to assess the overall water quality in the research area. The investigation was focus on stations along a stretch of the Euphrates River in Najaf governorate. Fig. 1 displays the locations of water quality monitoring stations (S1) and (S2) at Al-Kufa river and Al-Abassiya river respectively along the Euphrates River in Najaf city. Tables 1 to 4 show the monthly average values for 12 water parameters for S1 and S2 stations, respectively.

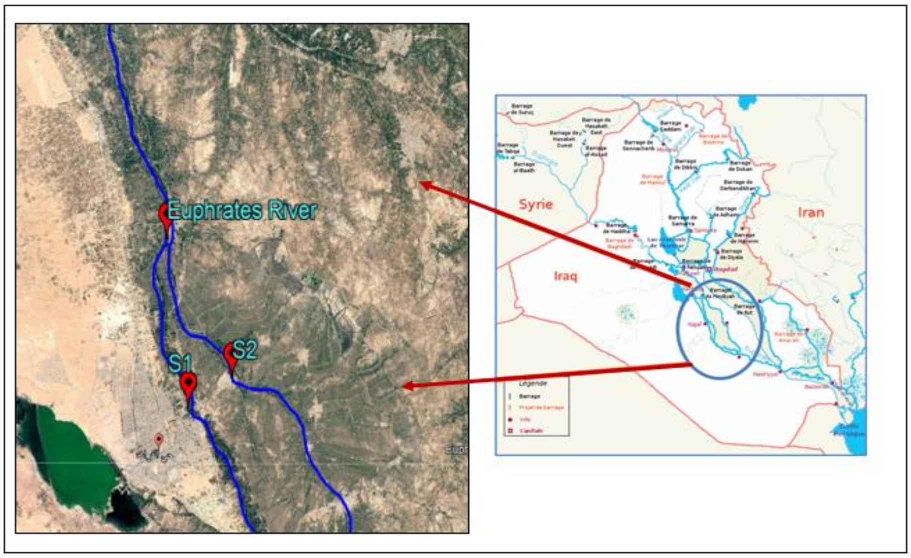

Fig. 1. Study area and Samples locations.

Table 1. Parameter values at S1 for the year 2022.

Month	pH	DO	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	TH	SO_4^{2-}	Cl^-	TDS	Alk	TUR
January	7.3	13.8	0.15	5.1	143.2	29.75	480	373	165	937	80	9.77
February	7.28	14.25	0.13	5.75	144.4	33.18	497	392	165	1021	115	5.34
March	7.11	14.4	0.16	5.8	135.4	34.6	480	393	180	1059	117	15.6
April	6.97	12.85	0.1	3.14	139.2	29	467	384	167	1031	110	12.3
May	6.75	13.15	0.1	3.91	152	31.71	510	383.5	177	1100	105	9.1
June	7	12	0.1	4	146.8	34.86	510	399.5	173	1062	106	7.6
July	7.26	10.65	0.1	3.85	110.8	33.66	415	391	182.5	1075	109	7.55
August	7.35	10.15	0.1	5.24	107.2	29.76	390	466	181	1070.5	110	7
September	7.06	11.75	0.07	3.42	111.2	28.3	390	417	182	1054	94	14.35
October	6.91	12.4	0.12	4.41	133.2	28.1	448	419	172	1058	108	16.5
November	6.8	13.05	0.12	4.2	118.8	29.76	419	377	165	991	113	19.8
December	7.1	11.15	0.15	5.95	124.88	34.38	453	367	165	987	118	16.55
Objectives	6.5-8.5	>2	3	10	200	50	750	250	200	750	200	5

*Bolded values do not fulfill the goal.

