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Statistical analysis for water quality index for Shatt-Al-Hilla river in Babel city

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ABSTRACT

The work aims to investigate the Water Quality Index (WQI) of the Shatt-al-Hilla River, a branch of the Euphrates river in Babel city, Iraq. Twelve important and influential parameters were taken into account to evaluate the WQI, namely the temperature of water (Temp), total hardness (TH), electrical conductivity (EC), acidity (PH), total dissolved solids (TDS), sulfate (So_4^{-2}), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+1}), biological oxygen demand (BOD), potassium (K) and turbidity. Raw and treated water quality was evaluated using two models, Weighted Calculation and Canadian Cabinet for the Environmental Water Quality Index (CCME WQI). The study area included three water treatment plants, namely New Hilla (NH), Al-Hussein (HE), and Al- Hashimyah (HA), which discharge their treated water into the Shatt-al-Hilla river. Raw and treated water samples were collected and tested regularly for nine months, from October 2020 to June 2021. The results showed all chemical and physical parameters (for both raw and treated water) met the Iraqi standards except Ca^{+2}, turbidity and EC for raw water and temperature for treated water.

Key words: CCME WQI method, raw water, Shatt-Al-Hilla river, statistical analysis, treated water, weighted arithmetic method

HIGHLIGHTS

- This paper studied Water Quality Index for the Shatt-al-Hilla River in Babel city, Iraq.
- Twelve parameters were considered in this study.
- Three Water Treatment Plants were included in this study.
- All parameters were within the Iraqi standards, except the Ca, Turbidity and EC.

1. INTRODUCTION

Water is one of the most indispensable resources; hence life is not possible on this planet without water (Abdulla *et al.* 2020; Salah *et al.* 2020a). Water quality is defined in terms of its physical, chemical and biological parameters, and evaluating these parameters is important before use for any intended purposes, such as potable, agricultural, recreational and industrial water usage, and so on (Alobaidy *et al.* 2010). Drinking water in Iraq is secured from rivers, lakes, wells and springs, which are usually exposed to various pollutants that result from the diffusion from non-point and point sources (Hashim *et al.* 2021a; Omran *et al.* 2021), which are difficult to control, monitor, and evaluate, such as sewage (Hashim *et al.* 2020a; Zanki *et al.* 2020), agricultural and industrial effluents (Emamjomeh *et al.* 2020a, 2020b). In addition, global warming plays a serious role in the freshwater shortage in Iraq (Zubaidi *et al.* 2020a; Zubaidi Salah *et al.* 2020), where the last studies revealed a significant shortage in precipitations (Salah *et al.* 2020b, 2020c). Furthermore, the rapid increase in urbanization (Al-Jumeily *et al.* 2019; Alnaimi *et al.* 2020; Farhan *et al.* 2021) and industrial activities, such as petroleum and cement industries (Grmasha *et al.* 2020; Al-Sareji *et al.* 2021; Obaid *et al.* 2021) near the sources of freshwater in Iraq, have intensified the problem.

Therefore, the need for water treatment technologies and water monitoring policies becomes more urgent than any time before (Al-Hashimi *et al.* 2021; Hashim *et al.* 2021b). In this context, many methods were used to remediate water from a certain pollutant of a set of pollutants, such as filtration (Abdulraheem *et al.* 2020; Alhendal *et al.* 2020; Alyafei *et al.* 2020), electrocoagulation (Aqeel *et al.* 2020; Hashim *et al.* 2020b), ultrasonic-based methods (Al-Marri *et al.* 2020), and adsorbents (Alenazi *et al.* 2020a, 2020b). For example, Hashim *et al.* (2020c) used a combined treatment method that utilises both electrocoagulation and ultrasonic techniques to remediate water from biological pollutants, and the results obtained proved this combined method can remove all pathogens within 15 minutes at relatively cost. Additionally, Abdulhadi *et al.* (2021) used the electrocoagulation method to remove complex pollutants from water, and the results indicated this method removed 99% of iron and organic pollutants from water. Additionally, forcasting methods were used to predict the possible changes in the abundancy of freshwater, such as those studies of Zubaidi *et al.* (2020b) and Al-Saati *et al.* (2021).

Other studies focused on the evaluation of water quality. One of the most effective ways to communicate information on water quality trends is using suitable indices (Al-Mansori 2017).

The current study aims at evaluating the water quality of Shatt-al-Hilla River in Babel city, Iraq, which is the only source of freshwater in Babylon governorate, which is home for about 2 million people. In this research, the water quality index was calculated for raw and treated water at three sites, namely New Hilla (NH), Al-Hussein (HU), and Al-Hashimyah (HA). The study was conducted from October 2020 to June 2021. The analysis was conducted using a mathematical method and the Canadian method, and the results were analyzed statistically using the SPSS software.

