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MATHEMATICAL COMPUTATION OF WATER QUALITY INDEX FOR THE ASSESSMENT OF AL-HILLA RIVER ECOSYSTEM

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ABSTRACT

Al-Hilla River has a great importance to the people in the vicinity which serves as a main drinking and irrigation source. The aim of the current study is to estimate the Water Quality Index (WQI) of Al-Hilla River, southern Baghdad using the weighted arithmetic water quality index method. Water samples were collected from 7 stations in March in which eight water quality parameters were analyzed: Turbidity, total dissolved solids, dissolved oxygen, concentration of hydrogen ion, electrical conductivity, chlorides, alkalinity and biological oxygen demand. The calculated WQI of Al-Hilla River indicates that the river water is unsuitable for drinking which is majorly attributed to the total dissolved solids and turbidity. This interprets the condition of the river which can help the local authority in taking action by identifying the sources of pollution and improving the water quality and stakeholders should be involved in the decision making and mitigation alternatives.

Key words: WQI, Al-Hilla River, Euphrates River, Iraq

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1. INTRODUCTION

The two dominating surface water sources in Iraq are Tigris and Euphrates and their tributaries. Besides the surface water, ground water and springs can be considered as supporting sources [1]. Nowadays, Iraq facing a real water crisis as the discharge in both of Tigris and Euphrates goes down to a remarkable values which affects the drinking, irrigation and other uses in the country. This is due to the building of many dams on both of the rivers in the riparian countries, climate change and the severe decrease in annual precipitation which reduces Iraqi share of water [2]. With the available quantity of water, the quality is highly recommended to be investigated. According to the Ministry of Water Resources, 32 percentages of Iraqis has an access to clean drinking water and only 19 percentages has an access to an acceptable sewage system [3 and 4]. There are varieties of pollutants being disposed into both rivers from the non-point sources (i.e. runoff) and point sources (like industrial wastes, agricultural and sewage) [5]. This necessitates more studies on water quality in Iraqi rivers in order to identify the major sources of pollution and mitigation alternatives.

[6] Assessed the Water Quality Index (WQI) of 11 streams and the receiving UM- Al Naaj marshland at Misan governorate, Iraq using five water quality parameters in which it is indicated that the quality of water ranging from good to excellent. [2] Assesses the drinking water quality of Al-Kufa River for a duration of 12 months using the WQI and the Geographic Information System (GIS) in which it is indicated that the quality of Al-Kufa River is classified as very poor. This is due to the human activities along the river banks. [7] Evaluated the water quality via WQI of Al-Gharraf River, branch of Tigris River in the southern parts of Iraq in which samples were collected from five stations for duration of one year and eleven water quality parameters were considered. Results showed different index for different stations in which the water is poor in stations 1,2,3 and 4 whereas showed very poor quality in station 5. Another study was performed in Iraq in which ten water quality parameters were adopted to estimate the WQI in Dokanlake in northern parts of the country. Results showed that the quality of water is deteriorating which was good in years 1978, 1979, 1980, 1999, 2000 and 2008 to be a poor quality in 2009 and it is recommended the continuous monitoring of the water quality in the lake for proper management and action [8].

The objectives of the current work is to apply the water quality index (WQI) for Al-Hilla River based on the monitored water quality parameters and to help the local authority concerning proper organization of water resources. Furthermore, is to shape a base data which will help in future water supervision and protection preparations.

2. MATERIALS AND METHODS

2.1. Study Area

The study area is located in Al-Hilla city, Babylon, south of the capital Baghdad. Euphrates River enters Babylon and divided into two rivers; the first one goes to Karbalaa and the second one enter to Al-Hilla city and supply the water to the city. Figure 1 depicts the study area.

