Journal of Engineering and Sustainable Development
http://jeasd.uomustansiriyah.edu.iq/index.php
https://doi.org/10.31272/jeasd.25.3.4

Vol. 25, No. 03, May 2021
ISSN 2520-0917

WATER QUALITY INDEX OF TIGRIS RIVER WITHIN BAGHDAD CITY: A REVIEW

*Tamarah A. Adnan[1]   Eman A. Mohammed[1]   Abdul-Sahib T. Al-Madhhachi[2]

1) Department of Environmental Engineering, College of Engineering, Mustansiriyah University, Baghdad, Iraq
2) Department of Water Resources Engineering, College of Engineering, Mustansiriyah University, Baghdad, Iraq.

Received 7/10/2020 ***Accepted in revised form 15/11/2020*** ***Published 1/5/2021***

Abstract: Tigris River is the only potable source in Baghdad city therefor many water treatment plants were built on the banks such as Al-Karkh, Sharq Dijla, Al-Sadr, Al-Wathba, Al-Karama, AlQadisia, Al-Dora, Al-Wahda, and Al-Rashed project. Tigris River suffers from the pollution that comes from various sources such as Industry, domestic sanitation, and farming activities therefore several indices were used to calculate water quality within Baghdad to convert physicochemical parameters of water to a single value that represents the river status (good, bad, very bad, etc..).The aim of this review paper to show the results of previous studies about the water quality for the Baghdad region. Most results showed that water quality was good in the north of the city of Baghdad and bad in the south of Baghdad. The deterioration of water quality was due to many reasons such as the discharge of wastewater directly into the river without pretreatment, increase in (Electic conductivity, Turbidity, and total suspended solids, total hardness, Iron ion, the fecal coliform)concentrations, and Climate change, therefore, Tigris River needs intensive treatment before using by humans.

Keywords: *The Tigris River, water quality index, water treatment plant, physicochemical parameters.*

1. Introduction

The water quality index is an essential method to simplify complex data and technical reporting of water quality information. This, in turn, is important to provide a structured framework for evaluating and comparing the quality of water from different water sources [23]. Water quality indices are not aimed at replacing the detailed, but rather tools designed to provide a guide to support water quality experts and policymakers with fast details [18]. Water quality index was proposed early in 1965, to define the State of Water Quality in the River [16]. Many indices have been developed by many researchers. WQI consists of steps, these steps are a selection of parameters, generating sub-indices, Generate parameter weights, and aggregate process to calculate the final index value. Water quality can be categorized into three broad physical, chemical, and biological categories, each of which consists of several parameters[24]. This paper introduces and reviews the water quality of the Tigris River within Baghdad by using different indices.

Tigris River is one of the Middle East's largest rivers. The total length of the Tigris River is 1850km (the total length within Iraq 1418km and about 50km within Baghdad) [3,17]. Tigris River is the source of drinking water therefore

**Corresponding Author*: tamaraamjed1994@gmail.com

the assessment of the quality of the Tigris river in Baghdad City has been extensively studied in recent years using various water quality indices. Researchers used different sites to calculate the water quality index some of these sites represent in “Fig. 1”, Which represents the north, middle, and south of Baghdad.

