



Evaluation of Water Quality Index in Euphrates River, Iraq: By Using the Weighted Arithmetic Method

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Abstract— Water is the world's most significant natural resource. It is a necessary component in the survival of all forms of life. A variety of pollutants, mostly from wastes discharged into the river, pose a challenge to the Iraqi Euphrates River. Effluents from municipal wastewater treatment plants are a significant source of contamination to the river, although industrial effluents and farmland drainage also contribute significantly. Water contamination is a significant issue that poses risks to both human health and the environment. In this study, the Shatt Al-Kufa branch of Euphrates River in Kufa City was chosen as a case study. The determinants of the quality of the Kufa Shatt water that were selected for this study which: pH, Turbidity (Turb.), Dissolved oxygen (DO), Alkalinity (Alk.), Total Dissolved Solid (TDS), Total Hardness (T.H), Calcium (Ca²⁺), Magnesium (Mg²⁺), Sodium (Na⁺), Potassium (K⁺), Chlorides (Cl⁻) and Sulphate (SO₄). The research was carried out over six months (July to December 2023). pollution problems arise, especially in densely populated urban areas. Najaf city is a good example of such an example, as it produces a large amount of wastewater from various and numerous sources that reach the Euphrates River directly without any type of treatment. Kufa station also contains a discharge point from the sewage treatment plant. Describing the water quality and determining the extent of the impact of the treated wastewater discharge point on Al-Manathira station in Shatt Al-Kufa are the main objectives of the current study. The Results of the overall WQI according to the Weighted Arithmetic Method were categorized as good at Kufa and Manathira stations (90.79 and 96.073) respectively. High turbidity and SO₄ concentrations were the primary factors that reduced the water quality index at two of the stations, according to the results.

Keywords— Kufa station, water quality index, TDS, Euphrates River.

1. Introduction

Water is the world's most significant natural resource. It is a necessary component in the survival of all forms of life, life cannot occur without it [1]. The amount of water on Earth remains constant at approximately 1.4 billion cubic kilometers. Nearly all bodies of water are saltwater, with freshwater making up just 1.76 percent; a large portion of this freshwater is situated in areas where the temperature never rises above freezing. So, the amount of water present in the earth's soil, atmospheric water, rivers, lakes, and reservoirs is less than 0.4% [2]. Reservoirs, lakes, marshes, and streams make up fifteen percent of

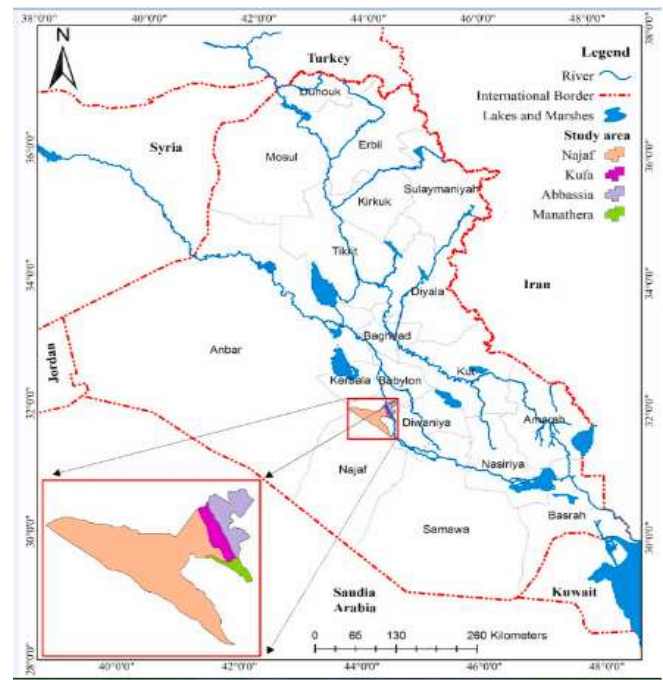
Iraq's total land area. A variety of pollutants, mostly from wastes discharged into the river, pose a challenge to the Iraqi Euphrates River. Municipal wastewater treatment plant effluents are a significant pollutant to the Euphrates River, even though agricultural runoff and industrial effluents also contribute significantly [3]. Water pollution poses a significant threat to both human health and the environment. Access to high-quality drinking water is essential for maintaining personal well-being. Drinking water should possess aesthetic qualities such as clarity, colorlessness, and good aeration, while also being free from any unpleasant taste or odor. Microbiological, physical, chemical, and radiological properties are too employed to assess its appropriateness in relation to public