Table 2. Parameter values at S1 for the year 2023

Month	pH	DO	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	TH	SO_4^{2-}	Cl^-	TDS	Alk	TUR
January	7.09	14	0.22	9.63	144	47.09	553	379	245	1218	135	7.54
February	7	15.7	0.16	7.37	140	43.92	530	393	184.5	1177.5	140	10.27
March	7.36	14.25	0.06	7.3	110	46.09	464	372	207.5	1091.5	105	13.11
April	6.9	12.3	0.03	6.24	121.2	43.18	480	414	222.5	1191.5	114	5.16
May	7.21	15.9	0.06	6.53	116.8	29.03	411	380	180.5	1014.5	128	5.16
June	7.18	13.25	0.07	5.89	138.4	28.05	461	335.5	182.5	1059.5	115	8.64
July	7.04	14.45	0.03	4.02	131.6	29.76	451	384	170	1039	105	12.27
August	7.04	12.1	0.045	3.91	126.8	21.71	406	347	159	990	102	19.3
September	6.62	9.1	0.44	5.88	127.6	26.1	426	360.5	168.5	985	103	13.8
October	7.32	14.3	0.045	3.29	136	33.91	479	395	175	1050	99	14.5
November	7.36	13.3	0.03	5.02	149.6	30.49	498	381	165.5	1039	104	20.15
December	7.34	15.05	0.03	6.71	136	31.02	473	359	173.5	1031.5	110	17.4
Objectives	6.5-8.5	>2	3	10	200	50	750	250	200	750	200	5

*Bolded values do not fulfill the goal.

Table 3. The value of Parameters at S2 for the year 2022

Month	pH	DO	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	TH	SO_4^{2-}	Cl^-	TDS	Alk	TUR
January	7.35	11.3	0.09	5.18	136	19	418	378	167	905	94	4.1
February	7.25	14.45	0.07	4.69	139	34.1	488	378	161	970	111	2.54
March	7.23	15.25	0.1	4.54	120	29.9	423	388	165	960	110	4
April	7.29	14.7	0.07	3.4	131	29	448	380	164	980	109	5
May	7	16.65	0.09	3.42	138	30.4	470	362.5	165	1019	105	6.1
June	6.97	10.4	0.07	3.54	145	34.6	508	370	179	1030	105	11.6
July	7.26	11.35	0.1	3.58	107	32.2	400	378	180	1043	100	9.9
August	7.39	11.35	0.06	3.6	97.6	30.7	370	427	176	1027	100	11.7
September	7.07	11.35	0.09	3.29	104.7	27.7	376	410	168	1014	98	11.65
October	7.05	13.5	0.07	3.34	129	28.77	441	395	169	1022	102	16.45
November	6.83	13.5	0.04	3.89	116	29.28	410	363	161	963	103	13.5
December	7.11	13.25	0.1	6.17	112	31.7	412	334	164	935	119	8.7
Objectives	6.5-8.5	>2	3	10	200	50	750	250	200	750	200	5

*Bolded values do not fulfill the goal.

Table 4. The value of Parameters at S2 for the year 2023

Month	pH	DO	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	TH	SO_4^{2-}	Cl^-	TDS	Alk	TUR
January	7.38	14.45	0.075	9.23	128	45.86	508	370	235	1151.5	130	6.61
February	7.58	17.5	0.1	6.62	134.4	44.4	518	396	225.5	1104	132	7.83
March	7.54	14.2	0.135	6.68	105.6	44.89	448	335	200	1038	111	3.5
April	7.51	16.15	0.12	5.6	114.4	41.96	458	397	215	1120	110	4.5
May	7.38	16.8	0.045	6.91	111	28.79	396	384	182	994.5	119	6.81
June	7.43	17.75	0.045	5.4	127.2	29.74	441	344	180.5	1025.5	110	7.1
July	7.08	13.15	0.045	3.69	124.4	28.05	426	355.5	167	995	109	11.69
August	7.215	11.95	0.03	3.69	122.4	22.66	399	345.5	158.5	992.5	104	20.2
September	6.71	12.1	0.075	5.6	132.4	21.47	419	343	165	981.5	104	21.95
October	7.18	16.15	0.06	2.89	132.4	31.47	460	384	177	1028.5	104	22.55
November	7.18	11.9	0.03	4.91	141.2	28.06	460	346	162	991	107	17.15
December	7.37	14.15	0.03	6.17	131.6	30.74	455	320	169.5	994	105	12.45
Objectives	6.5-8.5	>2	3	10	200	50	750	250	200	750	200	5

*Bolded values do not fulfill the goal.

