EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(5), 177–184
https://doi.org/10.12912/27197050/165901
ISSN 2719–7050, License CC-BY 4.0

Received: 2023.04.02
Accepted: 2023.05.20
Published: 2023.06.01

Application of the Water Quality and Water Pollution Indexes for Assessing Changes in Water Quality of the Tigris River in the South Part of Iraq

Idrees A.A. Al-Bahathy[1*], Zahraa Zahraw Al-Janabi[2], Rana R. Al-Ani[2], Afrah A. Maktoof[3]

[1] College of Environmental Science, Al-Qasim Green University, Babil, Iraq
[2] Environment Research Center, University of Technology, Baghdad, Iraq
[3] Biology Department, College of Science, University of Thi-Qar, Thi-Qar, Iraq
* Corresponding author's e-mail: idrees@environ.uqasim.edu.iq

ABSTRACT
Two water quality indices (WQI) were applied in the Tigris River using thirteen water quality parameters (pH, chlorides, sulfate, nitrate, salts, $BOD_{5,}$ iron, boron, zinc, lead, cadmium, copper, and chromium) in this study. They were calculated for the six years from 2008 to 2013 and then compared with sets of standard values of river maintaining systems. The results indicated that the water quality of the Tigris River for CCME-WQI was generally "Fair" to "Good" in 2008, 2009, and 2010 (CCME WQI range: 69.67–88.46) for all sites. CCME WQI values fell from "Marginal" to "Fair" in all sites over the last two years (2012 and 2013). WPI was " pure" to " Moderately polluted " from 2008–2011 (WPI range: 0.63–1.55) for all sites. Whereas, WPI values dropped to ranging from " Moderately polluted " to "polluted" (WPI range: 1.15–2.39) in all sites in 2012 and 2013. The effect of various human activities and dryness were evident on some parameters such as the heavy metals, Sulfate, Chlorides, Salts and Nitrate. Where their concentrations exceeded the permissible limits of the river maintaining system in most of the sites, and thus were the reason for the decline in the values of the indices. So, the monitoring of the Tigris River is important for proper management and for preserving this important water source.

Keywords: CCMEWQI; WPI; Tigris River; South Iraq.

INTRODUCTION

Freshwater resources are the most important things on earth and are fundamental for all forms of life [Ayat et al., 2021]. Distinguishing the effects and fluctuations of biogeochemical processes as well as understanding the fluctuations in physicochemical parameter values of water quality is important for water management [Abed et al., 2018].

The quality of surface water plays a main role in the biological processes of aquatic biota. Surface water quality is very sensitive to anthropogenic activities and is critical for economic development and the sustainability of the environment [Ewaid et al., 2018].

Rivers are our historical, natural heritage and most important wealth. Rivers are important sources of freshwater for achieving various services for humans, such as daily use, irrigation, and industrial needs. The majority of a river's water is contaminated by significant pollutant loads from all around the world due to river systems' transferring pollutants, and other materials by the river current [Galib, 2017]. Urbanization is an important cause of water pollution [Bdyut, 2017]. Direct disposal of wastewater, which contains heavy metals, detergents, acids, alkalis, dyes, and other pollutants, has an impact on water quality [Roy and Shamin, 2020]. In recent years, there has been an increase in public awareness regarding water pollution. As a result, new techniques for implementing long-term water management were considered. As a result, continual monitoring of water resources is critical for determining water quality for different uses [Ewaid et al., 2020]. Many water quality indices were used to evaluate the water quality over space and time. A water quality index is a single numerical value that represents the status of the quality of water and indicates unfavourable or undesirable water quality conditions [Galib et al., 2018, Li and Liu, 2018]. WQIs function by combining a set of variables into a single value, unitless score, allowing for comparisons between various water bodies or the observation of changes in water over time [Aljanabi et al., 2021]. WQI has also proven to be a simple method for giving information to the public and decision-makers [Banda and Kumarasamy, 2020].

Many studies covered the limnology and water quality of the Tigris and other Iraqi water bodies. Many researchers have reported in different areas within Iraqi waters, such as [Mirza and Nashaat, 2018, Al-Azawii et al., 2018, Zahraa et al., 2019, Al-janabi et al., 2019, Al-Bahathy and Nashaat, 2021, Majeed et al., 2022, Aljanabi et al., 2022, Nashaat and Al-Bahathy, a2022, Nashaat and Al-Bahathy, b2022, Majeed et al., 2023]. Many water quality indices are used in order to evaluate the quality status of any river. Our study surveyed the water quality at different points in the southern part of the Tigris River by applying two indices: the Water Pollution Water Index (PWI) and the Canadian Council of Ministers of the Environment (CCME) to get an accurate view of water quality in the studied area.