health [4]. Water quality is a broad term that refers to the physical, chemical, and biological characteristics of water resources. It is crucial in determining aquatic ecosystems and public health [5]. Assessing surface water quality is a comprehensive process that involves multiple variables, each of which can significantly influence the overall water quality. Evaluating water quality (WQ) by testing numerous parameters across multiple samples is a complex task, and it is challenging to reach a conclusive judgement based solely on individual results. As a result, various approaches have been developed to analyze water quality and the use of water quality indices [6]. Water quality indices are methods that significantly reduce the amount of data and simplify the representation of water quality status. The WQI can be assessed based on a range of physical, chemical, and biological parameters. Globally, experts have developed various water quality indices to quickly and effectively assess the overall water quality in specific areas. The most commonly used types of water quality indicators are: arithmetic weighted (AWWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI). These indices are derived from comparing water quality parameters to governing standards, resulting in a lone value that represents the quality of a water source [7]. Water quality studies have focused on several cases where severe pollution problems arise, especially in densely populated urban areas. Najaf city is a good example of such an example, as it produces a large amount of wastewater from various and numerous sources that reach the Euphrates River directly without any type of treatment. Kufa station also contains a discharge point from the sewage treatment plant. Describing the water quality and determining the extent of the impact of the treated wastewater discharge point on Al-Manathira station in Shatt Al-Kufa are the main objectives of the current study. Additionally, to assess the physical and chemical characteristics of surface water at a different location in the Shatt Al Kufa.

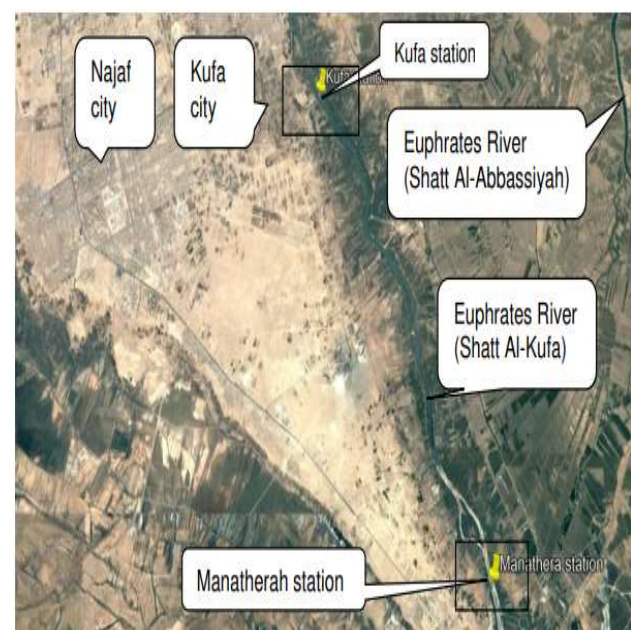
2. STUDY AREA

One of the driest and the hottest places in Iraq is Kufa. The coordinates of its location are $44^{\circ} 26'$ to $44^{\circ} 23'$ east of longitude [8] and $32^{\circ} 04'$ to 32° north of latitude. The Shatt Al-Kufa, a tributary of Euphrates River, runs alongside its banks. Euphrates River splits in two after passing Al-Kifil city: Al-Abbasiyya and Shatt Al-Kufa, the former of which is 73 km long and 100 m wide. All over the year, the water elevation for Shatt Al-Kufa is unstable, as it is mainly supplied by rainfall and kept water in ponds and reservoirs. Some residential buildings are situated on the opposite side of the river, and the regions surrounding it are well-known for their agricultural practices [9]. This research used the Kufa city branch of the Shatt Al-Kufa, which originates in Euphrates River. The water monitoring stations that were part of this study belonged to the Iraqi Ministry of Water Resources. Manathera Station, at $31^{\circ}55'24.41''\text{N}$,

$44^{\circ}29'22.11''\text{E}$, and Kufa Station, at $32^{\circ} 0'58.73''\text{N}$, $44^{\circ}25'32.50''\text{E}$, were the upstream and downstream boundaries, respectively. (Figure1) represents the location of the study area) [10].



(a)



(b)

Figure 1: (a) Study area location map, (b) Location of AL-Kufa and Al- Manatherah station

3. SAMPLE COLLECTION METHOD

Kufa and Manatherah are the two locations where water samples are taken daily from the river for six months (Jul.2023 –Dec.2023) and take the monthly average for its.