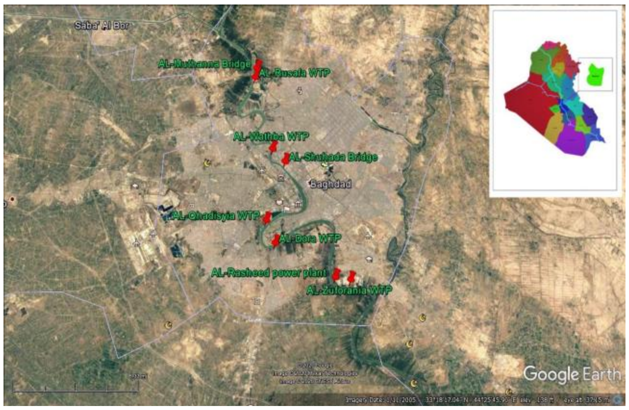

Figure1. The most common sampling sites within Baghdad city used by researchers

Many researchers used several methods to calculate the water quality index for the Tigris River in Baghdad, such as the Canadian Council of Ministers of the Environment (CCME) Water Quality Index, Fuzzy water quality index, and Weighted Arithmetic Index method. Several attempts have been made using statistical approaches such as cluster analysis, discriminant analysis, factor analysis, and principal component analysis to explore the structure and relationship of water quality variables [25]. WQI scores can be divided into two methods. The first method was that the value of the index increases with the increase in the level of pollution, and this method was referred to as the growing index of the scale. The second method where the value of the index decreases with the degree of pollution, and this method was referred to as the index of the decreasing scale [1], the aim of the scaling was the same since both indices represent water quality based on levels of pollution [13].

2. Methods of Water Quality Index review in Baghdad city

More researchers used different models to find water quality in Baghdad city. [7,6,12] used the Weighted Arithmetic Index to assess the water quality of the Tigris River in the Baghdad area. In this index the results were classified according to these categories (0-25) Excellent, (26-50) Good, (51-75) Poor, (76-100) Very Poor, and (>100) Unsuitable. There are three steps to calculate water quality, as shown in the below equations (1), (2), (3):

$$Q_i = 100 * [\frac{V_{actual} - V_{ideal}}{V_{standard} - V_{ideal}}] \quad (1)$$

Q_i: The quality rating of parameter
V_{actual}: Actual value of the water quality parameter
V_{ideal}: Ideal value of that water quality parameter
$V_{standard}$: Recommended Iraqi standard guidelines of the drinking water

$$W_i = \frac{K}{V_{standard}} \quad (2)$$

W_i: Relative unit weight for a parameter.
K: Proportionality constant, K=1/∑ (1/Si).

Finally, WQI was calculated by aggregating the quality rating with the unit weight using the equation (3):

$$WQI = \frac{\sum Q_i W_i}{W_i} \quad (3)$$

[4,14,12] used the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)[9] to evaluate WQI within Baghdad city. In this index the results were classified according to this category; Excellent (95-100), Good (80-94), Fair (65-79), Marginal (45-64), and Poor (0-44). To calculate this index must be calculated (F_1, F_2, F_3) as showed in the below equations:

$$F_1 = \left[\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right] \times 100 \quad (4)$$

$$F_2 = \left[\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right] \times 100 \quad (5)$$

$$excursion = \left[\frac{Failed\ Test\ Value}{Objective}\right] - 1 \quad (6a)$$

$$excursion = \left[\frac{Objective}{Failed\ Test\ Value}\right] - 1 \quad (6b)$$

$$nse = \frac{\sum_{i=1}^{n} excursion}{\#\ of\ tests} \quad (6c)$$

$$F_3 = \left[\frac{nse}{0.01\ nse + 0.01}\right] \quad (7)$$

$$CCMEWQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \quad (8)$$

Where,

F_1(the scope): which is the number of variables not meeting the water quality objectives

F_2(the frequency): which is the number of tests of the objectives are not meeting the water quality objectives

F_3(the amplitude): which is the amount that the objectives are not meeting the water quality

NSE: the normalized sum of excursions

n: the total number of variables

i: an iteration

Ewaid et al., [11] developed a new water quality index based on the fuzzy logic artificial intelligence framework for the routine evaluation of river water quality for drinking purposes. The Fuzzy Logic Inference System (FLIS) is a rule-based system in which fuzzy logic is used as a tool to represent different types of knowledge about a problem. FLIS was the method towards defining a mapping from input to output using fuzzy logic to give a basis for decisions made. The FLIS includes three important ideas: rules of inference, fuzzy group operations, and the membership function "Fig. 2".