3. CCME WATER QUALITY INDEX (CCMEWQI)

The CCME Water Quality Index (WQI), established by the Canadian government in 2001, provides a quantitative framework for evaluating ambient water quality conditions in relation to specific water quality targets. It is adaptable in terms of the kind and quantity of water quality factors to be examined, the time frame for application, and the kind of water body (lake, river reach, stream, etc.) that is being examined. Here, the CCME WQI is determined using twelve parameters and ranked by comparing it to one of the following categories [CCME WQI, 2001].

Excellent: Water quality is safeguarded with almost no threat or impairment; conditions are extremely like natural levels (CCME WQI Value 95-100).

Good: (CCME WQI Value 80-94): circumstances hardly deviate from ideal or natural levels, and water quality is safeguarded with only a slight threat or harm.

Fair: (CCME WQI Value 65-79): Water quality is generally safe but may be endangered or compromised; conditions may occasionally deviate from ideal or natural values.

Marginal: Water quality is often threatened or compromised; circumstances routinely deviate from ideal or natural levels (CCME WQI Value 45–64).

Poor: (CCME WQI Value 0-44): circumstances typically deviate from ideal or natural values; water quality is nearly always endangered or compromised.

The following is how the Canadian Council of Ministers of the Environment (CCME) developed the CWQI [6]:

F1 (scope measure) shows the proportion of parameters (out of all the parameters tested) that do not match the criterion at least once during the period in question.

$$F_1 = \frac{Number\ of\ failed\ variable}{Total\ number\ of\ variables} \text{x}100 \quad (1)$$

F_2 (Frequency) is the proportion of individual tests that fall short of goals (sometimes known as "failed tests"):

$$F_2 = \frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests} \text{x}100 \quad (2)$$

F_3 (Amplitude) is a measure of how much failed test values deviate from their goals.

F_3 The calculation of is done in three phases:

i) An "excursion" is the number of times an individual concentration exceeds (or falls short of, if the target is a minimum) the objective. It can be written as follows. When the objective cannot be exceeded by the test value:

$$excursion_i = \left(\frac{Failed\ test\ value_{\ i}}{Objective_{\ j}}\right) - 1 \quad (3)$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_{\ j}}{Failed\ test\ value_{\ i}}\right) - 1 \quad (4)$$

ii) By adding up the deviations of individual tests from their goals and dividing by the entire number of tests (both those that meet and those that don't), one can get the overall level of noncompliance with the objectives. The normalized sum of excursions, or nse, is a variable that is computed as follows:

$$nse = \frac{\sum_{i=1}^{n} excursion}{number\ of\ tests} \quad (5)$$

iii) After that, an asymptotic function that adjusts the normalized sum of the excursions from objectives (nse) to produce a range between 0 and 100 is used to calculate F3.

$$F_3 = \frac{nse}{0.01\ nse + 0.01} \quad (6)$$

The CCME Water Quality Index (CCME WQI):

$$CCMEWQI = 100 - \left(\frac{\sqrt{F_1{}^2 + F_2{}^2 + F_3{}^2}}{1.732}\right) \quad (7)$$

Table 5 shows how the WQI results of the surface water in this study compare to the allowable limits of the drinking water standards established by the World Health Organization (WHO).

Table 5. Allowable limit of Water Quality Parameters in Surface Water According to WHO Standards (WHO, 2011).

Parameters	pH	DO	PO_4^{3-}	NO_3^-	Ca^{2+}	Mg^{2+}	TH	SO_4^{2-}	Cl^-	TDS	Alk	TUR
Objectives	6.5-8.5	>2	3	10	200	50	750	250	200	750	200	5