MATERIALS AND METHODS

Study area

The Tigris River is one of the main rivers in Iraq whose length is 1,900 km, 20% of which is in Turkey, 78% in Iraq, and 2% is located in Syria, and meets with the Euphrates at Al-Qurna to form the Shatt al-Arab [Van der, 1975]. The study on the Tigris River was conducted by collecting samples from the following five sites for six years from 2008 to 2013 (Figure 1):

1. Al-Aziziyah/ site 1 (32°54’4.62”N) (45° 3’54.00”E): It is situated in a town which is located on the Tigris River about 80 km northwest of Kut governorate.
2. Al-Kut/ site 2 (32°31’36.36”N) (45°47’13.14”E): the sampling site is a city located on the Tigris River, about 160 km southeast of Baghdad.
3. Ali al-Gharbi/site 3 (32°28’16.26”N) (46°41’8.16”E): this site was located in one of the districts of the Amara Governorate in Iraq, about 100 km north of the governorate between Amara and Kut city.
4. Amara/ site 4 (31°51’23.88”N) (47° 8’36.90”E): this sampling site was situated in a city in southeastern Iraq, about 320 km south of Baghdad. It lies on the right bank of the Tigris River.
5. Al-Qurnah/ site 5 (31° 0’43.68”N) (47°26’15.96”E): the site was sampled near a town in the south of Iraq, about 74 km north of Al-Basra city. Qurna is situated where the Tigris and Euphrates Rivers join to form the Shatt al-Arab River.

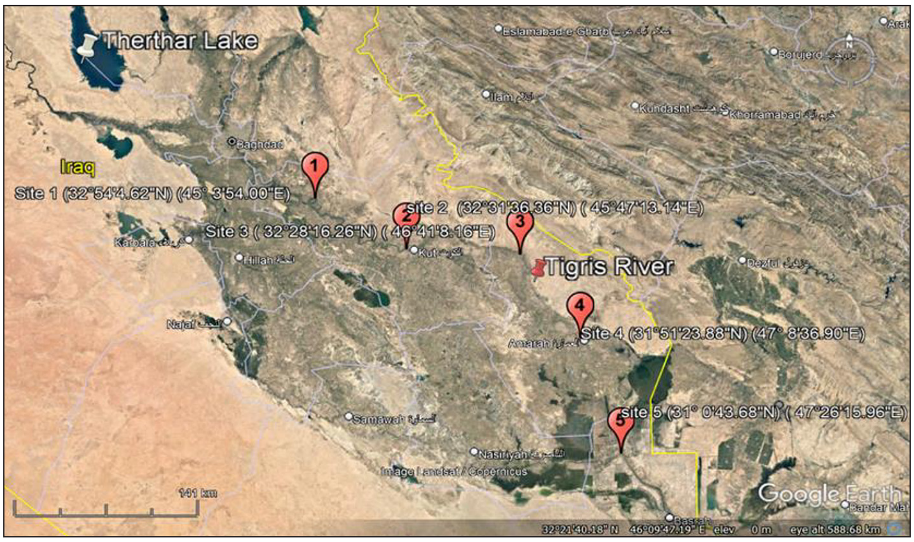


Figure 1. Sampling sites of the study area

Water quality parameters

Thirteen parameters were selected based on both the availability and importance of data. These parameters are: pH, chlorides, sulfate, nitrate, salts, iron, boron, zinc, lead, cadmium, copper, chromium, and BOD_5 were calculated for the five sites in the Tigris River for six years from 2008 to 2013, then compared with sets of standard values of rivers' maintaining systems and general water pollution mentioned in [Law 25, 1967]. The data was taken from the National Center for Water Resources Management/Ministry of Water Resources/Iraq and the parameters were analysed according to methods of [APHA, 19].

Application of the Canadian Council of Ministers of the Environment CCME

The *CCME* WQI was calculated by testing the thirteen parameters. The CCMEWQIs were calculated for the five sites from 2008 to 2013 using data from the thirteen parameters and then compared with sets of standard values (Table 1).

