Water quality index of Tigris River on Waist Governorate for aquatic life

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Abstract. In this study, a mathematical model Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) has been used. Several physical and chemical parameters are chosen to calculate the water quality index as follows: temperature, pH, total dissolved solids (TDS), turbidity, dissolved oxygen (DO), total nitrogen (TN) and total phosphorus (TP). The results showed that all stations received a poor assessment of the water quality index, indicating that the water of the Tigris River is highly polluted for aquatic life due to discharging of poorly treated wastewater from Al Azziziyah Wastewater Treatment Plant (AWWTP).

Keywords—River pollution; domestic wastewater; Turbidity; Dissolved Oxygen; Total Nitrogen; Total Phosphorus.

1. Introduction
The main sources affecting surface water quality are human activities and natural influences. Water quality can be determined without these sources through atmospheric processes, rock mineralization, nutrient spills, soil organic matter, hydrological factors and biological processes within the aquatic body that alter the physical and chemical components of water [1]. In recent years, water quality assessment has become very important in rivers affected by pollutant disposal. Industrial, municipal and household waste disposal are the main source of water pollution [2]. Stream pollution is any weakness to the local water properties through the disposal of industrial contaminants to the extent that it is no more useful for drinking purposes or backup the biotic societies living on it [3]. Disposal of polluted water from agricultural, industrial and municipal sources without treatment or partial treatment before discharge is a common practice in developing countries [4]. Physical and chemical properties of water determine the level of safety of the water system [5]. The physical and chemical properties are compared to determine water quality according to specific criteria [6]. The simplest and easiest way to evaluate and determine the state of water quality is the water quality index [7]. The water quality indicator can be expressed using a color, symbol, number or description for silver (water). This indicator consists of simple and less complex criteria that are used as water quality calculations [8]. The water quality index consists of four common stages: selection of parameter, conversion of the coefficient to a single scale, selection of the weight of the coefficients and the appropriate assembly function [9]. The water quality index may be used as an environmental indicator and has been developed to be used as an indicator of chemical and physical water quality [10]. The Canadian Water Quality Index compares the value of observations to an objective value as this objective value reflects water quality [11, 12, and 13]. The aim of this study...
is to apply the water quality index to assess water quality in the Tigris River within the boundaries of Al-Azziziyah by measuring the physical and chemical parameters that determine the level of water quality. Sites that do not exceed standard water quality have high scores of water quality index (close to 100), and sites zero. The advantages of CCME WQI can be summarized as represent measurements of a variety of variables in a single number; flexibility in the selection of input parameters and objectives; adaptability to different legal requirements and different water uses; statistical simplification of complex multivariate data and combine various measurements in a variety of different measurement units in a single metric.

2. Experimental Works

2.1. Study area
Wasit Governorate locates in the southern part of the central region of Iraq (figure 1). The city of Aziziyah locates in the north of Wasit province and southern the capital Baghdad, about 85 km and, an area of 2252 km² and represents 3% of the area of the province area, and Tigris River passes through its land.

![Figure 1. The image showing study area](image)

2.2. Sample collection
Samples were collected from five sites distributed within the study area. The locations of these stations were identified using the German GPS 60 (table 1). These sites cover areas where there are contaminants due to the discharge of the waste water treatment plant at the first site, and the agricultural and industrial activities and human waste in the river in other locations. Samples were taken during January 2019
(rainy month). Four samples were collected at each point in five different locations for one month on a weekly basis using a 1000 ml plastic bottle, which was first washed using hydrochloric acid to avoid contamination and then distilled water. Chemical and physical tests were conducted at the health laboratory of the Department of Civil Engineering at Wasit University. Water quality index was calculated through a set of physical and chemical parameters based on data availability and importance [14]. The parameters are pH, temperature, total dissolved solids (TDS), turbidity, dissolved oxygen (DO), total nitrates (TN) and total phosphates (TP). The water quality index for all sites was calculated on the basis of standards for the protection of aquatic life (table 2) [11].

| Station(#) | Distance (Km) | Longitude      | Latitude       |
|-----------|---------------|----------------|----------------|
| 1         | 0             | N36°31.334'    | E05°05.764'    |
| 2         | 1.5           | N36°30.820'    | E05°07.145'    |
| 3         | 3             | N36°20.820'    | E05°08.276'    |
| 4         | 5.5           | N36°20.820'    | E05°09.023'    |
| 5         | 9.5           | N36°20.820'    | E05°12.143'    |

Table 2. Water quality standard according to the Canadian Guideline.

| Parameter | Unit | CCME guideline |
|-----------|------|----------------|
| Temperature | °C | 15 |
| pH | - | 6.5-9 |
| TDS | mg/l | 500 |
| Turbidity | NTU | 5 |
| DO | mg/l | 5.5-9 |
| NO₂ | mg/l | 0.06 |
| PO₄ | mg/l | 0.3 |