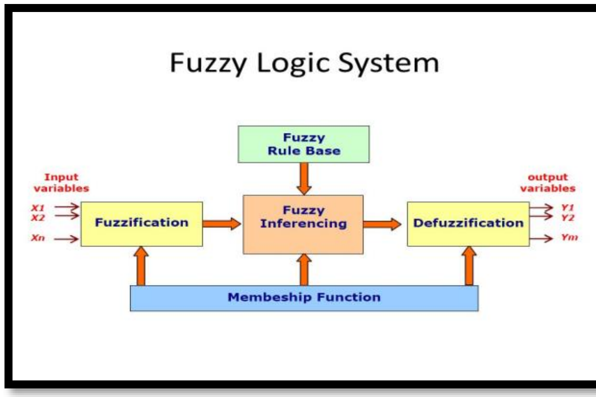

Figure 2. Artificial Intelligence - Fuzzy Logic Systems

The membership function is a curve that characterizes how each point in the input space was mapped to a membership rate in the vicinity of (0 and 1) "Fig. 3". The space of the input was known as the universe of discourse and the membership rate was the output-axis [22].

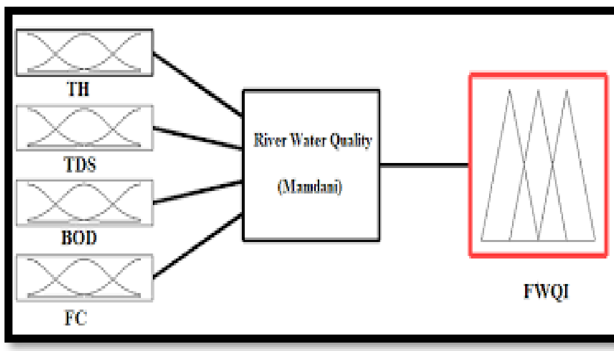

Figure 3. Membership functions of the FWQI.

The system in [11] study consists of 81 bases, 4 inputs, and one output, and was used to design a fuzzy Water Quality Index (FWQI) for the Tigris River and other Iraqi rivers. Five linguistic variables were identified, among which four input variables are biological oxygen demand (BOD), total hardness (TH), total dissolved solids (TDS), and fecal coliform (FC) and the output variable was the Fuzzy Water Quality Index (FWQI) "Fig. 2". The fuzzy logic toolbox package, Matlab (R2013b) was the tool used for simulating the system (MathWorks,2013). Each parameter has three membership functions and the output variable shows the water quality by 3 classes with the range 0-100.

4. Literature Review results of the Tigris River Water Quality Index in Baghdad City

Due to the increase in population, industrialization, and urbanization, the large quantities of sewage and industrial wastewater discharged into the river have contributed greatly to the pollution of the river. Many researchers have studied the water quality index of the Tigris River within Baghdad city “Table 1”.

Alobaidy et al. [8] indicated according to results in “Table 1” that the phenomenon of water quality deterioration along Tigris River was generally evident in the seven years of results for raw water. Therefore more effort should be made by the authorities to monitor different activities along the river bank. Urgent regulations on water conservation, the regulation of waste-water treatment systems between factories, and other activities should be enforced.

Rabee et al. [21]indicated according to results in “Table 1” that degradation in water quality as a result of increased concentration of the fecal coliform counts as well as turbidity.

Al-Janabi et al. [4] ;Muftin et al., [19] indicated that a decrease in water quality “Table 1” associated with the discharge of wastewater from domestic sewers into the water supply system, discharges of stormwater, discharges of industrial waste, untreated agricultural runoff, and other sources, all of which may have a major impact on the quality of the river system. The observed loss of WQI may also be behind the impact of dryness in the region in the last three years.