The CCMEWQI model includes three measures of variance; F_1, F_2 and F_3.

$$F1 = (\text{Number of faild variables}/\text{Total number of variables}) \times 100 \quad (1)$$

where: F_1 – represents the tests that exceed the water quality guideline,
F_2 – represents the percentage of failed tests that do not meet the objective.

$$F1 = (\text{Number of faild tests}/\text{Total number of tests}) \times 100 \quad (2)$$

F_3 (*Amplitude*) calculated by:

(i) Calculation of excursion refers to an individual concentration that does not meet the objective:

$$\text{Excursion} = (\text{Faild Test Value} / \text{Objective}) - 1 \quad (3)$$

Eq. 3 applied when the value of a failed test exceeds the objective)

or

$$\text{Excursion} = (\text{Objective} / (\text{Faild Test Value}) - 1 \quad (4)$$

Eq. 4 applied when the failed test value is less than the objective value),

(ii) Calculation of the normalized sum of excursions (nse):

$$nse = \sum_{i=1}^{n} \text{excursion} / \text{Number of tests} \quad (5)$$

(iii) Calculation of F_3:

$$F3 = (nse/(0.01nse + 0.01)) \quad (6)$$

The final WQI is calculated as (Eq. 7):

$$WQI = 100 - \sqrt{(F_1^2 + F_2^2 + F_3^2)}/1.732 \quad (7)$$

The CCME has been established to classify water quality as Excellent (95–100), Good (80–94), Fair (65–79), Marginal (45–64), Poor (0–45) [Karen et al., 2001].

Application of the water pollution index (WPI)

The water pollution index was calculated using equation 8. The average value of each parameter (Ai) was divided by the maximum value allowed (T) based on Rivers' maintaining system as shown in Table 1 [Law 25, 1967] and [Moran, 2018] for TDS. Then, the sum of the (Ai/T) was divided by the total number of parameters (n = 13). According to WPI, The quality of the

Table 1. Standard values of parameters according to Rivers maintaining system [Law 25, 1967]

Parameters values	Standers
pH	6.5–8.5
TDS	500*
Chlorides	200
Sulfate	200
Nitrate	15
BOD_5	5
Iron	0.3
Boron	1
Zinc	5
Lead	0.05
Cadmium	0.005
Copper	0.05
Chromium	0.05

Note: *Standard values of TDS according to [Moran, 2018].

water is classified as follows: Very pure (≤0.3), pure (0.3–1.0), moderately polluted (1.0–2.0), polluted (2.0–4.0), impure (4.0–6.0), heavily impure (≥6.0) [Maktoof et al., 2020].

$$WPI = \frac{1}{n}\sum_{i=1}^{n}\frac{Ai}{T} \quad (8)$$

RESULTS AND DISCUSSION

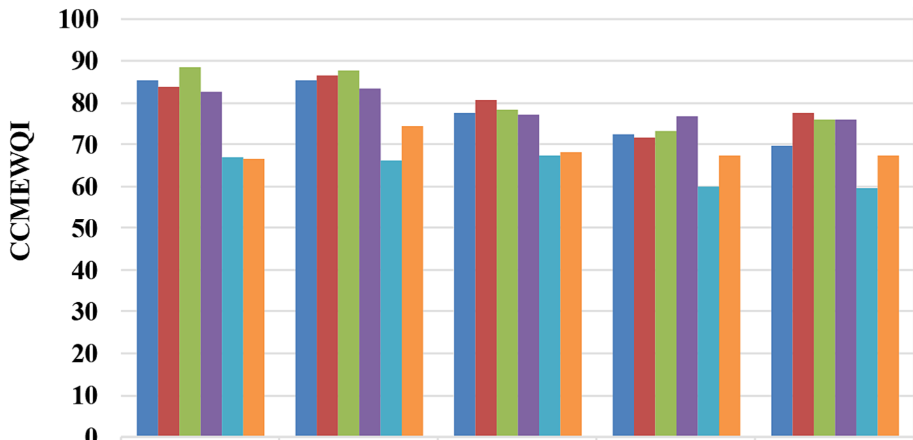
CCME and WPI calculation

For this study, CCME and WPI were selected for the evaluation of water quality. For these indices, 13 parameters, viz. pH, chlorides, sulfate, nitrate, salts, iron, boron, zinc, lead, cadmium, copper, chromium, and BOD_5, were used to test the Tigris River quality at five selected sites. The summary of the CCME and WPI index values of water samples is shown in Figures 2 and 3.