2. MATERIALS AND METHODS

2.1. Description of the study area

Shatt Al-Hilla is one of Iraq's famous rivers in Hilla city as well as its largest source of water, which extends to 101 km^2. The main source of the river is the Euphrates River, where the river comes from the north boundary of the province of Babylon until it reaches Al-Diwaniya province. Euphrates River is one of Iraq's main irrigation systems, particularly in its mid location. After passing the Al-Hindiya barrage, Shatt Al-Hilla flows out of the river of Euphrates (Salman *et al.* 2013). Shatt Al-Hilla is used for drinking and agriculture. It is considered a significant attraction, but has been exposed to negligence in recent years. Salinity slowly rising along the river was exacerbating the situation (Saod *et al.* 2019). The study area included three stations along the Hilla River, which extended from the city of Hilla to the town of Al-Hashimyah within the governorate of Babylon. These plants represent water treatment New Hilla (NH), Al-Hussein(HU), and Al- Hashimyah(HA). Latitude and longitude for each station are listed in Table 1. Geographical location of the study area is shown in Figure 1.

Table 1 | Latitude and longitude of stations

Station	Latitude	Longitude
New Hilla	32°30′54″	44°24′43″
Al-Hussein	32°23′32″	44°32′11″
Al- Hashimyah	32°22′24″	44°39′87″

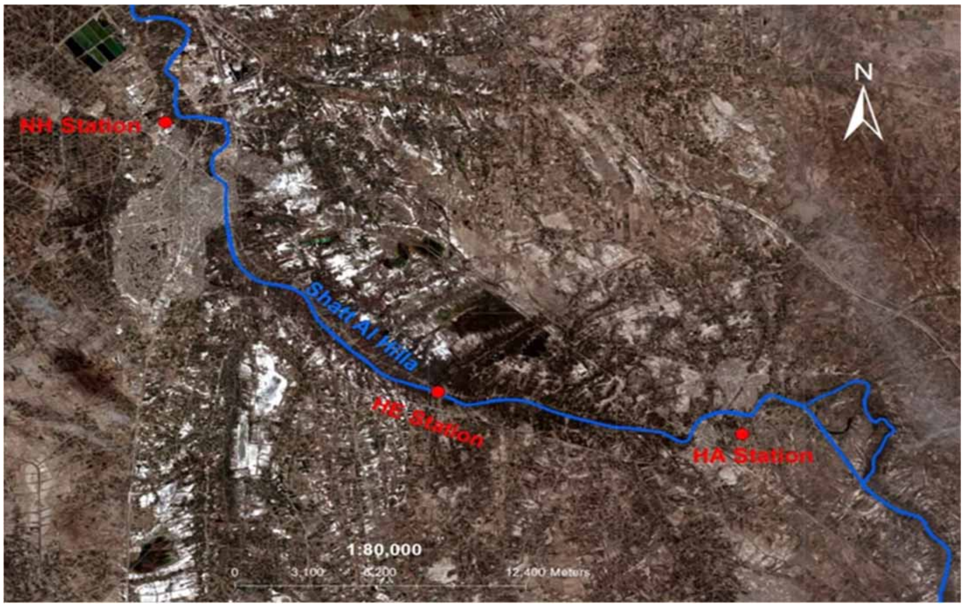

Figure 1 | Location of samples in Shatt Al-Hilla River (Department of Water Resources in Babylon, Iraq).

2.2. Samples collection and preservation

Water samples were collected from Shatt Al-Hilla river within Hilla City for (raw and treated) water for three different stations (New Hilla, Al-Hussein and Al-Hashimyah) to study the physical and chemical parameters and compare them with the Iraqi standard specifications Table 2. The water quality index was determined by using two models, which were the Weighted Arithmetic and Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). Water samples were collected monthly from (October 2020 to June 2021), where twelve parameters of raw and treated water were examined, included temperature (Temp), Total hardness (TH), electrical conductivity (EC), acidity (PH), total dissolved solids (TDS), sulfate (So_4^{-2}), calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+1}), Biological demand for oxygen (BOD), Potassium (K) and turbidity, then calculating the efficiency of the project based on the mathematical method. Then, the results were analyzed graphically using a statistical analysis program (SPSS).

Required chemical parameters were analyzed immediately after sample collection, according to Table 3.

Table 2 | Standard specifications for raw water and drinking water according to the Iraqi standards

Parameter	Maximum limits (raw water)	Maximum limits (treated water)
Temperature	30 °C	25 °C
pH	6.5–8.5	6.5–8.5
Total hardness (TH)	500	500
Calcium (Ca^{+2})	50	150
Magnesium (Mg^{+2})	50	100
Sulfate (SO_4^{-2})	400	400
Sodium (Na^{+})	200	300
Electrical conductivity (EC)	1,000	2,000
Potassium (K^{+})	12	10
Total dissolved solids (TDS)	1,500	1,000
Turbidity	5	5
BOD	5	–

Table 3 | Procedures used for detection of studied parameters

No.	Parameter	(APHA 2005)	Brand and model of the instrument
1	pH	pH meter	HANNA modal HI98107
2	EC	Portable multi meter	HACH 2100H JUMBO PPM
3	Ca^{+2},Mg^{+2} & total hardness	Titration with Na2EDTA	–
4	Sodium	Flame photometer	JENWAY, PFP 7
5	Sulphate	Calorimetry	–
6	Turbidity	Turbidity meter	Model AN HACH 2100N

2.3. WQI calculations

2.3.1. Weighted arithmetic index method

This method transforms vast quantities of quality knowledge of water to a single water level quality number. WQI was used as a guideline for the classification of surface water depending on the use of basic parameters of water characterization (Şener *et al.* 2017).