4. RESULTS AND DISCUSSION

After analyzing the data, the results for the study site showed that some elements had exceeded the permissible limits. Figs. 2 and 3 display The temporal variation of parameters (pH, DO, PO_4^{-3}, NO_3^-, Ca^{+2}, Mg^{+2}, TH, Cl^-, Alk, SO_4^2, TDS, and TUR) in the Shatt al-Kufa River's (S1) in 2022 and 2023, respectively. Remarkably, every value has not exceeded the permissible limits in the World Health Organization's specified parameters, except for Chloride (Cl-) values in 2023, which exceeded the permissible values of January, March, and April (winter season). High chloride levels in the winter months may be due to drinking water being contaminated with road salt during rainfall or melting snow from water sources, fertilizers, or leaking sewer systems (Pieper et al., 2028; Sérodes et al.,2021). For the parameters (pH, DO, PO_4^{-3}, NO_3^-, Ca^{+2}, Mg^{+2}, TH, Cl^-, and Alk), the maximum values were (7.35, 14.4, 0.16, 5.95, 152, 34.86, 510, 182.5, 118) and (7.36, 15.9, 0.44, 9.63, 149.6, 47.09, 553, 245, 140) in 2022 and 2023, respectively. and the lowest readings in 2022 and 2023 were (6.75, 10.15, 0.07, 3.14, 107.2, 28.1 ,390, 165, 80) and (6.62, 9.1, 0.03, 3.29, 110, 21.71, 406, 159, 99), respectively.

However, the Shatt al-Kufa River's (S1) values (SO_4^2, TDS, and TUR) in 2022 and 2023, all values were higher above the acceptable ranges within the guidelines set by the World Health Organization (WHO). The greatest values for the parameters ($SO4^2$, TDS, and TUR) in 2022 and 2023 were (466, 1100, 19.8) and (414, 1218, 20.15), respectively. and the lowest values in 2022 and 2023 were (367, 937, 5.34) and (335.5, 985, 5.16), respectively.

With the highest turbidity values recorded throughout the summer (June, July, August, September, October, November and December) it was found that all turbidity values surpassed the allowable limit of 5 NTU, this may be due to the dredging activities near the banks of the Euphrates River (Abed and Khudair, 2023). The increased turbidity in the river is a problem that effect on drinking water supplied to Najaf people (Abed et al.,2024; Abed and Khudair, 2023).

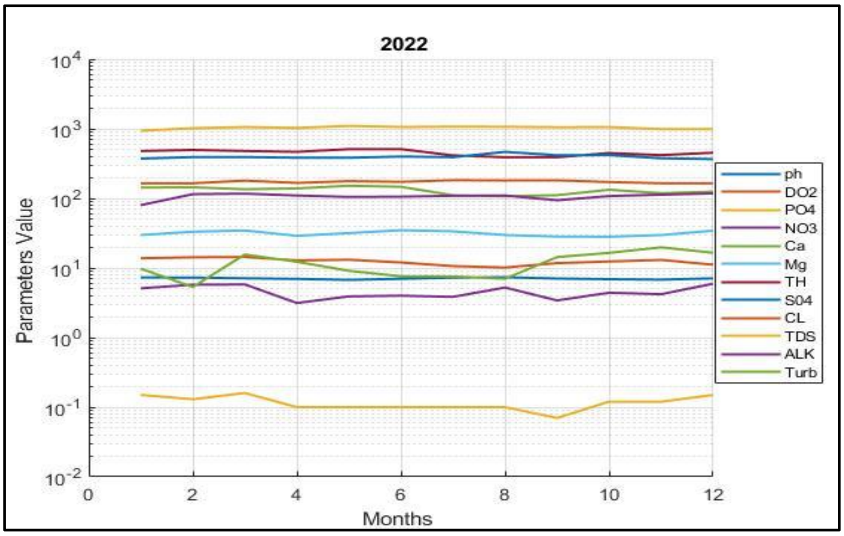

Fig. 2. The temporal variation of parameters value in station S1 for the year 2022.