The laboratories of Iraq's Ministry of Water Resources/Water Resources Management examined these samples. Samples were collected at a depth of one meter below the water's surface at Kufa and Manathera station. The samples were contained in a securely sealed plastic bottle with a capacity of 1.5 liters for physical and chemical analyses. The sample was refrigerated for preservation until analysis.

(SO₄), pH, turbidity (Turb.), alkalinity (Alk.), total hardness (T.H.), calcium (Ca⁺²), magnesium (Mg⁺²), sodium (Na⁺), potassium (K⁺), and chlorides (Cl⁻¹), which shows in table 1 and table 2 for two stations (Kufa and Manatherah).

The parameters which selected for this study were total dissolved solids (TDS), dissolved oxygen (DO), sulphate

Table 1: Concentrations of water quality parameters for Kufa station

Parameters	JUL	Aug.	Sep.	Oct.	Nov.	Dec.	Average
pH -----	7	7	6.7	7.3	7.36	7.34	7.1166
Turbidity NUT	12.27	19.3	19.35	14.5	20.15	17.4	17.16167
DO mg/l	14.45	12	7.85	14.3	13.3	15.05	12.82
TDS mg/l	1039	990	985	1050	1039	1031.5	1022.417
ALK mg/l	105	102	103	99	104	117	105
T.H mg/l	451	406	426	479	498	473	455.5
SO ₄ mg/l	384	337	360	395	381	358	396.1667
Na mg/l	100.5	100	82	81.15	80	99	90.44167
CL mg/l	170	159	168	175	165.5	173.5	168.5
Mg mg/l	29.7	21.7	26	34	30.5	31	28.8166
Ca mg/l	131.5	126.3	134	136	150	131	134.5
K mg/l	7.5	7.8	5.65	6.1	5.45	5.75	6.375

Table 2: Concentrations of water quality parameters for Manathera station

Parameters	JUL.	Aug.	Sep.	Oct.	Nov.	Dec.	Average
PH -----	7.02	7.15	6.64	7.08	7.21	7.4	7.08333
Turbidity NUT	10.27	21	19.35	15.25	24	14.5	17.395
DO mg/l	13.6	10	7.8	12.15	11.5	15.7	11.79167
TDS mg/l	118	1032.5	1135	1087	1077	1063	918.816
ALK mg/l	117	109	110	108	123	117	114
T.H mg/l	485	432	453	493	503	491	476.1667
SO ₄ mg/l	390	379	402.5	394	413	394	395.4167
Na mg/l	106	105.5	85	88	94.2	122	100.1167
CL mg/l	175.5	166	185	190	177.5	183	179.5
Mg mg/l	32.9	26.5	27.2	30.5	30.25	30.73	29.68
Ca mg/l	140	129.2	127	147	151.2	146	140.066
K mg/l	7.8	9.25	6.4	6.75	6.9	7	7.35

4. WATER QUALITY INDEX

Many researchers use the water quality index (WQI) a model to assess the state of surface water. The Water Quality Index is a singular term that encapsulates the overall condition of water quality. This method effectively selects appropriate treatment techniques to address specific issues, compares the water quality of various sources, and assesses the health of a watershed across its different regions. Simultaneously, the water quality index is employed to assess alterations in the water quality of ecosystems over a specified duration. The Water Quality Index (WQI) elucidated the data gathered for the assessment of physicochemical parameters of the water body to determine the level of water quality evaluation. The utilization of an index for assessing water quality has recently been innovated. As a general rule, WQI models have four steps: (a) selecting the water quality parameters, (b) conducting sub-indices for each parameter, (c) determining out how to weight the parameters (d) adding all the sub-indices together to get the overall WQI [11].

4.1 ARITHMETIC WEIGHTED METHOD

To define the treated water WQI of the most commonly measured water quality parameters, the WA-WQI method classified water quality according to purity degree. Equation (1) was utilized to compute the WQI, as follows: [12] [13] [14]

$$QWI = \frac{\sum Qi Wi}{\sum Wi} \quad (1)$$

Scale for rating the quality of parameters The value of Qi was calculated using Equation (2).

$$Qi = 100 \left[\frac{Vi - Vo}{Si - Vo} \right] \quad (2)$$

parameter unit weight (Wi) was calculated using Equation (3)

$$Wi = \frac{1}{Si} \quad (3)$$

Where

Vi: represents the concentration of each parameter in water.

The ideal parameter value is typically found in pure water. For all parameters except pH and DO, (Vo) is 0. However, for pH and DO, the value of Vo is 7.0 and 14.6 mg/l, respectively.

Si: standard parameter value.