To accurately depict water quality, the WQI system ideally contains a wide range of water quality criteria, which requires cost and time to calculate. The WQI approach, considered one of the most powerful ways to convey knowledge about water quality patterns to the common person and quality of water control policymakers, has been commonly used in aquatic environments in recent years (Ponsadailakshmi *et al.* 2018). The WQI can be used to highlight water pollutants, both inorganic and organic pollutants, for an effective water quality treatment.

The Water Quality Index (WQI) can be evaluated using the weighted arithmetic strategy that details the water body quality assessment (Călmuc *et al.* 2018). Classification of the computed WQI values shows in Table 4. The equation is:

$$WQI = \sum qi\ Wi / \sum Wi \tag{1}$$

Where:

Table 4 | Classification of water quality according to weighted arithmetic index (Singh 2010)

WQI value	Water quality
0–25	Excellent
26–50	Good water
51–75	Moderately polluted
76–100	Severely polluted
>100	Unfit and unsuitable for drinking

qi: is a relative value of water quality
i: is a number of parameters that are taken into account
Wi: is a factor that calculates parameter significance and *qi* is evaluated by:

$$qi = 100\ [Vi - Vo]/[Si - Vo] \tag{2}$$

where:
V_i: is the experimental value of each parameter.
V_O: is an ideal value of the parameter means that pH and dissolved oxygen 7.0 and 14.6 mg/L respectively and 0 for all other parameters (Călmuc *et al.* 2018).
S_i: is a standard permissible value of water in which an analyzed sample of water was included.
W_i: is a factor evaluated by:

$$Wi = K/S \tag{3}$$

where:
K is a constant, and evaluated by:

$$K = \left[1/\sum 1/Si\right] \tag{4}$$

The mean efficiency (*E*%) was calculated by using the equation below (Zaid Abed Al-Ridah 2020):

$$E\,\% = (Raw\ Water - Treated\ Water)/Raw\ Water \times 10 \tag{5}$$

2.3.2. CCME WQI method

The (CCME WQI) index was described by the Canadian Council of Ministers of the Environment Water Quality (Hurley *et al.* 2012; Ranjbar *et al.* 2016). The index scores are computed as:

$$\boldsymbol{CCME\ WQI} = 100 - (\boldsymbol{F}1 + \boldsymbol{F}2 + \boldsymbol{F}3)\hat{0}.5/1.732 \tag{6}$$

where, the index includes three components: F_1 (scope) represents the variables number not compliant with water quality limits:

$$F_1 = (\text{Number of failed variables/total number of variables}) \times 100 \tag{7}$$

F_2: represents the number of times these limits are not compliant:

$$F_2 = (\text{Number of failed tests}/\text{total number of tests}) \times 100 \tag{8}$$

F_3: represents the quantity by which failed tested values are not compliant with their objectives (limits), which is calculated as follows:

(i) The excursion calculated from Equation (9) when the test value must not be greater than the objective

$$Excursion\ i = (Failed\ test\ value\ i/Objective\ j) - 1 \tag{9}$$

or from Equation (10), where the test value is not less than the objective

$$Excursion\ i = (Objective\ j/Failed\ test\ value\ i) - 1 \tag{10}$$

(ii) The normalized sum of excursions (*nse*) represents the collective quantity by which single tests that are out of agreement are computed by summing the single-test excursions from their objectives and dividing by the number of the total test (all tests), is computed as:

$$nse \sum_{n=1}^{i} (Excursion/Total\ number\ of\ tests) \tag{11}$$

(iii) F_3 can be calculated as:

$$F3 = nse/(nse \times 0.01 + 0.01) \tag{12}$$

After the CCME WQI value was calculated, water quality was classified by linking it to the classes listed in Table 5.

Table 5 | The corresponding values of water quality in conformity with the CCME-WQI index (Lumb *et al.* 2006) and (Mahagamage & Manage 2014)

CCME-WQI-value	Water quality
Excellent	95–100
Good	80–94
Fair	65–79
Marginal	45–64
Poor	0–44

3. RESULTS AND DISCUSSION

It can be noted from Tables 6–11 that all the estimated values of the chemical and physical parameters of the s-tudied water treatment plants are within the Iraqi specifications except for calcium, turbidity, electrical conductivity of raw water, and temperature of treated water.

3.1. VARIATION OF WATER QUALITY INDEX

According to Iraqi water quality standard limits and using the prior equations, the monthly raw and treated WQI was calculated below.