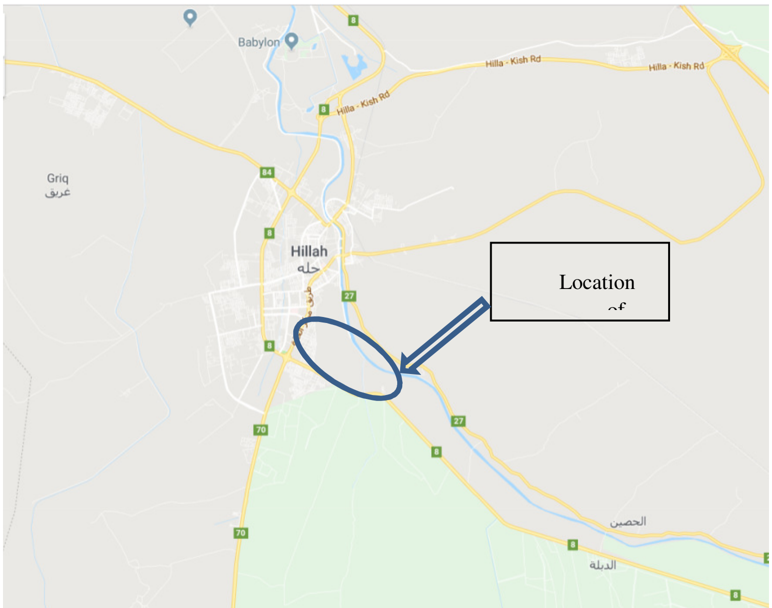

Figure 1 Location of the study area

2.2. Data Collection

Data collection includes water quality samplings that have been collected from seven stations in which each station consists of three locations (i.e. left, middle and right of

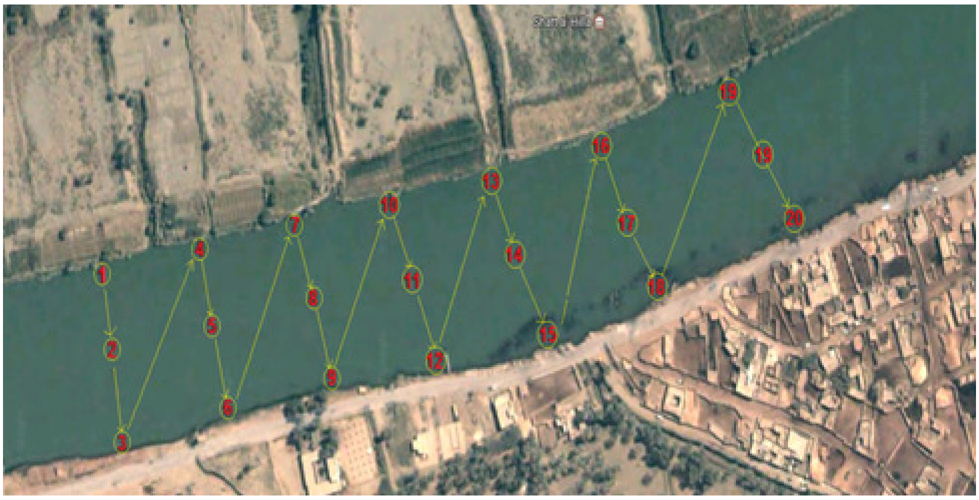

Figure 2 Water quality sampling stations

Table 1 Coordinates of water sampling

No.	Location	Latitude	Longitude
1	Left	32.4592	44.4426
2	Middle	32.4591	44.4422
3	Right	32.4592	44.4419
4	Left	32.4584	44.4422
5	Middle	32.4583	44.4424
6	Right	32.4582	44.4420
7	Left	32.4569	44.4431
8	Middle	32.4568	44.4428
9	Right	32.4567	44.4424
10	Left	32.4560	44.4434
11	Middle	32.4561	44.4430
12	Right	32.4559	44.4425
13	Left	32.4551	44.4437
14	Middle	32.4549	44.4433
15	Right	32.4546	44.4430
16	Left	32.4535	44.4444
17	Middle	32.4534	44.4439
18	Right	32.4532	44.4436
19	Left	32.4515	44.4435
20	Middle	32.4513	44.4449
21	Right	32.4508	44.4449

Water samples were collected in March. Samples were analyzed according to American Public Health Association (AHPA) standard methods [9]. Table 2 presents the monitored water quality parameters.