This method's advantages include the ability to apply a reduced number of water quality parameters according to the user's preferences. Assign varying weights to each parameter based on its significance. It studies the appropriateness of surface and groundwater for human usage and provides extensive

information on water quality to the concerned public [15]

5. RESULTS AND DISCUSSION

In this study, the physical and chemical parameters of Shatt AL-Kufa were analyzed for 6 months to determine the water quality index(WQI). Samples were taken from the Kufa and Manathera stations. In tables 3 and 4 above the concentration of the parameters for Kufa and Manathera stations were show. When the values of the parameters of the Shatt Al-Kufa water were compared with the values of the World Health Organization standard parameters for drinking water (shown in Table 5).

Table 5: water quality limits of parameters for drinking uses according to WHO standards (2017)

Parameter	WHO standards	Parameter	WHO standards
pH	6.5 - 8.5	TDS	1000
Turbidity	5	Na	200
DO	5	CL	250
Alkalinity	200	Mg	50
TH	500	Ca	75
SO ₄	250	K	12

*Note: All parameters are in mg/l except turbidity and pH

it was noted that the average monthly values at Kufa and Manathera stations for PH, ALK, Na,Ca,Mg,TDS, CL and K within WHO guidelines , while the average monthly values for turbidity, TDS and sulphate Exceeded permissible limits The values of turbidity for two stations were 17.16167 and 17.395 respectively, the occurrence of suspended particles in the water causes the sprinkling of light, resulting in a turbidity level higher than the allowable value of 5 NTU.The mean monthly total dissolved solids (TDS) concentrations at the Al-Kufa and Al-Manathera stations were 1022.417 and 1085.483 mg/l, respectively. As stated, it exceeds the permissible drinking limit of 1000 mg/l. The monthly average concentration of sulphate (SO₄⁻²) was 369.166 mg/l at the Al-Kufa station and 395.416 mg/l at the Al-Manathera station. These concentrations exceed the permissible limit of 250 mg/l.This indicates the impact of industrial and municipal wastewater release in close proximity to the positions and farming land (resulting from leaves falling into the river) on the riverbanks, as well as natural sources such as substances dissolved in rainfall. The quality of water was classified into five categories, variety from Excellent to Unfit for drinking, established on the calculated WQI value using Equation 1. [16], as illustrated in Table 6.

Table 6: presents the Water Quality Rating (WQR) based on (WA-WQI)

NO.	WQI range	Water type
1	< 50	Excellent water
2	50.1 – 100	Good water
3	100.1- 200	Poor water
4	200.1 – 300	Very poor water
5	> 300.1	Unfit for drinking

The WA-WQI values at the Al-Kufa and Al-Manathara stations were 90.79 and 96.073, respectively, as shown in Tables 3 and 4. The water quality at two stations is classified as good, as indicated by the Index (WAWQI) scores ranging from 50.1 to 100

Appendix A

Table 3: Calculation of water quality index for Kufa station

Parameters	Observed values (Vn)	Ideal value (Vi/v0)	Standard values (Si)	Unit Weight (Wi)	Quality Index (Qi)	Qi WI	Water Quality index (WQI)
pH -----	7.1166	7	8.5	0.117647	7.773333	0.91451	7.773333
Turbidity NUT	17.16167	0	5	0.2	343.2334	68.64668	343.2334
DO mg/l	12.82	14.7	5	0.2	19.38144	3.876289	19.38144
TDS mg/l	1022.417	0	1000	0.001	102.2417	0.102242	102.2417
Alk mg/l	105	0	120	0.008333	87.5	0.729167	87.5
TH mg/l	455.5	0	500	0.002	91.1	0.1822	91.1
SO ₄ mg/l	369.1667	0	250	0.004	147.6667	0.590667	147.6667
Na mg/l	90.44167	0	200	0.005	45.22084	0.226104	45.22084
CL mg/l	168.5	0	250	0.004	67.4	0.2696	67.4
Mg mg/l	28.8166	0	50	0.02	57.6332	1.152664	57.6332
Ca mg/l	134.5	0	200	0.005	67.25	0.33625	67.25
K mg/l	6.375	0	12	0.083333	53.125	4.427083	53.125
Average=							90.7938

6. CONCLUSIONS

1-All measured values at two stations of (pH, T.H, Alk, Na, Ca, CL and Mg) remained within the acceptable limits established by the World Health Organization

2- Measurements of sulfates (SO₄), total dissolved solids (TDS), dissolved oxygen and turbidity at two stations have exceeded the allowable limit determined by the World Health Organization (WHO).