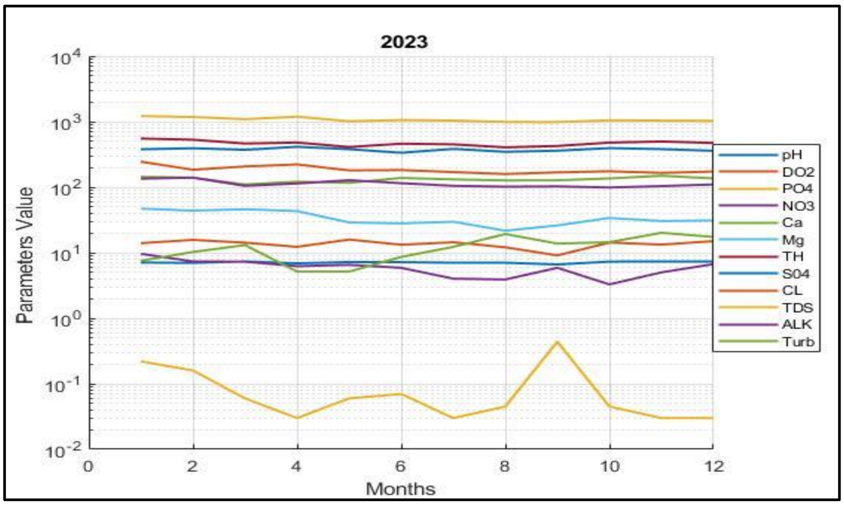

Fig. 3. The temporal variation of parameters value in station S1 for the year 2023.

The Al-Abassia River's (S2) parameters (pH, DO, PO_4^{-3}, NO_3^-, Ca^{+2}, Mg^{+2}, TH, CI^-, Alk, SO_4^{-2}, TDS, and TUR) in 2022 and 2023 are shown in Figs. 4 and 5 Interestingly, like with the previous station, none of the values went over the acceptable bounds set by the World Health Organization. Given that dissolved oxygen (DO) is a critical predictor of ecosystem health and water quality, this is a useful diagnostic of water quality, particularly when DO concentrations are high (Jasem and Khudair, 2023).

Also, like the station (S1), the 2023 chloride (Cl-) measurements were greater above the permitted limits during the winter. For the parameters (pH, DO, PO4-3, NO3-, Ca+2, Mg+2, TH, CI-, and Alk), the maximum values were (7.39, 16.65, 0.1, 6.17, 145, 34.6, 508, 180, and 119) and (7.58, 17.75, 0.133, 9.23, 141.2, 45.86, 518, 235, and 132) in 2022 and 2023, respectively. and the lowest readings in 2022 and 2023 were (6.83, 10.4, 0.04, 3.29, 97.6, 19, 370, 161, and 94) and (6.71, 11.9, 0.03; 2.89, 105.6, 21.47, 396, 158.5, and104) respectively.

Also, like the previous station (S1) data (SO4-2, TDS, and TUR), all of the values for 2022 and

2023 exceeded the World Health Organization's (WHO) allowable limits. The greatest values for the measures (TUR, TDS, and SO_4^{-2}) were recorded in 2022 at (427, 1043, and 16.45) and in 2023 at (397, 1151.5, and 22.55). In 2022, the lowest values were (334, 905, 2.54) and in 2023, they were (320,981.5, and 3.5), respectively. This could be due to wastewater from industries, poorly treated sewage, or soil salts from drainage in agricultural areas.

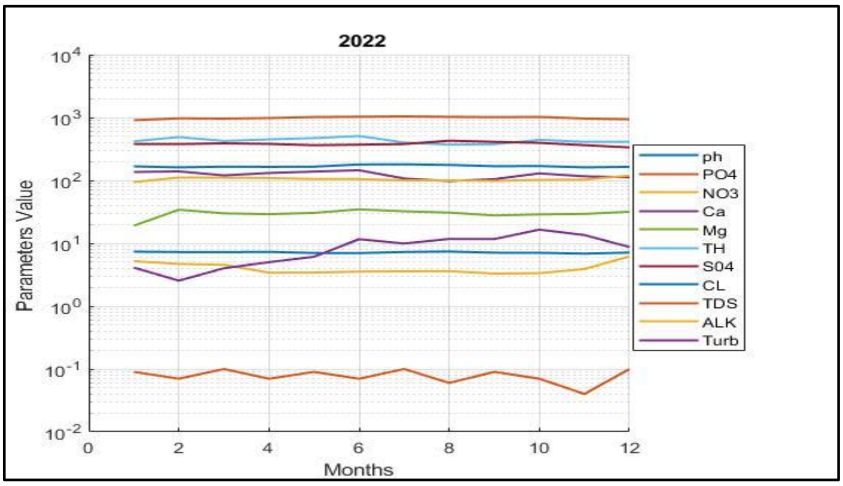

Fig. 4. The temporal variation of parameters value in station S2 for the year 2022.