As for the temporal trend, Figure 2 showed that the range of CCME WQI for the Tigris River at sites 1 (Al-Aziziyah) and 2 (Al-Kut) falls under the "good" category (CMME WQI range: 82.7–88.4) except for 2012 and 2013, where it descended to become under the "fair" category mainly (CMME WQI range: 66.08–74.2).

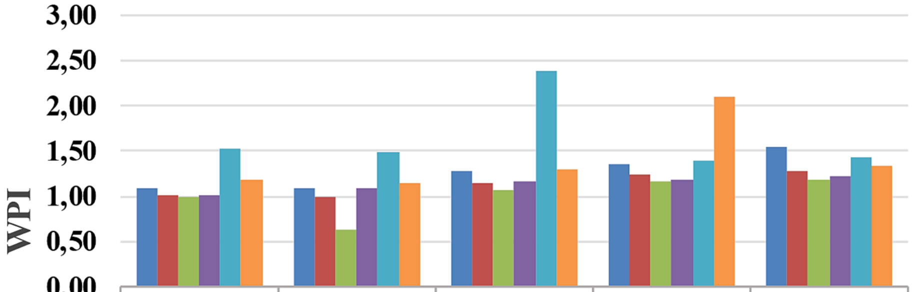
Site 3 (Ali Al-Gharbi), Site 4 (Amara) and Site 5 (Al-Qurnah) fell under the "fair" category, mainly for 2008, 2009, 2010 and 2011. Whereas, water quality ranged between "marginal" and "fair" categories for 2012 and 2013.

However, Figure 3 detected the water status of the Tigris River by WPI values was "pure" to "moderately polluted" in 2008, 2009, 2010, and 2011 (WPI range: 0.63–1.55) for all sites. Whereas, WPI values dropped from "moderately polluted" to "polluted" (WPI range: 1.15–2.39) in all sites in 2012 and 2013. This particular case is because 8 of the 13 analyzed parameters (Chlorides, Sulfate, Nitrate, salts, Boron, Copper, Chromium, and BOD_5) exceeded the maximum allowed concentrations for some tests according to standards of river maintenance from pollution shown in Law 25 [Law25, 1967], It may be due to there being high intervention between the effects of dry conditions causing high rates of salts in water and human activities, leading to increasing chlorides, sulfates, nitrates, boron, and copper. Chromium, BOD_5, which might be the main reason behind the depletion of WQI throughout this period, especially in the downstream sites where this result affected Factor 1 (F1) It indicates that a higher percentage of variables did not achieve their objectives. These results agreed with [Al-Obaid et al., 2010] when studying the Tigris River in Baghdad (2002–2008).



	SITE.1	SITE.2	SITE.3	SITE.4	SITE.5
2008	85,22	85,33	77,46	72,25	69,68
2009	83,86	86,68	80,47	71,43	77,32
2010	88,46	87,48	78,41	73,13	76,02
2011	82,70	83,42	76,91	76,72	76,02
2012	67,04	66,08	67,40	59,75	59,43
2013	66,46	74,29	68,03	67,31	67,32

Figure 2. CCME WQI values of various sampling sites of the Tigris River



	SITE.1	SITE.2	SITE.3	SITE.4	SITE.5
2008	1,08	1,09	1,28	1,35	1,55
2009	1,00	0,99	1,15	1,24	1,27
2010	0,98	0,63	1,07	1,16	1,19
2011	1,02	1,08	1,16	1,18	1,22
2012	1,52	1,49	2,39	1,39	1,43
2013	1,18	1,15	1,29	2,10	1,34

Figure 3. WPI values of various sampling sites of the Tigris River

The finding was consistence with the result of Al-Hussaini et al [Al-Hussaini et al, 2018] investigated environmental pollution of the Diyala River, one of the Tigris tributaries within Baghdad City (1999–2015).

However, for spatial profiles of water quality, the results in Figure 2 showed "fair" to "good" quality in upstream sites, Al-Aziziyah (Site 1), Al-Kut Site (Site 2), and Ali al-Gharbi (Site 3) throughout the study period (CCME WQI range: 66.08–88.40). However, the results in downstream sites Amara (Site 4) and Al-Qurnah (site 5) were "fair" to "marginal."