3- Concentrations of parameters were higher in Al-Manathara station than in Al-Kufa station due to the effect of sewage treatment plant discharges into the river.

4-The water quality of Shatt Al-Kufa River was evaluated using the WA-WQI method in this study. The results showed that the reason for the low value of the index was the presence of high levels of turbidity and high concentrations of SO₄ in the two stations throughout the months.

Table 4: Calculation of water quality index for Manathera station

Parameters	Observed values (Vn)	Ideal value (Vi/v0)	Standard values WHO (Si)	Unit Weight (Wi)	Quality Index (Qi)	Qi Wi	Water Quality index (WQI)
PH ----	7.08333	7	8.5	0.117647	5.555333	0.653569	5.555333
Turbidity NUT	17.395	0	5	0.2	347.9	69.58	347.9
DO mg/l	11.79167	14.7	>5	0.2	29.98278	5.996557	29.98278
TDS mg/l	1085.483	0	1000	0.001	91.8816	0.091882	108.84
Alk mg/l	114	0	120	0.008333	95	0.791667	95
TH mg/l	476.1667	0	500	0.002	95.23334	0.190467	95.23334
SO ₄ mg/l	395.4167	0	250	0.004	158.1667	0.632667	158.1667
Na mg/l	100.1167	0	200	0.005	50.05835	0.250292	50.05835
CL mg/l	179.5	0	250	0.004	71.8	0.2872	71.8
Mg mg/l	29.68	0	50	0.02	59.36	1.1872	59.36
Ca mg/l	140.066	0	200	0.005	70.033	0.350165	70.033
K mg/l	7.35	0	12	0.083333	61.25	5.104167	61.25
average=							96.073

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تقييم مؤشر نوعية المياه في نهر الفرات في العراق: باستخدام الطريقة الحسابية الموزونة

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الخلاصة – الماء هو المورد الطبيعي الأكثر أهمية في العالم. إنه عنصر ضروري لبقاء جميع أشكال الحياة. مجموعة متنوعة من الملوثات، معظمها من النفايات التي تُصَرَّف في النهر، تشكل تحدياً لنهر الفرات العراقي. المخلفات من محطات معالجة مياه الصرف الصحي البلدية هي مصدر رئيسي للتلوث في النهر، على الرغم من أن المخلفات الصناعية وتصريف الأراضي الزراعية تساهم أيضاً بشكل كبير. تلوث المياه هو قضية هامة تشكل مخاطر على صحة الإنسان والبيئة على حد سواء. في هذه الدراسة، تم اختيار فرع شط الكوفة من نهر الفرات في مدينة الكوفة كحالة دراسية. محددات جودة مياه شط الكوفة التي تم اختيارها لهذه الدراسة هي: أيون تركيز الهيدروجين (P_H)، العكارة ($Turb.$)، الأكسجين المذاب (DO)، القلوية ($Alk.$)، المواد الصلبة الذائبة الكلية (TDS)، الصلابة الكلية ($T.H$)، الكالسيوم (Ca^{+2})، المغنيسيوم (Mg^{+2})، الصوديوم (Na^{+})، البوتاسيوم (K^{+})، الكلوريدات- Cl والكبريتات (SO_4). تم إجراء البحث على مدى ستة أشهر من (تموز الى كانون الأول 2023). تظهر مشاكل التلوث، خاصة في المناطق الحضرية ذات الكثافة السكانية العالية وتعد مدينة النجف هي مثال جيد على ذلك، حيث تنتج كمية كبيرة من مياه الصرف الصحي من مصادر متنوعة وكثيرة تصل إلى نهر الفرات مباشرة دون أي نوع من المعالجة. تحتوي محطة الكوفة أيضاً على نقطة تصريف من محطة معالجة مياه الصرف الصحي. وصف جودة المياه وتحديد مدى تأثير نقطة تصريف مياه الصرف الصحي المعالجة على محطة المناذرة في شط الكوفة هما الهدفان الرئيسيان للدراسة الحالية. كانت نتائج مؤشر جودة المياه العام وفقاً للطريقة الحسابية الموزونة مصنفة على أنها جيدة في محطتي كوفة والمناذرة (90.79 و 96.073) على التوالي. كانت العكارة العالية وتركيزات SO_4 من العوامل الرئيسية التي خفضت مؤشر جودة المياه في محطتي الكوفة والمناذرة، وفقاً للنتائج.

الكلمات الرئيسية – محطة الكوفة، مؤشر نوعية المياه، المواد الصلبة الذائبة الكلية، نهر الفرات