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Research Article

Applied of CCME Water Quality Index for Protection of Aquatic Life for Al-Hussainiya River within Karbala City, Iraq

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Abstract

In the present study, Al-Hussainiya River within Karbala City was monitored for a variety of chemical and physical parameters to determine water quality during 2016. Water quality indices (WQIs) were calculated for protection of aquatic life, using the model of CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index). Ten parameters were selected namely: Lead, Cadmium, Iron, Turbidity, pH value, Dissolved Oxygen, Water Temperature, Nitrate, Chloride and Total Dissolved Solids (TDS). The results revealed that station 1 which was located in upstream of River was more polluted than the other stations. The WQI ranking was poor in all stations. The highest deviation occurred in lead, Cadmium, TDS, and Turbidity, this parameters made a big contribution in decreasing the value of WQI.

Keywords: *Water quality index, Aquatic life, Al-Hussainiya Rive.*

1. Introduction

Euphrates & Tigris Rivers in Iraq are the major sources of water. It is used for mainly important water uses such as industrial, livestock, drinking, fishing, and irrigation (Farhan, 1992). The aquatic ecosystem is composed of the biological community (producers, consumers, and decomposers), the physical and chemical (abiotic) components, and their interactions.

Within the aquatic ecosystem, a complex interaction of physical and biochemical cycles exists, and changes do not occur in isolation.

Aquatic systems undergo constant change However, an ecosystem has usually developed over a long period of time and the organisms have become adapted to their environment. In addition, ecosystems have the capacity to withstand and assimilate stress based on their unique physical, chemical, and biological properties. Nonetheless, systems may become unbalanced by natural factors, which include drastic climatic variations or disease, or by factors due to human activities. Any changes, especially rapid ones, could have detrimental or disastrous effects. Adverse effects due to human activity, such as the presence of toxic chemicals in industrial effluents, may affect many components of the aquatic ecosystem, the magnitude of which would depend on both biotic and abiotic site-specific characteristics (CCME 1999).

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Through the development of a number of indicators to summarize water quality data in an expressible and easily understood format (Couillard and Lefebvre, 1985). Water quality index development is a model proposed by the Canadian Council of Ministers of the Environment (CCME). The notion of (WQI) plays an important role to transform huge quantities of water quality data into a single number. On the other hand, this index transfer water quality data into simple terms (e.g. excellent, good, poor, etc.) by summarized as a unitless number on a scale from (zero to 100). Very clean water has an index of 100, and very polluted water has an index of 0 (Dojlido *et al*, 1994).

Water quality index determines and compares water quality conditions by the time which can be used in a variety of ways as an environmental indicator; improves comprehension of general water quality issues, evaluate the effectiveness of water quality management activities; and Illustrates the need for and effectiveness of protective practices (Bordalo *et al*, 2006).

The main objective of the present study was to research and develop capabilities in Iraq to predict and detect adverse changes in water quality and quantity and in Al-Hussainiya River in real time allowing for response to any threat to water quality.

2. Materials and methods

2.1 Study sites

Al- Hussainiya River represents the main source of the water requirement for Karbala City for different uses (drinking, irrigation, and other purposes).