3.1.1. Weighted arithmetic index method

3.1.1.1. Raw water quality index (RWQI). The raw water quality index results for all stations are shown in Table 12. It was found that the quality of raw water for all stations ranged between (53.977) in the HA station in January and (138,586) in the HE station in October. In addition, the mean WQI of the river ranged from

Table 6 | Laboratory chemical and physical indicators for raw water for New Hilla project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.466	28.833	13.933	1,044.666	406.333	116.333	28.333	307.000	690.666	73.666	2.900	0.25
11	7.533	22.366	9.666	980.333	354.000	84.333	34.666	258.333	600.000	67.000	3.933	0.27
12	7.350	16.200	10.933	914.333	351.666	75.333	39.666	207.333	543.333	72.666	4.166	0.3
1	7.340	17.633	9.333	917.333	316.000	67.333	37.000	213.000	547.333	70.000	3.333	0.87
2	7.700	19.067	8.867	919.000	314.667	66.667	35.000	220.000	551.000	70.667	3.167	0.3
3	7.767	18.533	9.167	918.333	321.333	67.333	34.667	221.667	551.000	70.667	3.100	0.303
4	7.633	21.666	9.167	917.333	311.666	59.333	32.000	212.333	526.333	68.666	3.200	0.31
5	7.600	24.333	9.166	911.666	303.666	60.000	31.333	209.333	523.666	64.666	3.066	0.303
6	7.666	25.500	11.166	898.000	292.666	58.000	29.666	200.333	508.000	57.666	2.933	0.296

Table 7 | Laboratory chemical and physical indicators for treated water for New Hilla project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.433	28.933	1.633	1,039.000	396.666	113.333	27.666	307.000	678.666	73.333	2.866	0
11	7.466	22.766	1.633	986.000	353.666	82.333	35.666	257.333	602.666	65.333	3.833	0
12	7.266	16.933	0.500	913.666	346.666	75.333	37.000	200.666	544.666	72.666	4.166	0
1	7.350	17.666	0.433	919.666	311.666	65.666	36.333	205.333	546.666	69.333	3.366	0
2	7.610	19.500	0.467	919.000	315.000	65.667	35.333	216.333	550.000	71.667	3.267	0
3	7.743	19.067	0.500	919.667	319.333	66.667	34.667	220.000	551.667	71.333	3.167	0
4	7.633	22.333	0.533	918.333	313.000	61.000	31.333	211.666	528.000	70.000	3.266	0
5	7.666	25.000	0.600	914.000	304.666	61.000	31.000	207.666	527.000	66.333	3.166	0
6	7.600	25.000	0.300	901.333	294.333	59.333	31.000	200.333	506.666	59.000	3.000	0

Table 8 | Laboratory chemical and physical indicators for raw water for Al-Hussien project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.366	29.433	18.600	1,035.666	399.666	115.333	27.000	310.000	682.000	76.333	3.033	0.316
11	7.266	24.700	15.133	972.000	325.333	80.333	30.000	233.000	575.666	77.000	3.033	0.326
12	7.666	17.400	10.333	926.666	340.000	74.666	37.000	220.666	580.666	76.000	4.066	0.313
1	7.733	19.066	11.670	926.333	321.666	68.000	37.000	207.666	554.666	55.333	4.000	0.303
2	7.600	23.067	10.600	1,034.667	335.333	71.000	37.667	229.333	556.000	83.667	3.933	0.303
3	7.533	20.667	11.000	1,034.333	335.667	70.333	38.000	230.000	556.667	84.333	4.000	0.29
4	7.600	22.333	10.666	1,031.333	324.000	67.000	37.666	220.333	548.000	79.333	3.900	0.296
5	7.600	23.666	11.000	1,014.000	316.000	65.000	34.666	210.000	539.333	75.333	3.766	0.296
6	7.833	28.666	12.666	975.000	312.000	69.000	32.666	198.000	521.000	69.000	3.900	0.32

Table 9 | Laboratory chemical and physical indicators for treated water for Al-Hussien project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.466	29.033	4.133	1,072.333	410.333	117.333	26.666	304.666	705.000	81.666	3.100	0
11	7.433	24.400	3.500	969.666	339.666	81.000	32.000	230.000	574.666	78.000	3.166	0
12	7.500	17.500	3.333	931.333	342.000	74.666	37.666	215.666	584.000	76.333	4.133	0
1	7.666	18.900	1.266	952.333	324.666	70.666	38.666	211.000	582.666	63.333	4.133	0
2	7.500	22.833	2.433	1,044.333	342.333	71.000	40.000	232.000	583.667	85.333	4.000	0
3	7.400	19.833	1.833	1,041.333	340.000	70.667	39.333	232.333	583.000	86.000	4.100	0
4	7.500	21.000	1.733	1,037.666	330.333	68.666	39.000	222.000	562.333	81.333	3.900	0
5	7.600	21.666	1.466	1,020.666	321.000	66.666	36.000	212.333	552.000	76.333	3.833	0
6	7.733	28.333	1.333	1,011.000	316.666	70.333	33.666	202.000	526.000	71.666	3.633	0