Figure (3) showed that WPI ranged from "pure" to "moderately polluted" in upstream sites: Al-Aziziyah (Site 1), Al-Kut site (Site 2), and Ali al-Gharbi (Site 3) and in downstream sites in Amara (Site 4) and Al-Qurnah (Site 5), the WPI results ranged from "moderately polluted" to "polluted" (1.18–2.39).

The main reasons for the lower water quality in downstream sampling sites (Sites 4 and 5) may be increased parameter numbers that exceed the allowed standards, such as heavy metals, sulfates, and chlorides, which resulted from the discharge of city wastewater and salts from drainage tributaries. Whereas nitrate and sulfate were caused by agricultural effluents, which increased from north to south. These findings agreed with the findings of [Al-Mayah et al., 2021], which found that intensive communities and city wastewater along the Tigris River deteriorated the quality of the Tigris River from north to south. Similarly, Abed et al [Abed et l., 2021] found the same results when assessing the Tigris River within Baghdad City, which confirms that the city has a great impact on the WQ of the Tigris River.

Cluster analysis

Figure 4a shows the temporal variation dendrogram of three clusters during the study period for CCME. The first cluster consists of two sub-clusters; (1) triple of 2008, 2010, and 2011 years, where the results were referred to the closest average values of CCME, which included "good and Fair" (Canadian Council of Ministers of the Environment 2001) 77.988, 80.7, and 79.154 for 2008, 2010, and 2011, respectively. (2) A single sub-cluster of the 2009 year. This year, the CCME value was recorded as 79.95 "good". The second cluster is characterized by a single sub-cluster; the 2012 year, which the result referred to as the "marginal" value of CCME (63.94). The third cluster shows a single sub-cluster; the 2013 year was recorded as a "fair" value of CCME (68.68) (Table 2).

The dendrogram of temporal variation for WPI during the study period was illustrated in Figure 4–b. The results show three clusters. The first cluster consists of two sub-clusters: (1) pair of 2009–2011 years in which the values of WPI 1.05 and 1.13 "moderately polluted" were recorded. (2) A single sub-cluster in the 2008 year where the value of WPI (1.27) "moderately polluted" was recorded. The second cluster shows pair of sub-cluster 2010–2013 years, in these years the values of WPI (1.01 and 1.41) "moderately

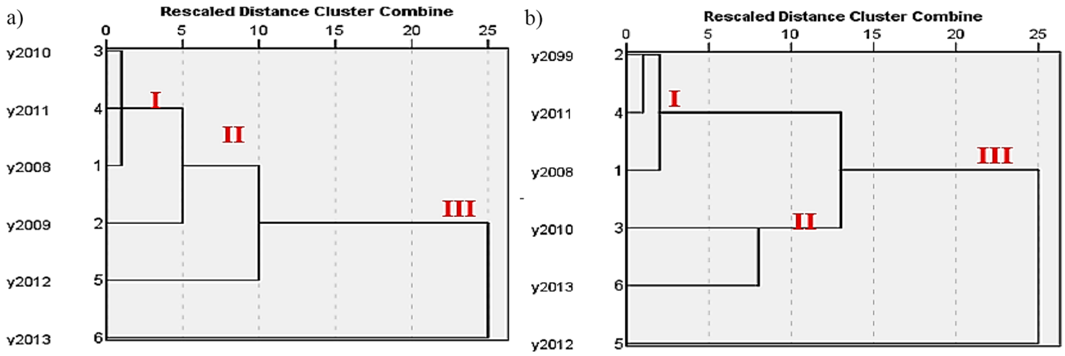


Figure 4. Dendrogram of temporal variations (a) CCME values of Tigris (b) WPI values of Tigris

polluted" was observed. The third cluster included only a single sub-cluster in 2012, and the result was referred to as 1.65 "moderately polluted" for WPI value (Table 2).

The dendrogram of spatial variation in Figure 5a shows three clusters during the study period. The first cluster is characterized by two sub-clusters: (1) pair of Site 1-Site 3, in which the results are referred to as the "fair" value of CCME (78.96 and 74.78). (2) a single sub-cluster, Site 2, in which the value of CCME 80.55 "Good" was obtained. The second cluster shows a single sub-cluster, Site 4. At this site, the value of CCME (70.10) "fair" was observed. The third cluster illustrates only a single sub-cluster, Site 5, and the result is referred to as 70.97 "fair" for the CCME value (Table 3).