Abdul-Rahman and Ahmad, [2] indicated that the successful parameter that reduced the index “Table 1” was the presence of a large number of Fecal Coliform bacteria and the presence of high iron ion concentrations that exceed the goals along the river stream so that within these (WTPs) there was a need to add an iron removal unit, or by adding an aeration unit at present (WTPs), especially in AL-Wahda and AL-Rashid (WTPS). Besides, due to the presence of high values of (EC) and high concentrations of (TDS) in most intakes (WTPS).

Ismail, [17] indicated that The high WQI value (polluted water) was due to high turbidity, total hardness TH, electrical conductivity (EC), and total solids(TDS) in the water and can also be related to the numerous human activities at the banks of the River “Table 1”.

Al-Janabi et al., [5] indicated that the primary factors responsible for assessing and degrading the river water quality were lead, iron, and turbidity“Table1”.To preserve water quality for further use, these parameters need to be modified.

Hazzaa, [15] indicated that a high concentration of Iron and turbidity led to degrading water quality “Table 1”.

Ewaid et al. [10]indicated that during the rainy season (winter and autumn season), the high value of TDS, Turbidity, and EC contributed to the high value of WQI (poor quality) “Table 1”.

Gubashi and Ahmed, [12] indicated that the water quality of Tigris was good north of Baghdad and start to degrade in the south of Baghdad especially in Diyala River“Table 1”.

Table 1. The list of selected studies used the Water Quality Index as a method for presenting water status of Tigris River within Baghdad city

Authors	period of study	Sites within Baghdad city	Parameters that used to calculate WQI	Types of indices	Results of WQI
Alobaidy et al.,[8]	February 2002 to December 2008	Al-karkh, East Tigris, Al-Karamah, Al-Wathbah, Al-Qadisiya, Al-Dawrah, Al-Rashid	pH, Alkalinity Turbidity, Total Dissolved Solids, Hardness, Calcium, Magnesium, Chloride, Sulphate, Ammonia, Fluoride, Iron and Aluminum	Weighted Arithmetic Index	Raw water quality index values declined along the stretch of the river from "Poor" to Very poor" to "Unsuitable"
Rabee et al., [21]	February to October 2009	Al-Tarmiyahm, Al-Utafiah, Al-Jadiriah, Al-Rasheed, Al-Zafaraniah	temperature, pH, the saturated ratio by dissolved oxygen, biological oxygen demand, nitrate, phosphate, fecal coliform, turbidity, and total dissolved solids	Weighted Arithmetic Index	The overall index of water quality showed that the Tigris River was in the medium class
Al-Janabi et al., [4]	February to December 2010	Sader Al-Qanat, Al-Aoadia, Al-Zafrania	pH, Total Dissolved Solids, Calcium, Total Alkalinity, Ammonia, Nitrate, Nitrite, Turbidity, Lead Chromium, Iron	Canadian Council of Ministry of the Environment (CCME)	Poor water quality in all sites
Abdul-Rahman and Ahmad,[2]	2009-2010	Al-karkh, Tigris- East, Al-Wathba, Al-Karama, Al-Qadisiya, Al-Dora, Al-Wahda, AL-Rashid	DO, pH, BOD_5, Temp., PO_4^{-2}, Tur., TDS, NO_3^{-1}, Fe, F, AL, ALK, Ca^{+2}, Hardness, CL^-, Mg^{+2}, Color, SO_4^{-2}, Fecal coliform bacteria, EC	Canadian Council of Ministry of the Environment (CCME)	Al-Karkh and Tigris-east (WTPs), categorized as good quality, while Al-Karama, Al-Qadisiya and Al-Wathba (WTPs) categorized as fair-class
Ismail,[17]	2013	Al-Karkh, East Dijlah, Al-Karama, Al-Wathba, Al-Qadisiya, Al-Dora, Al-Rashid	pH, turbidity, color, dissolved oxygen, BOD, hardness, total dissolved solids, total coliforms, sulfate, nitrate, chloride, arsenic, and fluoride	Overall Index of Pollution (OIP)	Al-Karkh, East Dijlah , Al-Karama and Al-Wathba WTPs are categorized as acceptable. Qadisiya WTP categorized as slightly polluted. Al-Doura WTP and Al-Rasheed WTP categorized as heavily polluted