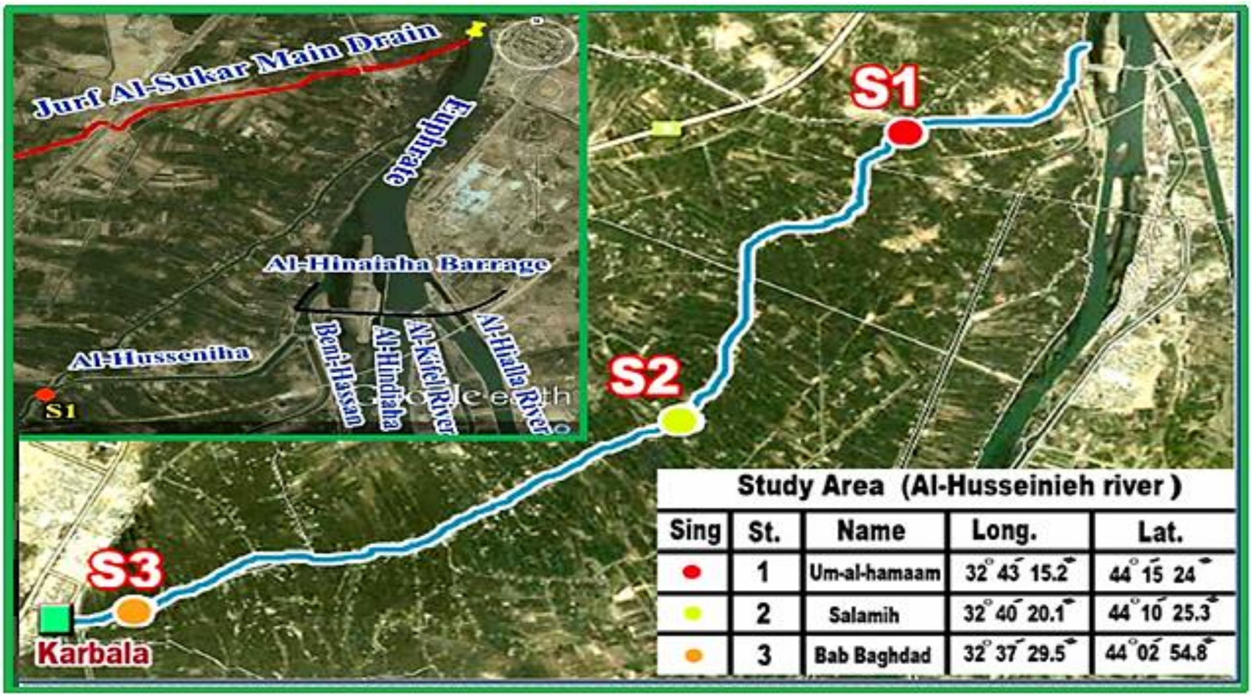

Figure 1: Illustrate studied stations on Al-Hussainiya River in karbalaa city, Iraq (Google earth 2013)

The river flows from the downstream of Al- Hindiya Barrage regulator (lie on the Euphrates river in Al-Mussayab town 70 km south of Baghdad), then the river heading towards the south-west where it passes through agricultural land characterized by groves dense of dates palm and fruit trees categorically distance of about 30 km until it reaches to the city of Karbala, which lies 100 km south of Baghdad. The average annual discharge of the Al-Hussainiya River up to 25 m^3 / s and the nature of soil in irrigated lands on both sides of the river are clay loam. The three sites cover the river lenght from north to south, where site 1-Um Al- Hammam, 2-Asalamih and 3-Bab–Baghdad, Locations with the Coordinates that are taken by Geographical Positioning System (GPS) Fig. (1).

2.2 Sampling

Subsurface water samples were collected from three sites from the middle and two banks of the river during January to June 2016 from each station using clean polyethylene bottles. Samples were analyzed for chemical and physical properties immediately after collection. The Canadian Water Quality Index (CWQI) was calculated by selecting a set of ten parameters based on both importance and availability of data. These parameter are Lead, Cadmium, Iron, Turbidity, pH value, Dissolved Oxygen, Water Temperature, Nitrate, Chloride and Total Dissolved Solids (TDS), all the parameters were analyzed according to (APHA 2005). CCME WQI were compared to the CCME guideline for the protection of aquatic life (CCME 2007).

2.3 Water Quality Index Calculations

The detailed formulation of WQI, as described in the Canadian WQI Technical Report [8], is as follows:

$$CWQI = 100 - \left(\frac{\sqrt{F1^2+F2^2+F3^2}}{1.372}\right)$$

Calculation of the index is based on of three terms: scope (F1), frequency (F2) and amplitude (F3). Division of these terms by 1.732 is based on the fact that each of the three factors contributing to the index can reach the value of 100.

Explanation of each term of the index

- Factor 1 (F_1): scope

This factor expresses the percentage of parameters did not comply with the corresponding guideline during the study period.

$$\text{Scope, } F_1 = \frac{\text{Number of failed variables}}{\text{Total number of variables}} * 100$$

- Factor 2 (F_2): Frequency

This factor represented the percentage of individual tests that do not meet the guidelines ('failed tests):

$$\text{Frequency, } F_2 = \frac{\text{Number of failed tests}}{\text{Total number of tests}} * 100$$

- Factor 3 (F_3): amplitude

Represents the difference between the non-compliant analytical results with the guidelines to which they refer. The term F3 is an asymptotic function, representing the normalized sum of excursions (nse) in relation to guidelines within the range of values from 0 to 100.

$$Amplitude, F_3 = \left(\frac{nse}{0.01\,nse + 0.01}\right)$$

To calculate the overall degree of non-compliance, we add the excursions of non-compliant analytical results and divide the sum by the total number of analytical results. This variable is called the normalized sum of excursions (nse).

$$\text{nse} = \frac{\sum_{i=1}^{n} excrusion}{\text{No.of tests}}$$

There are two possible ways of determining the excursion:

$$excursion = \left(\frac{\text{Failed test value}}{\text{Objective}}\right) - 1$$

When the test value must not fall below the objective:

$$excursion = \left(\frac{\text{Objective}}{\text{Failed test value}}\right) - 1$$

CCME WQI categorization scheme for aquatic as shown in Table (1)

Table 1: CCME WQI categorization scheme (CCME, 2001)

WQI value	Ecological condition
95–100	***Excellent***: Water quality is protected with virtual absence of threat or impairment; conditions very close natural or pristine levels.
80–94	***Good***: Water quality is protected with only minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
65–79	***Fair:*** Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45–64	***Marginal***: Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0–44	***Poor***: Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3. Result and discussion

The calculated values and the rating of WQI is presented in Fig.(2) where water quality of Al-Hussainiya River was Poor in all stattions. The results of the physical and chemical analysis of Al-Hussainiya River water are represented in Table (2).