Figure 5b shows the spatial variation dendrogram of three clusters during the study period for WPI. The first cluster consists of two sub-clusters; (1) a pair of Site 2-Sit 3, which the results referred to 1.07 and 1.39 values of CCME that included "moderately polluted". (2) A single sub-cluster of Site 1. On this site, the value of WPI 1.06 "moderately polluted" was recorded. The second cluster is characterized by a single sub-cluster, Site 5, which the result referred to as a "moderately polluted" value of WPI (1.33). The third cluster showed a single sub-cluster; Site 4 recorded a "moderately polluted" value of WPI (1.40) (Table 3).

CONCLUSIONS

The Canadian Council of Ministers of the Environment Water Quality Index and Water Pollution Index were used in this study to determine the water quality of the Tigris River. They are good tools for this purpose. Water quality scores descended in all sites in the last two years (2012 and 2013) compared with 2008, 2009, 2010 and 2011 due to the effects of dryness and human activities. On the other hand, water quality may become lower from Site 1 to Site 5 due to the discharge of city wastewater, drainage tributaries, and agricultural effluents, which are higher from north to south.

Based on the results obtained, the Tigris water quality was evaluated differently concerning the two indices. According to the CCME WQI index, 63% of sampling stations were classified as "fair", 30% were classified as "good", and 6% were classified as "marginal". Compared to the WQI, the WPI gave a score of 84% for water that was "moderately polluted", 10% for water that was "pure", and 6% polluted.

Table 2. The temporal variation of average values for CCME and WPI from 2008 to 2013 years

Year	CCME	WPI
2008	77.98	1.27
2009	79.95	1.05
2010	80.7	1.01
2011	79.15	1.13
2012	63.94	1.65
2013	68.68	1.41

Table 3. The spatial variation of average values for CCME and WPI for 2008 to 2013 years

Year	CCME	WPI
Site 1	78.96	1.06
Site 2	80.55	1.07
Site 3	74.78	1.39
Site 4	70.10	1.40
Site 5	70.97	1.33

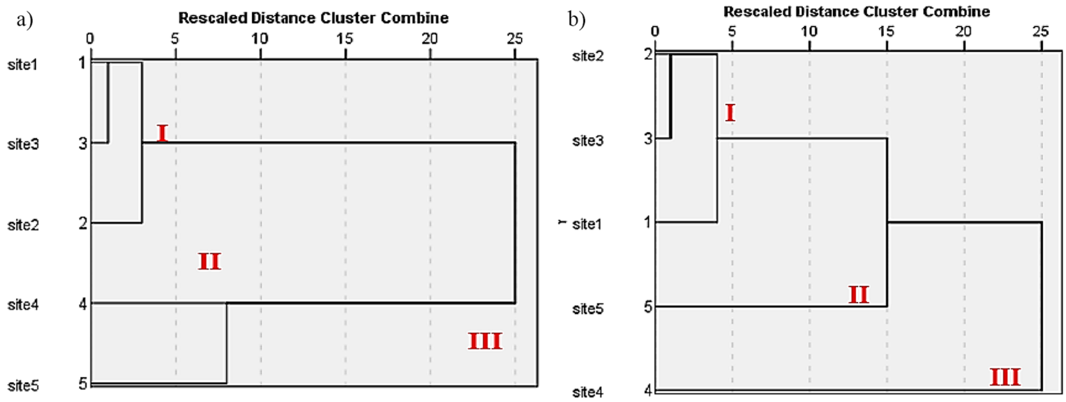


Figure 5. Dendrogram of spatial variations (a) CCME values of Tigris (b) WPI values of Tigris

The differences between the two indices were due to the weight of each parameter in the formula. Thus, the CCME-WQI will be applied when assessing water quality in areas where there are permanent sources of pollution. As regards the WPI, its low sensitivity to certain parameters makes it appropriate for a general characterization of watercourses. Therefore, a suitable index must be selected for the type of pollution source.

Acknowledgments

The authors are highly thankful to the National Center for Water Resources Management, Ministry of Water Resources for their support.