Al-Janabi et al.,[5]	2013	Sader Al-Qanat , Al-Aoadia, Al-Zafrania	lead, Iron, Zinc, Manganese, Turbidity, pH value, Dissolved Oxygen, Water Temperature, Phosphate, Ammonia, Nitrate, and Nitrite	Canadian Council of Ministry of the Environment (CCME)	The rating of the WQI was from marginal in site 1, 2 to poor in site 3.
Hazzaa,[15]	from 2005 to 2013	Al-Qadisiya, Al-Dora, Al-Wahda , Al-Rasheed	temperature, turbidity, pH, total hardness, magnesium, calcium, sulfate, iron mg/L, fluoride, nitrate, chloride, color, conductivity	Canadian Council of Ministry of the Environment (CCME)	water quality index for the raw water can be classified as bad water
Ewaid et al.,[10]	2016	Al-Karkh, Sharq Dijla, Al-Sadr, Al-Wathba, Al- Karama, Al- Kadhimya, Al-Qadisia, Al-Dora, Al-Wahda, Al-Rashed	NO_2^{-1}, NO_3^{-1}, Tur, TH, pH, EC, TDS, DO, BOD_5, COD, and Na^{+1}	The assigned weight method	Poor water quality during (winter and spring)season, better quality during (summer and autumn)season.
Muftin et al.,[19]	2018	Al- Rasheed thermal power plant	temperature, turbidity, pH, EC, DO, CO_3, Calcium, Magnesium, sulfate, nitrate, Phosphate	Canadian Council of Ministry of the Environment (CCME)	bad water during winter, fair in spring and marginal in summer and autumn
Gubashi and Ahmed, [12]	2019	Tharaa – Tigris, Muthanna Bridge, Shuhada Bridge, Dora, confluence point of Diyala River	total hardness, calcium, pH, chloride, magnesium, nitrate, sodium, boron, Turbidity, and sulfate	The weighted Arithmetic method, Canadian Council of Ministry of the Environment (CCME), and the third water quality method developed by Erdenebayar	water quality index with the three methods showed poor to Unsuitable class, except Al-Muthanna Bridge, it was a good quality index
Al-Musawi and Al-Rubaie,[6]	2011 to 2017	Al-karkh, East Tigris, Al-sodar, Al-karama, Al-wathba, Al-qadisya, Al-dora, Al-wahda , Al-rasheed	Turbidity, Alkalinity, pH, Total hardness, Magnesium, Calcium, Chloride, Iron, Conductivity, Sulfate, Ammonia, Nitrate, Orthophosphate and Total solids	The weighted Arithmetic method	range from poor to polluted

Al-Obaidy et al,[7]	2013	Al-Muthana Bridge, Wathba WTP and The Medical City, Al-Rasheed Power Plant-2 and State Company for Vegetable Oils Industry	pH, Total Dissolved Solid, Total Hardness, Calcium, Magnesium, Chloride, Turbidity, Nitrite, Nitrate, sulfate, and Zinc	The weighted Arithmetic method	poor and unsuitable
Hassan et al,[14]	October 2011 to December 2012	Al-kriat, AL- Taifiya AL-Jadriyah, Diyala Bridge	temperature , electrical conductivity (EC), salinity (S‰), current flow, total dissolved material, total solid suspended, total alkalinity, dissolved oxygen, biochemical oxygendemand, total nitrogen and total phosphorus	Canadian Council of Ministry of the Environment (CCME)	poor- marginal
Flaieh et al,[20]	2008-2011	Al-rashed, Al-wahda, Al-Karkh, East-Tigrus, Al-wathba, Al-Karama, Al- Qadsiya, Al-Dora	pH, Electrical conductivity, Total suspended solids , Temperature, Turbidity , Total alkalinity, Total hardness, Calcium,Magnesium, Sulfate, Total solids,Iron, Aluminum, Nitrite, Nitrate, Ammonia, Silica, and Orthophosphate	The weighted Arithmetic method	Poor

Al-Musawi and Al-Rubaie, [6] indicated that the water quality of the Tigris River with Baghdad city range from poor to polluted “Table 1” especially in Al-Wathba WTP that located in the middle of Baghdad city. The river has high iron concentrations and was the main cause of the rise in WQI values (poor quality).