Table 2 Water quality parameters

No.	Parameter	Unit	Site
1	Turbidity	NTU	Laboratory
2	TDS	mg/l	Laboratory
3	DO	mg/l	In situ
4	pH	pH units	In situ
5	Electrical Conductivity	µS/cm	In situ
6	Chlorides	mg/l	Laboratory
7	Alkalinity	mg/l	Laboratory
8	BOD	mg/l	Laboratory

2.3. Water Quality Index Calculation

The water quality index for the river was calculated based on weighted arithmetic index method for eight parameters namely: pH, turbidity, TDS, BOD, DO, alkalinity, chlorides and electrical conductivity for seven stations in which each station got three sampling points (i.e. left side, middle and right side of the river) as indicated in Figure 2. The weighted arithmetic water quality index method was applied [10] in which the water quality parameters were multiplied by a weighting factor and are then aggregated using a simple arithmetic mean using the following equations:

$$\mathrm{Qi} = \left(\frac{\mathrm{Mi} - \mathrm{Li}}{\mathrm{Si} - \mathrm{Li}}\right) \times 100$$

$$\mathrm{Wi} = \frac{\mathrm{K}}{\mathrm{Si}}$$

$$\mathrm{WQI} = \sum_{i=1}^{n} \frac{WiQi}{\sum_{i=1}^{n} Wi}$$

Where, Qi is the sub index of the ith parameter, Wi is the unit weightage of the ith parameter, n is the number of parameters included, Mi is the monitored value of the parameter, Li is the ideal value, Si is the standard value of the ith parameter.

According to [11], the quality of water regarding the WQI classification is given in Table 3

Table 3 Water Quality Index Classification

Range	Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unsuitable for drinking

3. RESULTS AND DISCUSSIONS

Based on the equations listed above, the WQI for the seven stations in Al-Hilla River was calculated using the weighted arithmetic index method for the eight parameters mentioned earlier in this study. The results of water quality monitoring for the seven stations are presented in Table 4. In each station, three samples are collected (left side, middle and right side of the river) and then average values for each station were adopted. Based on the results of monitoring in the river, there are some differences in water quality parameters within the seven stations. WQI calculations denoted that the quality of the water is decreasing as moving downstream. This can be attributed to the multiple discharge points (i.e. sewage from multiple sources) along the river which introduces various pollutants. The Iraqi water crises caused by building of dams in Turkey, limited rain and the old irrigation system (produces high losses) which subsequently results in fluctuations in water level and hence encouraged the drainage of groundwater into the river water body [12]. This fluctuation in water level affects the quality of water especially in summer when the water from reservoirs (full of organic materials and sediments) is discharged into the water body to compensate the reduction in water level [13]. Furthermore, soil erosion caused by runoff has dramatic impact as it introduces large quantities of sediments and suspended solids to the water body [14].

Table 6 illustrates the results of WQI for the stations of one to seven which are 474.95, 505.97, 510.86, 480.34, 447.7, 526.21 and 501.43 respectively in which the water quality in all stations is classified as unsuitable for drinking (refer to Table 3).

In Al-Hilla River, each of the monitored water quality parameters give different value for different stations due to the reasons highlighted earlier as illustrated in Table 4. For the turbidity, it is considered as an essential water quality parameter since it affects the water via suspended particles and affects other parameters like DO and BOD [15]. It is clear that the turbidity values for all the stations are much higher than the standard value < 5 NTU specified by WHO [3]. The turbidity values play an important role in deteriorating the WQI for the seven stations. For the TDS values, it is clear also that some of the monitored values are higher than the standard value specified by WHO [3] is 1000 mg/l. According to Table 4, the TDS values in stations 1, 2, 4, 5, 6 and 7 are exceeding the standard value except station 3 which is below the recommended level.

Table 4 Monitored values of water quality parameters

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Turbidity	80	85	87	79	73	88	81
TDS	1009.8	1012.95	617.85	1037.7	1011.15	1011.15	1019.25
DO	7.2	6.8	6.6	6.5	7.1	7.3	7.5
pH	6.69	6.69	7.06	6.68	6.75	6.85	6.87
EC	1122	1125.5	980	1153	1123.5	1123.5	1132.5
Cl	150	163	188	197	211	199	201
Alkalinity	245	220.5	140.5	273	204	236	252
BOD	2	2.61	3.2	3.56	4.3	4.7	7.3

The DO is an important water quality parameter in evaluating the quality of water since it is essential in bacterial actions in breaking down the organic matter available in water [16]. The DO values monitored in the river are higher than the standard value 5 mg/l. concerning the pH values; they are different between stations in an acceptable level with a standard value of 7.5

The values of electrical conductivity (EC) monitored in the river for all the stations show very high level as compared with the standard value of 250 µS/cm set by WHO [3]. The values of chlorides were acceptable in which they are below the standard set by WHO. For the alkalinity, only station 3 is below the standard < 200 mg/l as $CaCo_3$ whereas other stations recorded higher values.