REFERENCES

1. Abed, A.N., Al-Kindi, G.Y., Hussain T.A. 2021. Assessment of the Water Quality Index of the Tigris River between the University of Baghdad and Diyala River. Eng. Technol. J., 39(3), 512–519. DOI: 10.30684/etj.v39i3A.1392
2. Abed, I.F., Nashaat, M.R. 2018. Interactions between the ecological dejiala river properties, Southern Iraq," Iraqi J. Sci., 59(2), 1026–1040. https://ijs.uobaghdad.edu.iq/index.php/eijs/article/view/413
3. Al-Azawii, L.H.A., Nashaat, M.R., Muftin, F. S. 2108. Assessing the effects of Al-Rasheed electrical power plant on the quality of Tigris River, Southern of Baghdad by Canadian Water Quality Index (CCME WQI). Iraqi J. Sci., 59(3A), 1162–1168. DOI: 10.24996/ijs.2018.59.3A.2
4. Al-Bahathy, I.A., Nashaat, M.R. 2021. Impact of Hindiya Dam on Rotifera Community of Euphrates River on the Northern of Babil Governorate, Iraq. Iraqi Journal of Science, 62(9), 2872–2886. DOI: https://doi.org/10.24996/ijs.2021.62.9.4
5. Al-Hussaini, S.N.H., Al-Obaidy, A.H.M.J., Al-Mashhady, A.A.M. 2018. Environmental assessment of heavy metal pollution of Diyala River within Baghdad City. Appl. Water Sci., 8(3), 1–6. https://doi.org/10.1007/s13201–018–0707–9
6. Al-Janabi, Z.Z., Shahed, R.Z., AlHassany, J.S., Al-Obaidy, Abdul Hameed, M.J., Awad, E.S., Maktoof, A.A. 2019. Geochemical Evaluation of Heavy Metals (Cd, Cr, Fe, and Mn) in Sediment of Shatt Al-Basrah, Iraq. Eng. Technol. J., 37(2), 237–241. DOI: 10.30684/etj.37.2C.6
7. Aljanabi, Z.Z., Al-Obaidy, A.H.M.J., Hassan, F.M. 2021. brief review of water quality indices and their applications, IOP Conf. Series: Earth and Environmental Science 779: 012088. DOI: 10.1088/1755–1315/779/1/012088
8. Aljanabi, Z.Z., Hassan, F.M., Al-Obaid, A.H.M.J. 2020. Heavy metals pollution profiles in Tigris River within Baghdad city. IOP Conf. Series: Earth and Environmental Science, 1088, 012008. DOI: 10.1088/1755–1315/1088/1/012008
9. Al-Mayah, W.T., Al-Mayyahi, S.O.M., Al-Shammary S.H. 2021. Water quality assessment in terms of water quality index (WQI): A case study of the Tigris River, Baghdad, Iraq. in IOP Conference Series: Earth and Environmental Science, 779(1), 12078. DOI: 10.1088/1755–1315/779/1/012078
10. Al-Obaidy, A.H.M.J., Maulood, B.K., Kadhem, A.J. 2010. Evaluating raw and treated water quality of Tigris River within Baghdad by index analysis. J. water Resour. Prot., 2(7), 629–635. DOI: 10.4236/jwarp.2010.27072
11. American Public Health Association (APHA). 1988. Standard Methods for examination of water and wastewater., An. Hidrol. Médica, vol. 20th Edit, 874.
12. Ayat, N.A., Al Kindi G.Y., Hussain T.A. 2021. Assessment of the Water Quality Index of the Tigris River between the University of Baghdad and Diyala River. Engineering and Technology Journal, 39(3A), 512–519. DOI: 10.30684/etj.v39i3A.1392
13. Banda, T.D., Kumarasamy M.V.2020. Development of water quality indices (WQIs): A review. Polish J