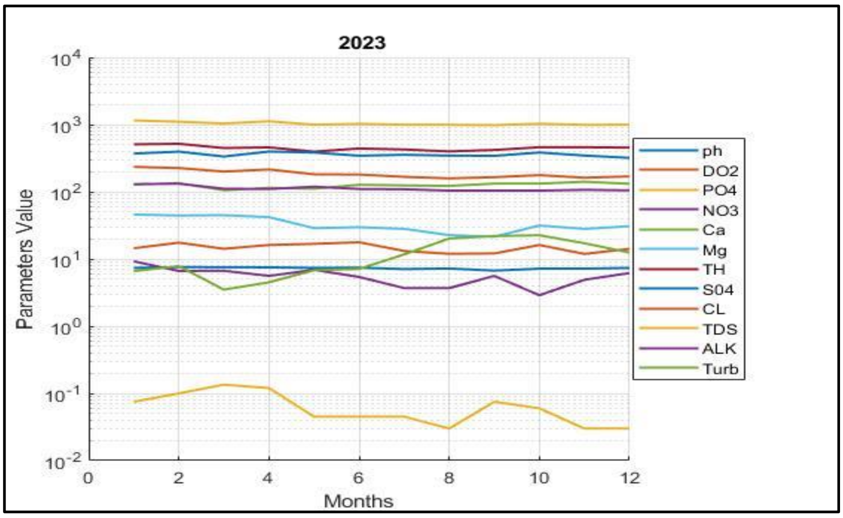

Fig. 5. The temporal variation of parameters value in station S2 for the year 2023.

Fig. 6 and 7 shown The temporal variation of the water quality index (WQI) of water samples from station S1 for the years 2022 and 2023. The quality in 2022 was assessed as fair based on the WQI results. However, the WQI findings for 2023 showed that the quality was in the marginal range,perhaps as a result of increasing all parameter levels. in contrast to 2022,The highest values were (79.12 and 65.81) at the S1 station in 2022 and 2023. and the lowest values in 2022 and 2023 were (75.33 and 49.63) respectively.

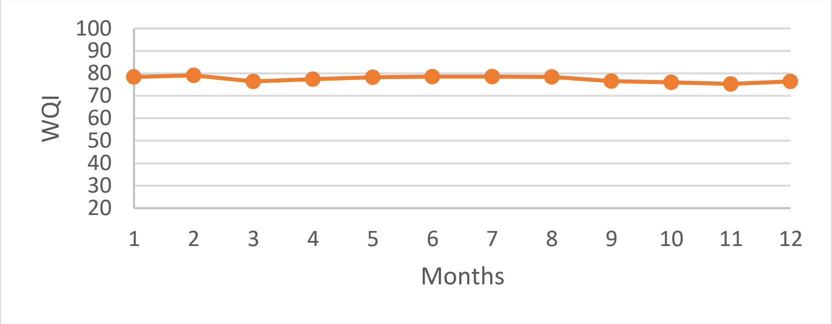

Fig. 6.The temporal variation of (WQI) in station S1 for 2022.

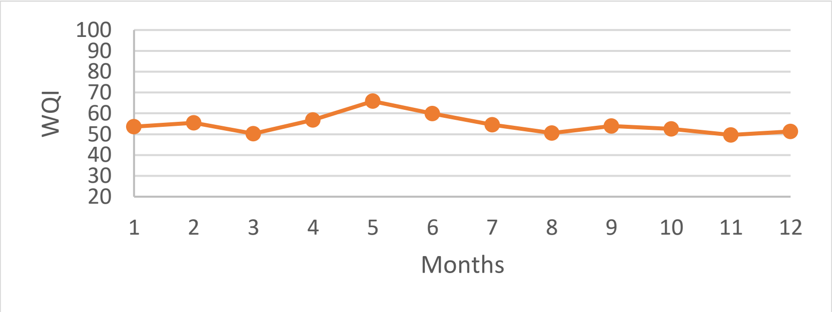

Fig. 7.The temporal variation of (WQI) in station S1 for 2023.