Al-Obaidy et al,[7] indicated that the water quality of the Tigris River within Baghdad city range from poor and unsuitable“Table 1” because of drainage of domestic and industrial wastewater, the discharge of stormwater, agricultural runoff, and other anthropogenic activities.

Hassan et al,[14] indicated that Temperature and total nitrogen play a major role in decrease the quality of the Tigris River"Table 1".

Flaieh et al,[20] indicated that the decrease in WQI of Tigris River within Baghdad "Table 1" due to the high turbidity concentrations, TH, EC, and TDS in the water, and various human activities on the river bank are attributable to this.

6. Conclusions

A Water Quality Index (WQI) is a method for assessing water conditions at certain times and places. It aggregates parameters of water quality into usable information that is quick and easily understood and can thus be used by both the authorities and the general public. The analysis presented in this paper on the Tigris River water quality index inside the city of Baghdad. To find the water quality in the city of Baghdad, many criteria and different indices were used. Most of the findings showed that water quality in Baghdad, varying from good, bad very bad. Most of the results confirmed that the water quality was good in the north of the city of Baghdad and becomes bad towards the south of Baghdad. The deterioration of water quality was due to many reasons such as :

1. Discharge of contaminants from domestic sewers, industrial waste, agricultural runoff, and other sources of pollutants that discharge into water bodies.
2. Increased the concentration of (EC, TDS, Turbidity, TH, Iron ion, the fecal coliform, etc..) that reduce the quality of water
3. The dryness in the region may be behind the WQI depletion.

These reasons confirm that the water of the Tigris River in Baghdad needs severe treatment to control pollution and then prepare the water for human use.

Acknowledgments

I thank Al-Mustansiriyah University Staff, College of Engineering for its help and support for this research.

Conflict of interest

There are no conflicts to declare.

Abbreviations

FWQI	Fuzzy Water Quality Index
FLIS	Fuzzy Logic Inference System
WTP	Water Treatment Plant

7. References

1. Abbasi, T., Abbasi, S.A., 2012. "Water Quality Indices".Elsevier, Amsterdam.
2. Al, E. A. R. M. F., & Ahmad, D. (2013). "Comparison of Water Quality Index at Intakes of Water Treatment Plants in Baghdad City". Tikrit Journal of Engineering Sciences, 20(4), 23-34.
3. Ali, A., Al-Ansari, N., & Knutsson, S. (2012). "Morphology of Tigris river within Baghdad city". Hydrology and Earth System Sciences, 16(10), 3783-3790.
4. Al-Janabi, Z, Al-kubaisi, A, and Al - Obaidy, a (2012) "Assessment of water quality of Tigris River by using Water Quality Index (CCME) (WQI)". Journal of Al-Narhrain University, 15 (1), 119-126.
5. Al-Janabi, Z. Z., Al-Obaidy, A. H. M. J., & Al-Kubaisi, A. R. (2015). "Applied of CCME Water Quality Index for Protection of Aquatic Life in the Tigris River within Baghdad city". Al-Nahrain Journal of Science, 18(2), 99-107.
6. Al-Musawi, N. O., & Al-Rubaie, F. M. (2017). "PREDICTION AND ASSESSMENT OF WATER QUALITY INDEX USING NEURAL NETWORK

MODEL AND GIS CASE STUDY: TIGRIS RIVER IN BAGHDAD CITY”. The journal of applied research. 3. 343-353.