Table 10 | Laboratory chemical and physical indicators for raw water for Al-Hashimyah project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.200	28.800	14.000	1,037.666	402.666	101.000	28.000	305.333	684.666	72.333	2.800	0.253
11	7.200	24.966	12.000	980.666	342.666	87.000	30.500	270.000	610.000	75.666	3.133	0.263
12	7.466	19.000	12.000	932.333	365.000	76.333	43.666	213.666	570.333	68.000	4.133	0.243
1	7.133	18.000	6.000	949.333	312.333	71.666	38.000	208.333	551.666	71.000	3.366	0.256
2	7.167	18.433	8.600	950.333	314.000	71.333	36.333	212.667	553.667	71.667	3.333	0.277
3	7.200	18.567	10.667	951.667	315.000	70.333	35.333	213.667	554.333	72.000	3.300	0.287
4	7.266	20.000	11.500	948.333	319.000	71.666	36.666	211.333	554.333	71.000	3.533	0.3
5	7.200	22.000	9.666	944.666	317.000	69.000	34.666	209.333	551.333	68.000	3.566	0.286
6	7.400	24.000	13.666	900.000	305.000	70.333	31.000	200.000	555.000	67.000	3.433	0.283

Table 11 | Laboratory chemical and physical indicators for treated water for Al-Hashimyah project

Month	pH	Temp	Turb	EC	TH	Ca	Mg	SO_4	TDS	Na	k	BOD
10	7.200	28.566	5.000	1,039.333	394.333	112.000	28.666	304.666	688.666	73.333	2.666	0
11	7.366	24.233	2.833	1,002.000	360.666	88.666	33.666	265.333	660.000	71.666	3.133	0
12	7.400	20.333	4.200	942.333	364.000	75.666	43.333	209.000	581.000	68.000	4.100	0
1	7.166	17.866	1.066	947.666	311.000	70.333	36.000	213.000	583.000	69.666	3.333	0
2	7.267	18.267	1.067	949.333	313.333	70.333	36.666	213.000	576.000	71.000	3.300	0
3	7.267	18.267	1.133	950.333	313.667	69.333	36.333	212.333	577.000	71.333	3.300	0
4	7.300	19.666	1.000	949.000	317.000	71.000	37.333	210.000	560.333	70.333	3.500	0
5	7.200	21.333	1.133	946.666	315.000	69.333	36.000	208.333	557.000	69.666	3.500	0
6	7.300	23.666	0.966	902.666	311.000	69.666	32.666	197.333	558.333	67.666	3.533	0

Table 12 | Raw water quality index values of the stations

	(2020–2021)		
Month	**NH**	**HE**	**HA**
10/2020	115.289	138.586	104.564
11/2020	92.031	112.362	93.366
12/2020	91.456	100.048	102.327
1/2021	83.969	109.887	53.977
2/2021	91.670	99.645	70.152
3/2021	95.819	98.975	83.133
4/2021	90.725	99.573	91.075
5/2021	89.694	101.241	78.092
6/2021	103.376	120.740	108.527
Mean	94.892	109.006	87.246

(87,246) in the HA station to (109.006) in the HE station. From these WQI values and according to Table 4, the river water was classified as 'highly polluted' to 'unfit for drinking' for the studied stations during the study period of the year (2020–2021). The poor water quality in the Hilla River is due to the untreated household pollutant disposal site, which was discharged directly through wastewater (Singh 2010). The monthly values (WQI) of raw water are shown in Figure 2, and this figure represents (WQI) of the stations selected during the study period.

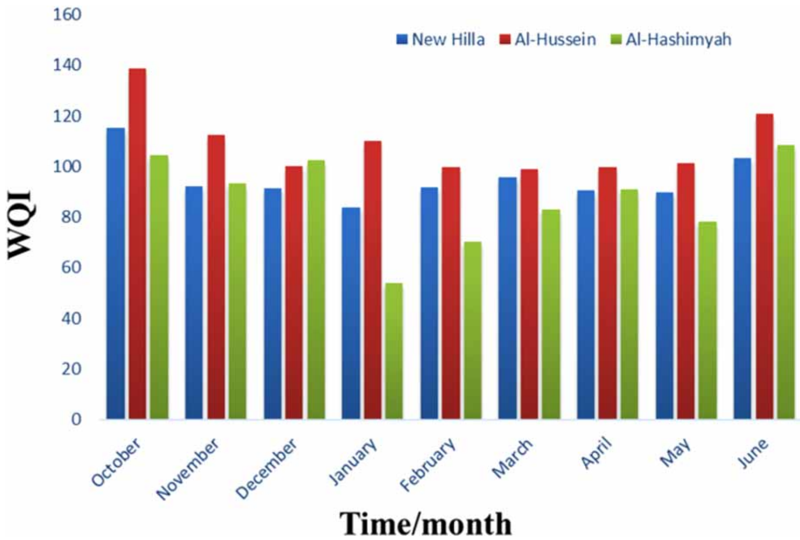

Figure 2 | Temporal variation in WQI from October 2020 to June 2021 for raw water.