2.3. Calculation and classification of water quality index (WQI)

The water quality index was calculated and classified in two phases, firstly a mathematical formula expressing the index to determine the amount of deviation and compliance with the water quality standards is used. The formula consists of three important components; the first component called the scope and represents the percentage of the number of parameters that are out of compliance with the total number of measured parameters [11].

\[
F_1 (\text{Scope}) = \left( \frac{\text{Number of Failed Variables}}{\text{Total Number of Variables}} \right) \times 100 \quad \ldots \ldots \ldots \ldots (1)
\]

The second component is called frequency and refers to as the percentage of failed tests (do not meet the guidelines)

\[
F_2 (\text{Frequency}) = \left( \frac{\text{Number of Failed Tests}}{\text{Total Number of Tests}} \right) \times 100 \quad \ldots \ldots \ldots \ldots (2)
\]

The third component is called amplitude and represents the number of failed tests that do not comply with the guidelines and is calculated in two steps:
1. \( excursion = \left[ \frac{Objective}{Failed \ Test \ Value} \right] - 1 \) ................ (3)

(When the test value should not fall below the target)

\[ excursion = \left[ \frac{Failed \ Test \ Value}{Objective} \right] - 1 \] ................ (4)

(When the test value should not exceed the target)

2. \( nse = \frac{\sum excursion}{Number \ of \ Tests} \) ................ (5)

\( F_3 \) (Amplitude) = \[ \frac{nse}{0.01 \ nse + 0.01} \] ................ (6)

The following equation gives a numeric value between 0 and 100 for water quality status

\[ CWQI = 100 - \left[ \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right] \] ................ (7)

Water quality is classified into five categories according to CCME WQI (Table 3).

| Parameter   | CCME WQI value |
|-------------|----------------|
| Excellent   | 95-100         |
| Good        | 80-94          |
| Fair        | 60-79          |
| Marginal    | 45-59          |
| Poor        | 0-44           |

3. Results and Discussion

The water quality index (WQI) gives one value that reflects water quality. Rating standards allow for easy and simple quality assessment [15]. The chemical and physical properties of water greatly help to save aquatic life. The results of the study showed that the values of the water quality index are 23, 26, 31, 29 and 33 in stations 1, 2, 3, 4 and 5, respectively (Figure 2).
Figure 2 Values of water quality index for five stations

It can be said that the water of the Tigris within the study area is much polluted for aquatic life, because all stations indicated a poor evaluation of the water quality index. This is due to many Industrial, municipal and agricultural pollutants into the river without treatment [16]. The results showed that the first station exhibited the lowest assessment because of the discharges of Al- Azziziyah wastewater treatment plant that adversely affects the quality of the river.

The decreasing and increasing value of the water quality index is due to measured physical and chemical processes. Water temperature values ranged from (15-18.3) °C, all within the limits. The temperature is an important factor because it affects the characteristics of the river such as photosynthesis of plants, the amount of oxygen dissolved in water and the amount of metabolism of organisms [17]. pH is an important factor for water quality. The values of pH changed from 7.8 to 8.3, all within permissible limits. Water is almost alkaline [18].

The values of total dissolved solids varied between (503 – 1120) mg/L exceeding in all stations the permissible limits and recommended by the CCME. The main source of high concentration of TDS is water pollution from sewage and industrial sources [19]. The turbidity values ranged between 88.5 to 305 NTU and exceeded the limit in all points. High values of turbidity are resulted from the amount of mud, silt and organic and inorganic materials during winter [14]. Dissolved oxygen is used as a measure of water quality, a very important factor in aquatic life [5]. The values of dissolved oxygen at all locations within the recommended limits for CCME. The normal values of dissolved oxygen concentrations are due to several factors, including low temperature, oxygen mixing with water and low salinity [18]. The total nitrogen level in all stations exceeds the permissible limit. The decrease in total nitrogen concentration in the Tigris reflects a decrease in biological processes in winter [20]. Sources of nitrogen compounds in the ecosystem are animal waste, wastewater, fertilizers, decomposition and disintegration of organic matter and nitrogen stabilization processes [21, 22]. The concentration of phosphorus exceeded the maximum allowed (0.3 mg/L) at all sites and ranged between (0.5-1.23) mg/l. High phosphorus concentrations adversely affect the aquatic environment and act on lack oxygen and excessive growth of plants and algae [23].

4. Conclusion
It can be concluded from this study that the water quality index (WQI) gives a clear and simple assessment and can reduce water quality data to only one value. As the water quality index (WQI) is able to calculate water quality clearly and realistically, it can also be used to help water quality management and decision making.
5. References

[1] UNEP/GEMS, United Nations Environment Programme Global Environment Monitoring System/Water Programme. Water Quality for Ecosystem and Human Health. UN GEMS/Water Programme Office c/o National Water Research Institute 867 Lakeshore Road Burlington, Ontario, L7R 4A6 CANADA available on-Line, 2006.