Eventually, the BOD values for the stations of one to six recorded lower values than the standard value of 5 mg/l except station 7 which recorded a value of 7.3 mg/l.

The ideal values and standard values for the eight water quality parameters are presented in Table 5 below:

Table 5 Standard and ideal values of water quality parameters

Parameter	Standard value	Ideal value
Turbidity	5	0
TDS	1000	0
DO	5	14.6
pH	7.5	7
EC	250	0
Cl	350	0
Alkalinity	200	0
BOD	5	0

The estimated water quality index values for the seven stations are presented in Table 6 below.

Table 6 Water quality index for the seven stations

Station	WQI	Quality
1	474.95	Unsuitable for drinking
2	505.97	Unsuitable for drinking
3	510.863	Unsuitable for drinking
4	480.34	Unsuitable for drinking
5	447.703	Unsuitable for drinking
6	526.216	Unsuitable for drinking
7	501.433	Unsuitable for drinking

As highlighted in Table 6 above, the WQI index values for all the stations show that the water is unsuitable for drinking. This is attributed majorly to the high turbidity and TDS values that exceed the standard values specified by the WHO [3]. The original WQI values and the WQI (excluding turbidity and TDS) were presented in Table 7 below.

Table 7 Comparison between the original WQI and the WQI without turbidity and TDS

Station	WQI	Quality	WQI (Excluding TDS and Turbidity)	Quality
1	474.95	Unsuitable for drinking	62.754	Poor
2	505.97	Unsuitable for drinking	68.67	Poor
3	510.863	Unsuitable for drinking	60.784	Poor
4	480.34	Unsuitable for drinking	77.66	Very poor
5	447.703	Unsuitable for drinking	76.98	Very poor
6	526.216	Unsuitable for drinking	74.393	Poor
7	501.433	Unsuitable for drinking	91.866	Very poor

As illustrated in Table 7, the original water quality index for all the stations indicates that the water is unsuitable for drinking but when the TDS and turbidity were excluded, the WQI values were changed in which the water quality is poor in stations 1, 2, 3 and 6 whereas the quality is very poor in stations 4, 5 and 7. Based on that, the water quality can be improved by reducing the TDS and turbidity values to desirable limits. The TDS values can be minimized by treating the sewage water prior to their direct disposal into the river and reducing human activities that have a direct impact to the water body [17]. For the turbidity values, it is highly recommended that erosion control measures are installed along the river banks so as to minimize the erosion of soil at source [18]; [19]; [20]. Furthermore, sediment control measures that capture the sediments before being washed into the water [14]. Drainage control measures can also be installed to capture and minimize the runoff water [21]; [22].

4. CONCLUSIONS AND RECOMMENDATIONS

Al-Hilla River has a great importance to the people in the region for drinking and irrigation purposes. This study aimed to assess the water quality of Al-Hilla River via estimating the WQI of the river based on eight parameters. Based on the monitored water quality parameters for seven stations, the WQI values were very high which expresses water quality "unsuitable for drinking". This is attributed to the disposal of drainage of irrigation water, untreated sewage and runoff of water to the water body. It is noticed that the turbidity and TDS values were higher than the standard values in remarkable values. The WQI for the seven stations were re-calculated excluding the turbidity and TDS to get a real evaluation of the water quality. For some of the stations the quality were altered to polluted and for the rest of stations altered to very polluted. Even with the exclusion of turbidity and TDS the water is not suitable yet for drinking. Thus, this is emphasis on adopting control measures (erosion, sediment and drainage controls) to improve runoff quality. Furthermore, it is recommended to take more samples during different months of the year to give a better representation of the data and involving more parameters. Eventually, stakeholders must be involved in the decision making and mitigation alternatives.

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