3.1.1.2. Treated water quality index (TWQI). Table 13 shows the variation in (WQI) monthly values of treated water for the specified stations during the study period. The treated water quality index (TWQI) ranged between (34.237–58.271), (52.952–76.171) and (31.986–72.142) in NH, HE and HA, respectively. This means that the treated water ranges from 'Poor' to 'Marginal' at the NH plant, 'Marginal' to 'Fair' at the HE plant, and 'Poor' to 'Fair' at the HA station. The monthly values (WQI) of the treated water are plotted according to Figure 3.

The mean efficiency (E%) was calculated using Equation (5). As shown in Table 14 and Figure 4, the New Hilla treatment plant was efficient compared to the other water treatment plants. The quality of treated water has decreased along the river (from Al-Hussein station to Al-Hashimyah station) due to low raw water quality and low water efficiency (E%).

Table 13 | Treated water quality index values of the stations

	(2020–2021)		
Month	**NH**	**HE**	**HA**
10	53.832	76.171	67.848
11	55.307	67.579	58.706
12	34.237	69.583	72.142
1	36.690	62.275	31.986
2	51.240	63.876	37.467
3	58.271	52.952	37.981
4	53.765	57.404	39.556
5	56.692	60.574	35.767
6	50.378	68.300	33.430
Mean	50.046	64.302	46.098

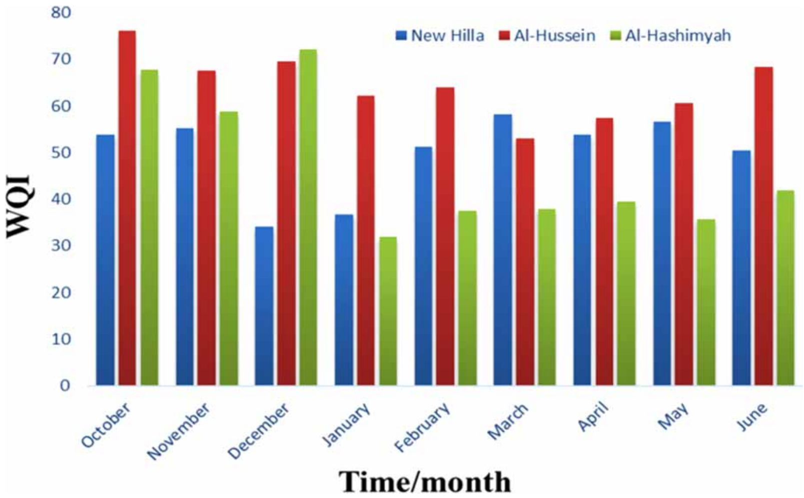

Figure 3 | Temporal Variation in WQI from October 2020 to June 2021 for treated water.

Table 14 | Mean efficiency (E %) of the stations (AbdAL-Hussein 2015)

Year	(2020–2021)		
Station	**NH**	**HE**	**HA**
E %	47.13	40.78	47.04

3.1.2. CCME WQI method

Table 15 and Figure 5 show a summary of the values of F_1, F_2, F_3, CCME WQI values and water quality assessment for all stations, where the raw water quality value was (81.232), (79.307) and (80.931) for the three stations respectively. This indicates that the water quality can be classified as 'good' for NH, 'acceptable' for HE and 'good' for HA. This is because some standards for raw water samples such as Tur, Ca and EC exceed water quality standards (Rachedi & Amarchi 2015). Human actions also affect water quality, with wastewater pollution and agricultural runoff from lands near the river affecting water quality (Hassan *et al.* 2018). The results showed that the treated water is of high value, as the value of treated water ranged between 94,620 and 94.718, indicating that the quality of the treated water in the three plants was 'good'. The higher concentration of criteria may be

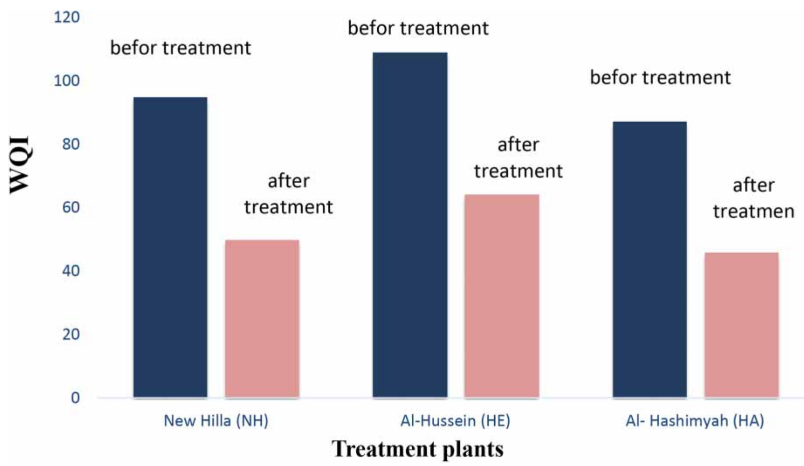

Figure 4 | Graphical comparison of water quality index for three treatment plants (by Weighted arithmetic method).