7. Al-Obaidy AHM, Awad ES, Zahraw Z (2016b) “Impact of Medical City and Al-Rasheed power plant effluents on the water quality index value of Tigris River at Baghdad city”. In: 2nd Conference on Environment and Sustainable Development 28–29 Oct. Engineering and Technology Journal 34A (4):715–724.
8. Alobaidy, 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”. journal of water resource and protection, 2(7), 629.
9. CCME, Canadian Council of Ministers of the Environment (2001). “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.
10. 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”. Environmental Technology & Innovation, 11, 390-398.
11. Ewaid, S. H., Hussein, T. D., & Emran, F. K. (2018). “Fuzzy Logic Inference Index to Assess the Water Quality of Tigris River within Baghdad City”. Al-Mustansiriyah Journal of Science, 29(3 ICSSSA 2018 Conference Issue), 16-20.
12. Gubashi, K. R., & Ahmed, N. Q. (2020). “Water Quality index in Tigris River within Baghdad City”. Journal of Engineering and Sustainable Development, 24(Special_ Issue_2020), 80-90.
13. Hallock, D. (2002). “A Water Quality Index for Ecology’s Stream Monitoring Program”. Washington Department of Ecology. <http://www.ecy.wa.gov/biblio/0203052.html> (Accessed in December 2014).
14. Hassan, F. M., AL-Zubaidi, N. A., & Al-Dulaimi, W. A. (2013, December). “An ecological assessment for Tigris River within Baghdad, Iraq”. In J. of Babylon Univ. Special Issue-Proceeding of 5th Inter. Conference of Env. Science Univ. of Babylon/Env. Research Center (pp. 3-5).
15. Hazzaa, M. M. (2017). “Evaluation the Quality of Raw and Treated Water for Number of Water Treatment Plants in Baghdad, by Using Canadian Model for a Water Quality Index”. Tikrit Journal of Engineering Sciences, 24(3), 84-90.
16. Horton, R.K., 1965. “An index-number system for Rating Water Quality”. Journal of Water Pollution Control Fed., 37(3):300-306.
17.
18. Ismail, A. H. (2014). “Applicability of Overall Index of Pollution (OIP) for Surface Water Quality in Assessment of Tigris River Quality within Baghdad”. Engineering and Technology Journal, 32(1 Part (A) Engineering), 74-90.
19. Luzati, S., & Jaupaj, O. (2016). “Assessment of Water Quality Index of Durresi-Kavaja Basin, Albania”. J. Int. Environ. Appl. Sci, 11, 277-284.
20. Muftin, F. S., Nashaat, M. R., & Alazawii, L. H. (2018). “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 Journal of Science, 59(3A), 1162-1168.
21. Flaieh HM, Abdul-Ahad MY, Mohammed-Ridha MJ (2014) “Assessing Tigris River

Water Quality in Baghdad city Using Water Quality Index and Multivariate Statistical Analysis". International Journal of Engineering Sciences & Research Technology 3: 687-699.

22. Rabee, A M, Abdul-Kareem, B M and Al-Dhamin, A S (2011) "Seasonal Variation of some Ecological Parameters in Tigris river water at Baghdad Region. Iraq". Journal of Water Resource and Protection, 3, 262-267.
23. Ross, T. J. (2010). "Fuzzy logic with engineering applications". 3rd Edition. John Wiley & Sons.
24. Sarkar C, Abbasi SA (2006) "Qualidex—new software for generating water quality index". Environ Monit Assess 119, 201–231.
25. Swamee, P., & Tyagi, A. (2007). "Improved method for aggregation of water quality subindices". Journal of Environmental Engineering,133(2),220-225, doi:10.1061/(ASCE)0733-9372(2007)133:2(220).
26. Wan, J., Bu, H., Zhang, Y., & Meng, W. (2013). "Classification of rivers based on water quality assessment using factor analysis in Taizi River basin, northeast China". Environmental earth sciences, 69(3), 909-919.