Assessment of Tigris River Water Quality in Mosul for Drinking and Domestic Use by Applying CCME Water Quality Index

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Abstract
The current research concentrated on the application of the Canadian Council of Ministers of the Environment Water Quality Index for drinking and domestic use (CCME WQI). Ten sampling sites were hosen along the river reach to collect water samples and faraway from the riverbanks where the flowing stream is considerably high in Mosul City. The fieldwork was done from 2008 to 2014. Ten parameters were selected, namely: pH Value, Calcium, Nitrate, Turbidity, Dissolved Oxygen, Chloride, Total Dissolved Solids, Phosphate, and Sulfate. The results have shown that the water quality of Tigris River was ranged between 93.7- 66.3, and that station 1 which was situated in upstream of River was excellent than the other stations. This work confirms the need for serious action, and it must undergo preliminary treatment before use for drinking.

Keyword: Water Quality Index, Tigris River.
Introduction
River Tigris has been and will always be one of the most significant rivers in the region in addition to his twin river Euphrates as well. Since they are extended over a very vast land in the Middle East, so they considered as main sources of water supply in the region.
Recently, wastewater has been greatly increased as a result of increasing the population and the continuous rural population resettlements in cities seeking a presumed better standard of living [1]. Such criminal act killed the population in large cities, and industrial development comes at the forefront of the reasons that led to the breach in the environmental balance [2]. Water pollution can be defined as the deterioration in the quality of natural water sources due to toxic elements and vehicles, which add to the increasing Concentration water resources, as these articles either be dissolved or in the form of material stuck, or sediments at the bottom of the River [3-4].
One of the simplest approaches to evaluate the water quality situations is by applying of water quality indices, which are considered as a tool for giving a cumulatively derived mathematical expression defining a certain level of water quality [5-6]. WQI recognizes and compares water quality backgrounds over time, which can be used in a variety of methods as an ecological sign; assess the efficiency of water quality management actions [7-8-9].
The aim of the present work is to evaluate the existing water quality, through the examination of some selected water quality variables of Tigris River so as to appreciate the impacts of unregulated waste discharge on the quality of the river water in addition to compare and explain its suitability for human consumption.
Materials and Methods

Study area

This research study included a survey of the Tigris River Basin in the city of Mosul between the dam area to the northwest of Mosul and the Qayara area southeast of Mosul. The total length of the river is 155Km. Several sites were chosen along the Tigris River within the study area (Figure 1).

![Figure 1: Mosul City showing the coordinates of the ten stations for taking water samples from Tigris River](image)

Sampling

Water samples were collected from the ten sites of the Tigris River by using clean polyethylene bottles.

The CCME WQI calculated by choosing of a set of ten variables. The fieldwork was conducted from 2008 to 2014. Ten parameters were selected namely: pH Value, Total Dissolved Solids, Nitrate, Calcium,
Dissolved Oxygen, Turbidity, Chloride, Sulfate, and Phosphate. CCME WQIs were calculated for the ten sites in the Tigris River using sets of the guideline values (Table 1) [10-11-12].

Table 1: Standard Values

| Parameter | CCME     | WHO     |
|-----------|----------|---------|
| pH        | 6.5-8.5  | 6.5-9.5 |
| TDS (mg/l) | 1000    | 1000    |
| SO₄²⁻ (mg/l) | 400    | 250     |
| Cl⁻ (mg/l)  | 350     | 45-250  |
| Ca²⁺ (mg/l) | 150    | 75      |
| Mg²⁺ (mg/l) | 100    | 100     |
| NO₃⁻ (mg/l) | 50     | 50      |
| PO₄³⁻ (mg/l) | 0.5   | 0.4     |
| DO (mg/l)   | <5      | <5      |
| Turb. (NTU.) | 5      | 5       |

Calculation of the CCME WQI

The CWQI equation is computed using three factors as follows[10]:

$$CWQI = \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

Factor 1 (F1): scope: The percentage of the variables that exceed the guideline:

$$F_1 = \left(\frac{\text{Number of failed Variables}}{\text{Total Number of Variables}}\right) \times 100$$

Factor 2 (F2): Frequency: This factor represented the percentage of individual tests that do not meet the guidelines (failed tests):

$$F_2 = \left(\frac{\text{Number of failed Tests}}{\text{Total Number of Variables}}\right) \times 100$$
Factor 3 (F3) amplitude: Represents the number of readings that exceeded the standards and according to the following steps:

1- Calculation of the deviation Excursion When the values of readings are higher than the values of the standards criteria are calculated from the following equation:

\[
\text{Excursion}_i = \left\{ \frac{\text{Failed Test Value}_i}{\text{Objective}_j} \right\} - 1
\]

Or where the values of the readings are less than the values of the standard criteria computed from the following equation:

\[
\text{Excursion}_i = \left\{ \frac{\text{Objective}_j}{\text{Failed Test Value}_i} \right\} - 1
\]

-2- The sum of the standard deviations nse and the sum of the readings not meeting the standards is calculated by the sum of the deviations divided by the total sum of the tests:

\[
nse = \frac{\sum_{i=1}^{n}\text{Excursion}_i}{\text{number of tests}}
\]

F3 is then computed from the following equation:

\[
F_3 = \frac{nse}{0.01nse + 0.01}
\]

CCME WQI categorization was presented in Table 2 [13].

### Table 2: CCME WQI Designation

| Suitability   | WQI Value |
|---------------|-----------|
| Excellent     | 100-95    |
| Good          | 80-94     |
| Fair          | 65-97     |
| Marginal      | 45-64     |
| Poor          | 0-44      |
Result and Discussion

The CCME WQI results for drinking showed that most samples of the Tigris are classified as (good) quality water except for the tenth site. The highest value of the guide (93.7) was recorded at the first location (beginning of Mosul Dam in 2012) When the lowest value (66.39) in the tenth location near the refinery Qayyarah in 2014 (Figure 2)
Figure 2: Represents the variation in the values of CCME WQI for drinking purposes over the years

The results showed that the variables that were not within the limits of the standards consistently are concentrations of dissolved oxygen and Turbidity, while the phosphate concentrations exceeded the standards in some cases.

It is clear from (Figure 3) that the quality of water in the northern part of the city of Mosul is good due to the small number of sources of pollution, and then begin the decline in the quality of the Tigris River while passing through the city of Mosul, especially in the southern part of the river
starting from the sixth site near the bridge of Al-Huria and to the tenth location near the refinery Qayara, where the value of the index to (77.3), and this reflects the impact of pollutants from residues the city and the human waste and oil wastes that flow into the river [14-15-16].

![Figure 3: Represents the variation in the values of CCME WQI for drinking purposes with sites](image)

The results of the analysis of variance showed a significant effect of the difference of sites and years on the values of the water quality index for drinking at the level of probability (0.01).

To illustrate the effect of sites on the studied traits, Table (3) refers to the mean effect of the sites in the studied traits. It is noted that differences in the values of the guide for drinking purposes by the site effect did not reach the statistical significance. The highest value (90.433) for the first site and the lowest value (77.302), and that the differences between the two averages did not reach the moral limit as indicated by the least significant difference (LSD) at the level of probability (0.05), while the rest of the sites had little difference between them.
Table 3: The average effect of sites on water quality index characteristics

| WQI for Drinking | Sites  |
|------------------|-------|
| 90.433           | Site 1|
| 89.650           | Site2 |
| 87.358           | Site3 |
| 87.005           | Site4 |
| 87.398           | Site5 |
| 85.732           | Site6 |
| 87.235           | Site7 |
| 86.183           | Site8 |
| 84.583           | Site9 |
| 77.302           | Site10|
| 15.724           | L.S.D (0.05) |

As for the effect of years on CCME WQI values for drinking purposes, the highest value of the guide was 90.045 in 2011 and the lowest of 80.448 in 2013. The differences did not reach the moral level at the level of probability (0.05). The difference was significant, while the rest of the years were slightly different (Table 4).

Table 4: The average effect of years on water quality index characteristics

| WQI for Drinking | Years |
|------------------|-------|
| 82.848           | 2009  |
| 88.650           | 2010  |
| 90.045           | 2011  |
| 89.852           | 2012  |
| 80.448           | 2013  |
| 85.885           | 2014  |
| 14.619           | L.S.D (0.05) |

The results show that the water of the river is not suitable for direct consumption for drinking purposes, which is further treated by liquefaction stations and water purification, but it is not the advanced type because it does not deal with many contaminants [15,16] (Moderately-
good) water is protected, but is threatened and weak and sometimes deviated from the level required, as has been noted in previous studies [17-18].

Conclusion

Application of CCME WQI in this study has been found revealed that the water quality is found to be good quality water suitable for drinking purposes after treatment, treatment, and purification, as the values of the guide varied between (90-77).

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