Table 15 | F_1, F_2, F_3 and CCME WQI values and water quality classification of the stations

		(2020–2021)		
Year/Stations		**NH**	**HE**	**HA**
Raw water	CCME WQI value	81.232	79.307	80.931
	Classification	Good	Fair	Good
	F_1	25	25	25
	f_2	17.592	21.296	17.592
	F_3	11.050	14.351	12.501
Treated water	CCME WQI value	94.718	94.620	94.718
	Classification	Good	Good	Good
	F_1	9.090	9.090	9.090
	f_2	1.010	2.020	1.010
	F_3	0.158	0.296	0.143

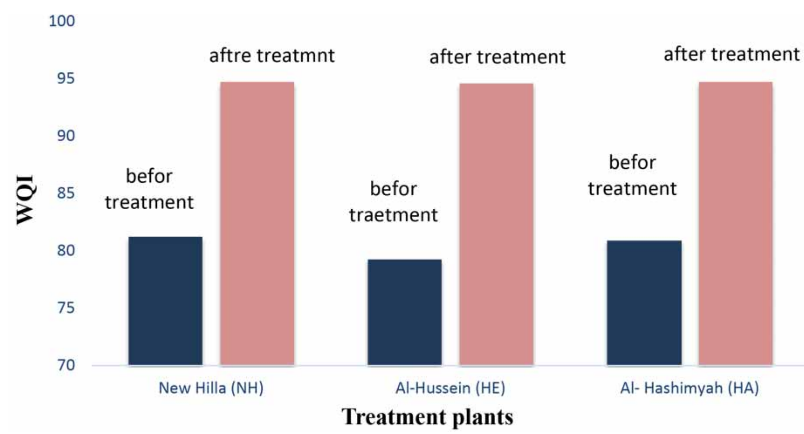

Figure 5 | Graphical comparison of water quality index for three treatment plants (by Canadian method).

caused by either local sewage pollution or the high presence because river or rain velocities are very high, and soil filtration is high (Alobaidy *et al.* 2010; Rachedi & Amarchi 2015; Hassan *et al.* 2018).

Table 16 summarizes the water quality in each specific station using the weighted calculation method and CCME water quality indicators, and the result from the treated water shows the convergence of the indicators for all stations. Meanwhile, the difference in points is clearly visible in the state of raw water in all stations, so

Table 16 | The treated water quality of each station and each index

	NH		HE		HA	
WQI	**RW**	**TW**	**RW**	**TW**	**RW**	**TW**
Mean of weighted arithmetic	94.892 Severely polluted	50.046 Good water	109.006 Unfit and unsuitable for drinking	64.302 Moderately polluted	87.246 Severely polluted	47.028 Good water
CCME	81.232 Good	94.718 Good	79.307 Fair	94.620 Good	80.931 Good	94.718 Good

the water quality ranged between 'highly polluted' and 'unsafe for drinking' by the method of weighted calculation, while it was 'good' to 'fair' according to Canadian method. The study believed that the difference of scores might be related to the index theory on which the criterion was built and that CCME gave a higher level of water quality that could be considered and thus a more flexible weighted calculation method. Although indicators are used to determine water quality worldwide, no indication has been accepted as universal. This allows researchers, environmental agencies, policymakers, and others to continue exploring and modifying existing ones to obtain a more accurate, transparent, comprehensive and global index.

4. STATISTICAL ANALYSIS

4.1. Raw water for three stations

The following are the results of the descriptive statistics of raw water data for the New Hilla project for the year (2020–2021), which were recorded according to the characteristics of each factor and the value of the general averages, standard deviations and standard error rate for each of them. The truth is described in detail in Tables 17–19:

Table 17 | Means, standard deviations, and average error of the characteristics for the New Hilla project

	N	Mean		Std. deviation
The characteristics	**Statistic**	**Statistic**	**Std. error**	**Statistic**
WQI	9	94.89	3.08	9.24
K	9	3.31	0.15	0.44
Na	9	68.41	1.62	4.87
TDS	9	560.15	18.42	55.26
SO_4	9	227.70	11.35	34.05
Mg	9	33.59	1.20	3.60
Ca	9	72.74	6.12	18.36
T.H	9	330.22	11.67	35.00
EC	9	935.67	15.62	46.87
Turb	9	10.16	0.55	1.64
Temp	9	21.57	1.38	4.13
PH	9	7.56	0.05	0.15

4.2. Drinking water for three stations

The following are the results of the descriptive statistics of raw water data for the New Hilla project for the year (2020–2021), which were recorded according to the characteristics of each factor and the value of the general averages, standard deviations and standard error rate for each of them. The truth is described in detail in Tables 20–22.