Table 2: Mean of Physical and Chemical parameters of water in Al-Hussainiya River during 2016

Parameters	Station 1	Station 2	Station 3	*CCME guideline*
Pb (mg/l)	0.0737	0.0580	0.0614	0.007
Cd (mg/l)	0.0730	0.0249	0.0259	0.0002
Fe (mg/l)	0.2183	0.6267	0.3986	0.3
Turbidity (NTU)	4.6100	12.0800	6.5350	5
pH	8.1342	8.0433	8.0442	6.5 - 9
DO (mg/l)	8.0617	7.3417	7.8617	5.5 - 9
Water Temp. (°C)	21.3417	21.6917	21.2500	15
NO3 (mg/l)	3.4953	6.2735	6.2363	13
Cl (mg/l)	135.1408	136.2992	130.8842	250
TDS (mg/l)	539.5833	527.8333	519.5000	500

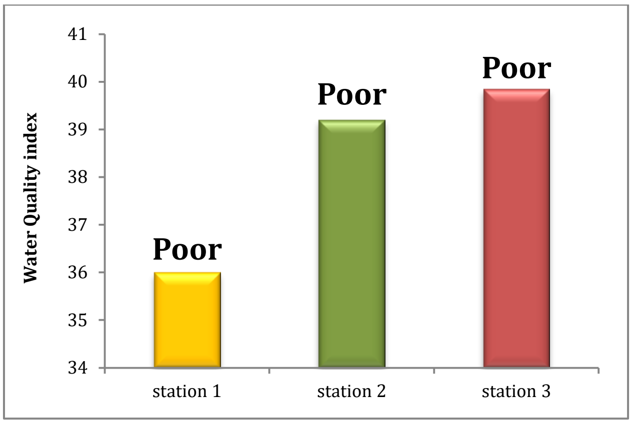

Figure 2: Water quality index for aquatic life along Al-Hussainiya River

Table (3) presents a summary of three measures of factors, i.e. F_1 (scope), F_2 (frequency) and F_3 (amplitude) of water use for protection of aquatic life. The table shows, F_3 has higher values than F1 and F2 at all the selected river stations. It denotes that there are a higher percentage of individual failed than percentage of failed variables and the amount by which they failed. The table also denotes that F3 values show a decreasing trend from station 1 to station 2 to station 3. This trend concludes that more water quality individual failed tests (did not meet their objectives) in the upstream reach (which represented station 1). So, from these results, it can be concluded with confidence that the quality of river water deteriorates from the lower to upper reaches.

Table 3: The calculated values of CCME-WQI in Al-Hussainiya River

Term of the Index	St.1	St.2	St.3
Scope, F1	60	60	60
Frequency, F2	43.3	53.33	53.33
Excursion	142.1	63.5	59.33
nse	4.7	2.11	1.98
Amplitude, F3	82.45	68.1	66.4
CCME-WQI	36	39.2	39.85

Table (4) provides a detailed vision of the water quality case at the selected sampling stations and summarizes the calculation of WQIs. The table lists those water quality parameters that exceeded the acceptable limits for different uses most of the time during the sampling period.

Table 4: The calculated values of CCME-WQI in Al- Hussainiya River

Stations	Number of failed variables	Number of failed tests	Variables with most failed tests	Variables with highest nse
St.1	6	13	Temp., Turbidity, TDS, Cd, Pb, Fe	Cd
St.2	6	16	Temp., Turbidity, TDS, Cd, Pb, Fe	Cd
St.3	6	16	Temp., Turbidity, TDS, Cd, Pb, Fe	Cd

The water quality parameters according to the highest value of normalized sum of excursions (nse) are also given in the table. It is clear from the table (4) that Cd constituted the largest values.

Reasoning out for the poor quality of water, Table (3) provides accurate information. Cadmium and Lead always exceeds the CCME guideline throughout the study which indicates a serious pollution by Cadmium and Lead. Iron exceeds the CCME guideline occasionally.

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. Some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the organisms. However, at higher concentrations they can lead to poisoning. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted (Yamaguchi *et al*, 2007).