Fig.8 and 9 display the water quality index (WQI) temporal change in water samples from station S2 for 2022 and 2023. The water quality in January, February, March, and April was classified as good based on the WQI results. However, the WQI results indicated that in May, June, July, August, September, October, November, and December, the quality was in the fair category, presumably due to an increase in the levels of TDS, SO4-2, and TUR. The 2023 WQI results, however, indicated that the quality fell into the fair range. The highest values were (86.1 and 79.33) and the lowest values were (76.2 and 71.81) in 2022 and 2023 respectively.

The WQI and its spatial variation for all the sampling stations fluctuated between good, fair and marginal quality classes over the given period.

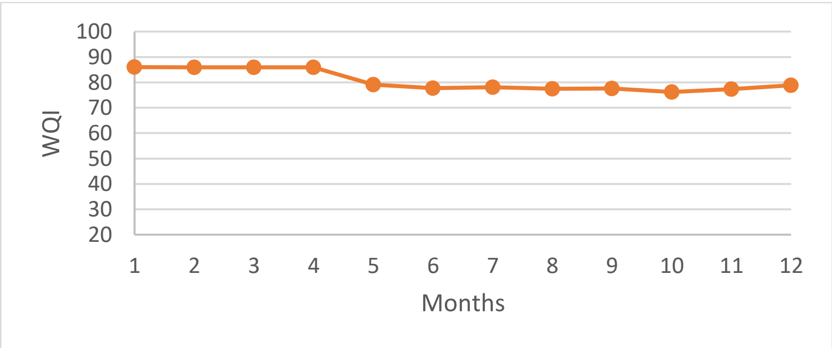

Fig. 8. The temporal variation of (WQI) in station S2 for 2022.

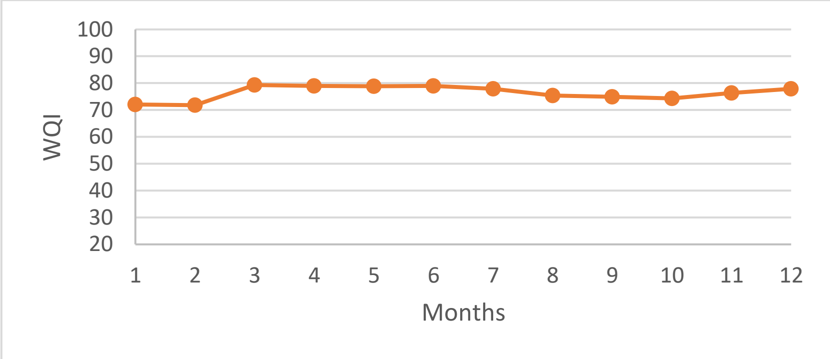

Fig. 9. The temporal variation of (WQI) in station S2 for 2023.

5. CONCLUSIONS AND RECOMMENDATIONS

It is well recognized that both natural and man-made activities are contributing to the Euphrates River's rising water pollution levels, which are negatively affecting aquatic life and public health. Therefore, the primary goal of this study was to evaluate the drinking water quality in several Euphrates River locations across the Al-Najaf Governorate. Two regions' worth of drinking water samples were gathered. Using established methods, all of the samples were examined for 12 physicochemical criteria. The findings indicate that all of the samples had turbidity, total dissolved solids, and SO4-2 levels that were higher than the recommended WHO levels. This demonstrates the dangers of pollution and contaminated drinking water. The WQI displayed clear fluctuation, with good, fair, and marginal quality, respectively, according to the CCME WQI. Accordingly, this study recommends that the Euphrates River water undergo adequate treatment to ensure its suitability for human consumption. Furthermore, strict control over waste discharges particularly those associated with effluent water—is essential to safeguard the river and its tributaries from pollution.

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