[2] Campbell, L. M. Mercury in Lake Victoria (East Africa): Another emerging issue for a Beleaguered Lake. PhD, Thesis. Waterloo, Ontario, Canada, 2001.

[3] Agrawal, A., Pandey, S. R. and Sharma, B. 2010. Water pollution with special reference to pesticide contamination in India. Journal of Water Resources and Protection, 2, 432-448. https://doi.org/10.4236/jwarp.2010.25050

[4] E. J. Abdullah, “Evaluation of surface water quality indices for heavy metals of Diyala River-Iraq,” Evaluation, Baghdad: University of Baghdad, 2013.

[5] Lomniczi, I.; Boemo, A. and Musso, H. Location and Characterization of Pollution Sites by Principal Component Analysis of Trace Contaminants in A Slightly Polluted Seasonal River: A Case Study of the Arenales River (Salta, Argentina) J. Water SA., Vol. 33, No. 4, pp. 479-485, 2007.

[6] Robertson, D.M.; Saad, D.A. and Heisey, D.M. A regional Classification Scheme for Estimating Reference Water Quality in Streams Using Land-Use-Adjusted Spatial Regression-Tree Analysis J. Envir. Manag. Vol. 37, No. 2, pp. 209-229, 2006.

[7] W.K. Dodds, J.R. Jones and E.B. Welch. Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus. J. of Water Research, Vol. 32, pp.1455-1462, 1998.

[8] Fernández, N.; Ramírez A. and Solanon, F. Physico-Chemical Water Quality Indices- A Comparative Review. Revista Bista, Universidad de Pamplona, Bucaramanga, Colombia, ISSN(Versión impresa) 0120-4211, pp.19-30, 2004.

[9] House, M.A. Water Quality Indices. Unpublished Ph.D. Thesis. Middlesex Polytechnic, Queensway, Enfield, England, U.K. 1986.

[10] Salim, B.J.; Gholamreza, N.B.; Amir, S.; Masoud, T. and Mojtaba, A. Water Quality Assessment of Gheishagh River Using Water Quality Indices. J. Environmental Science, Vol. 6, No.4, pp.19-28, 2009.

[11] CCME, Canadian Council of Ministers of the Environment. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Canadian Water Quality Index 1.0 Technical Report. In Canadian Environmental Quality Guidelines, Winnipeg, Manitoba, 2001. (http://www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf).

[12] Khan, F.; Husain, T. and Lumb, A. Water Quality Evaluation and Trend Analysis in Selected Watersheds of the Atlantic Region of Canada” J. Environmental Monitoring and Assessment, Vol. 88, pp. 221–242, 2003.

[13] Lumb, A.; Doug, H. and Tribeni, S. Application of CCME Water Quality Index to Monitor Water Quality: A Case of the Mackenzie River Basin, Canada J. Environmental Monitoring and Assessment., Vol. 113, pp. 411-429, 2006.

[14] APHA, American Public Health Association. Standard Methods for the Examination of Water and Wastewater, 21st Edition Washington, DC. 22621, pp., 2005.

[15] Crabtree, R. W.; Cluckie, and Forster, C. F. A comparison of two quality models. Water Research, Vol. 20, pp. 53-61, 1986.

[16] WHO, World Health Organisation and United Nations Children’s Fund Joint Monitoring Programme for Water Supply and Sanitation. Progress on Drinking-Water and Sanitation: Special Focus on Sanitation.UNICER, NewYork, NY, USA, and WHO, Geneva, Switzerland, 2008.

[17] Suski, C. D.; Killen, S.S.; Keiffer, J.D. and Tufts, B.L. The influence of environmental temperature and oxygen concentration on the recovery of largemouth bass from exercise. Implications for live release angling tournaments. J. of Fish Biol. Vol. 68, pp.120-136, 2006.

[18] Ahipathy, M.V. and Puttaiah, E.T. Ecological Characteristics of Vrishabhavathy River in Bangalore (India). j. Environmental geology, Vol. 49, No. 8, pp.1217-1222, 2006.
[19] Boyd, C.E. Water Quality an Introduction. Kluwer Academic Publishers, Boston, USA, 330pp. 2000.
[20] WHO, World Health Organization. Nitrate and nitrite in drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality. WHO/SDE/WSH/07.01/16/Rev/1, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland, 2011.
[21] Environment Canada. Canadian water quality guidelines for the protection of aquatic life: Ammonia. In: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, 2010.
[22] McKenzie, J.M.; Siege, D.I.; Patterson, W. and McKenzie, D.J. A Geochemical Survey of Spring Water from the Main Ethiopian Rift Valley, Southern Ethiopia: Implications for Well-Head Protection. J. Hydrogeology Vol. 9, pp. 265-272, 2001.
[23] Fadiran, A.O.; Dlamini, S.C. and A. Mavuso. A Comparative Study of the Phosphate Levels in Some Surface and Ground Water Bodies of Swaziland. Bull. Chemical Society of Ethiopia, vol. 22, NO. 2, pp.197-206, 2008.