Heavy metals can enter a water supply naturally by chemical and physical weathering of igneous and metamorphic rocks and soils often release heavy metals into the sediment and into the air. Other contributions included the decomposition of plant and animal detritus, precipitation or atmospheric deposition of airborne particles from volcanic activity, wind erosion, forest fire smoke, plant exudates, and oceanic spray or by anthropogenic activity like, Domestic wastewater effluent contains metals from metabolic wastes, corrosion of water pipes, and consumer products (Kennish *et al*, 2009). Industrial effluents and waste sludges may substantially contribute to metal loading; the combustion of fossil fuels pollutes the atmosphere with metal particulates that eventually settle to the land surface. Urban stormwater runoff often contains metals from roadways and atmospheric fallout (Connell, 1984; Chen *et al*, 2006; Laws, 2000). Currently, anthropogenic inputs of metals exceeded natural inputs.

Another related factor that is of importance in reducing the water quality index is turbidity, which was considerably high, which exceeded the CCME guideline throughout the study. Turbidity in water is caused by presence of suspended particles such as clay, silt, finely divided organic matter, plankton and other microscopic organisms. Turbidity refers to water clarity. The greater the amount of suspended solids in the water, the murkier it appears. Water bodies that have high transparency values typically have good water quality (USEPA 1997).

The increasing of Turbidity refers to most of the anthropogenic activities that take place along the river.

These activities discharge suspended matter into the water and displace the settled matter. Hence, more soil particles, which constitute the major part of suspended matter contributing to the turbidity in most natural waters, were discharged into, or displaced in the water (WRC 2003).

The pH of an aquatic ecosystem is important because it is closely linked to biological productivity. Although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most major drainage basins of the world. pH values in this study ranged between 7.6-8.5 indicating that the water sampler are almost neutral to sub-alkaline in nature [16] and agree with Iraqi published data (Maulood *et al*, 1979; Al-Saadi *et al*, 2000).

Temperature affects the speed of chemical reactions, the rate at which algae and aquatic plants photosynthesize, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic residents. Temperature is important in aquatic systems because it can cause mortality and it can influence the solubility of dissolved oxygen (DO) and other materials in the water column (e.g., ammonia). In this study temperature show great fluctuation which return to fluctuate naturally both daily and seasonally (Sadalla 1998). Aquatic organisms often have narrow temperature tolerances. Thus, although water bodies have the ability to buffer against atmospheric temperature extremes, even moderate changes in water temperatures can have serious impacts on aquatic life, including bacteria, algae, invertebrates and fish. Thermal pollution comes in the form of direct impacts, such as the discharge of industrial cooling water into aquatic receiving bodies, or indirectly through human activities such as the removal of shading stream bank vegetation or the construction of impoundments (UNEP/GEMS 2006).

Oxygen that is dissolved in the water column is one of the most important components of aquatic systems. Oxygen is required for the metabolism of aerobic organisms, and it influences inorganic chemical reactions. Oxygen is often used as an indicator of water quality, such that high concentrations of oxygen usually indicate good water quality (UNEP/GEMS 2006). No stagnation for dissolved oxygen was observed at any station throughout the study period, the recorded values were always above 6.3 mg/l, the recorded values were always above 6.3 mg/l, whereas the high value reached 9 mg/l in station 1 during March. Oxygen enters the water by photosynthesis of aquatic biota and by the transfer of oxygen across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen) and salinity (freshwater holds more oxygen than does saltwater (Smith 1990).

Compounds of nitrogen (N) are major cellular components of organisms. Since the availability of these elements is usually less than biological demand, environmental sources can regulate or limit the productivity of organisms in aquatic ecosystems. In this study observed value of nitrate not exceed the CCME guideline in all stations, as a result of human activities (cultural eutrophication) through factors such as runoff from agricultural lands and the discharge of municipal waste into rivers. Nitrogen occurs in water in a variety of inorganic and organic forms and the concentration of each form is primarily mediated by biological activity (Dodds 1998).

Chloride concentration averaged ranged between (183-93 mg/l), where not exceed acceptable levels that recommended by CCME. It not a serious increasing which may be return to rainfall that helps solubility of chloride ion from adjacent land of the banks of the river as a result of soil erosion (Hem 1970).

Total Dissolved Solids (TDS) in natural water are often composed of the bicarbonate, sulfate and chloride of calcium, magnesium and sodium [24]. The result explained that TDS values were exceed the permissible level recommended by CCME for aquatic life. Main sources for TDS in receiving waters are leaching of soil contamination, agricultural and residential runoff, and point source water pollution discharge from sewage or industrial treatment plants (Boyd 2000).

Conclusion

The Canadian Council of Ministries of the Environment Water quality Index (CWQI) used for rating of water quality in Al- Hussainiya River indicated that the quality of water was poor. It was almost deteriorated or endangered. The condition in it usually deviated from permissible levels and the water is not capable to support or protect enough aquatic life. Lead, Cadmium, TDS, and Turbidity were the main factors responsible for determination of the River water quality. These parameters need to be modified to maintain the quality of water for further uses. The CCME-WQI served an important evidential in monitoring poor quality of aquatic system.

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