Environ Stud., 29(3), 2011–2021. DOI: 10.15244/pjoes/110526

14. Bidyut, K.S. 2017. Arsenic Contamination of Groundwater in West Bengal: Awareness for Health and Social Problems. Interna. J. of Appl. Scien. and Engine., 5(1), 43–46. DOI: 10.5958/2322–0465.2017.00005.3
15. Ewaid, S.H., Abed, S.A., Al-Ansari, N., Salih, R.M. 2020. Development and evaluation of a water quality index for the Iraqi rivers. Hydrology, 7(3), 1–14. DOI: 10.3390/hydrology7030067
16. Ewaid, S.H., Abed, S.A., Kadhum, S.A. 2018. Predicting the Tigris River water quality within Baghdad, Iraq by using water quality index and regression analysis. Environ. Technol. Innov, 11, 390–398. https://doi.org/10.1016/j.eti.2018.06.013
17. Ghalib, H.B. 2017. Groundwater chemistry evaluation for drinking and irrigation utilities in east Wasit province, Central Iraq. Appl. Water Sci., 7(7), 3447–3467. https://link.springer.com/article/10.1007/s13201–017–0575–8
18. Ghalib, H., Yaqub, M., Al-Abadi, A.2018. Hydrogeochemical modeling and isotopic assessment of the quaternary aquifer at Ali al-Garbi area in Misaan Governorate, South of Iraq. in Conference of the Arabian Journal of Geosciences, 121–124. DOI: 10.1007/978–3-030–01572–5_30
19. Karen, S., Kevin, C., Kim, H. 2001. Canadian water quality index 1.0 technical report and user's manual. Canadian Environmental Quality Guidelines Water Quality Index Technical Subcommittee, Gatineau, QC, Canada., 5.
20. Law25. 1967. Law 25/1967 Rivers maintaining system and general water from pollution No 25, Iraqi Official Gazette. Minist. Heal. Gov. Iraq.
21. Li, D., Liu, S. 2018. Water quality monitoring and management: Basis, technology and case studies. Water Quality Monitoring and Management: Basis, Technology and Case Studies. Academic Press, 368.
22. Majeed, O.S., Al-Azawi, A.J., Nashaat, M.R. 2022. The Effect of Tharthar-Tigris Canal on the Environmental Properties of the Tigris River Northern Baghdad, Iraq. Baghdad Science Journal, 19(6), 1177. https://orcid.org/0000–0001–8063–123X
23. Majeed, O.S., Al-Azawi, A.J., Nashaat, M.R. 2023. Application of Cndian Water Quality Index (CCME-WQI) for Aquatic Life to Assessment the effect of Tharthar Water upon the Quality of Tigris River Water Northern Baghdad City, Iraq, 6(3).
24. Maktoof, A.A, Zahraw, Z., Magtoop, M.G. 2020. Concentrations of some trace metals in water and sediment of main outfall drain in Al-Nassiriyia city by using pollution indices. AIP Conference Proceedings, 2290, 020013. DOI: 10.1063/5.0028595
25. Mirza N.N., Nashaat M.R. 2018. An Ecological Assessment for Interactions Between The Physico-Chemical Characteristics of Gharaf River Characteristics, Southern Iraq. Res. Ecol. An Int. Sci., 6(2), 244–2263. http://ecologyresearch.info/documents/EC0650.pdf
26. Moran, S. 2018. Clean water characterization and treatment objectives, An Appl. Guid. to Water Effl. Treat. Plant Des., Elsevier, 61–67.
27. Nashaat, M.R., Al-Bahathy, I.A.A. 2022a. Impact of Hindiya Dam on the Limnological Features of Euphrates River to the North of Babil Governorate, Iraq. Baghdad Sci. J., 19(3), 447. https://doi.org/10.21123/bsj.2022.19.3.0447.
28. Nashaat, M.R., Al-Bahathy, I.A.A. 2022b.Impact of Hindiya Dam on Copepoda Diversity in Euphrates River, North of Babylon Province, Iraq. Biological and Applied Environmental Research, 6(2), 121–143. DOI: 10.51304/baer.2022.6.2.121
29. Roy, M., Shamim, F. 2020. Assessment of Antropogenically Induced Pollution in the surface water of River Ganga: A study in the DhakhineswarGhat, WB, India. J. Water Pollut. Purif. Res., 7(1) 15–20.
30. Van der Leeden, F. 1975. Water resources of the world; selected statistics. New York [USA]: Water Information Center, 568.
31. Zahraw, Z., Maktoof, A.A., Al-Obaidy, A.H.M.J., Abdul Kareem, L.M., Shakir, E., Hassan, S.M. 2019. Estimation of heavy metal concentration for sediments of Shatt Al-Basrah canal by using ecological indices. Indian J. Public Heal. Res. Dev., 10(1), 970–974. DOI: 10.5958/0976–5506.2019.00213.4