Finally, the authors of this work recommend using sensing systems to monitor the water quality of freshwater. The possible sensing methods are electromagnetic sensors (Omer *et al.* 2021; Ryecroft *et al.* 2021) and

Table 18 | Means, standard deviations, and average error of the characteristics for the Al Hussein project

The characteristics	N Statistic	Mean Statistic	Mean Std. error	Std. deviation Statistic
WQI	9	109.01	4.48	13.43
K	9	3.74	0.14	0.41
Na	9	75.15	2.91	8.74
TDS	9	568.22	15.41	46.23
SO_4	9	228.78	10.86	32.59
Mg	9	34.63	1.32	3.95
Ca	9	75.63	5.19	15.57
T.H	9	334.41	8.73	26.19
EC	9	994.44	15.26	45.78
Turb	9	12.41	0.92	2.76
Temp	9	23.22	1.34	4.02
PH	9	7.58	0.06	0.17

Table 19 | Means, standard deviations, and average error of the characteristics for the Hashimyah project

The characteristics	N Statistic	Mean Statistic	Mean Std. error	Std. deviation Statistic
WQI	9	87.25	5.93	17.79
K	9	3.40	0.12	0.36
Na	9	70.74	0.90	2.70
TDS	9	576.15	14.94	44.83
SO_4	9	227.15	11.89	35.67
Mg	9	34.91	1.55	4.66
Ca	9	76.52	3.57	10.70
T.H	9	332.52	10.75	32.24
EC	9	955.00	12.50	37.50
Turb	9	10.90	0.84	2.52
Temp	9	21.53	1.24	3.72
PH	9	6.45	0.81	2.42

microwaves (Omer *et al.* 2021; Ryecroft *et al.* 2021). Also, it recommended monitoring the emissions of local industries due to their direct effects on the quality of surface water. For example, there are cement plants in the city of Babylon, and the emissions of this industry are responsible for many pollutions problems (Kadhim *et al.* 2020; Majdi *et al.* 2020; Mousazadeh *et al.* 2021), such as particulates (Shubbar *et al.* 2020a; Kadhim *et al.* 2021) and carbon dioxide (Shubbar *et al.* 2020b).

5. CONCLUSION

From this work, the following can be concluded:

1. The mathematical method shows that the water quality index for the three stations ranged from good water to unfit and unsuitable for drinking.

Table 20 | Means, standard deviations, and average error of the characteristics for the new Hilla project

The characteristics	N Statistic	Mean Statistic	Mean Std. error	Std. deviation Statistic
WQI	9	50.05	2.88	8.64
K	9	3.34	0.14	0.41
Na	9	68.78	1.52	4.56
TDS	9	559.56	17.26	51.77
SO_4	9	225.15	11.75	35.24
Mg	9	33.33	1.06	3.18
Ca	9	72.26	5.70	17.09
T.H	9	328.33	10.63	31.89
EC	9	936.74	15.10	45.31
Turb	9	0.73	0.17	0.52
Temp	9	21.91	1.32	3.97
PH	9	7.53	0.05	0.16

Table 21 | Means, standard deviations, and average error of the characteristics for the Al-Hussain project

The characteristics	N Statistic	Mean Statistic	Mean Std. error	Std. deviation Statistic
WQI	9	64.30	2.33	6.98
K	9	3.78	0.13	0.40
Na	9	77.78	2.36	7.09
TDS	9	583.70	16.49	49.48
SO_4	9	229.11	10.07	30.22
Mg	9	35.89	1.46	4.39
Ca	9	76.78	5.25	15.75
T.H	9	340.78	9.27	27.80
EC	9	1,008.96	15.84	47.51
Turb	9	2.34	0.36	1.07
Temp	9	22.61	1.34	4.01
PH	9	7.53	0.04	0.11

2. The results of the water quality index were good water to fair according to the Canadian method.
3. Most of the water quality index results were good. In the case of the Canadian method, CCME WQI is more flexible than other methods used to calculate quality.
4. The new Al-Hilla water treatment plant was more efficient than the Al-Hussein and Al-Hashimyah plant.
5. The low water quality in these stations along the Hilla River can also be noted as a result of the low quality of raw water and the low water efficiency in these stations.
6. There is a strong correlation between chemical and physical indicators with water quality.

Additionally, the following recommendations are suggested for future studies:

1. Study the effect of another parameter such as Cl, P, Na, and so on, and study more physical and chemical measures must be tested.

Table 22 | Means, standard deviations, and average error of the characteristics for the Hashimyah project

The characteristics	N Statistic	Mean Statistic	Mean Std. error	Std. deviation Statistic
WQI	9	47.03	5.01	15.04
K	9	3.37	0.13	0.38
Na	9	70.30	0.60	1.79
TDS	9	593.48	15.81	47.42
SO_4	9	225.89	11.75	35.25
Mg	9	35.63	1.32	3.96
Ca	9	77.37	4.80	14.40
T.H	9	333.33	10.41	31.22
EC	9	958.81	13.07	39.22
Turb	9	2.04	0.52	1.57
Temp	9	21.36	1.18	3.55
PH	9	7.27	0.03	0.08

2. Use other types of international indices to explain more carefully the water quality index and parameters affected.
3. Extend the study from upstream to downstream at all seasons to include other parameters such as heavy metals and microbial studies in an exhaustive view of the functioning of the river.
4. Use another statistical analysis method to explain the relationship between parameters and the water quality, such as ANN.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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