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Water Quality Assessment in Baghdad City at the Intakes of Three Water Treatment Plants

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Abstract:- The Tigris river water in this study was evaluated at three water treatment plants in Baghdad city for six months from January 27, 2019, to August 28, 2019, the water assessment has been done by using the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) for a total of 540 samples of 12 parameters and the parameters are Turbidity, Total Hardness as CaCO3, Chloride, pH, Sulfate, Total dissolved solids, Iron, Fluoride, Nitrite, Nitrate, Ammonia, Faecal Coliform. The calculated CCMEWQI for the three water treatment plants as signal station WQI were; Sharq Dijla (61.64726, marginal), Al Wathba (63.2286, marginal), Al Wihda (62.984135, marginal), and the calculated CCMEWQI for Tigris river passing through Baghdad city as multi-station WQI was (62.59553, marginal), the Tigris river passing through Baghdad city status is not promising since the water treatment plants on Tigris river in Baghdad city are already outdated. The CCMEWQI is calculated using MATLAB by developing a flexible and extraordinarily easy code for any types of parameters and guidelines and for any size of data.

Keywords:- *Water quality, Tigris, CMEWQI.*

I. INTRODUCTION

The quality of water is considered an essential worldwide environmental concern. The pollution of water is a consequence of erosion, human activities, agricultural and industrial activities [1]. Unprocessed industrial discharges and untreated domestic waste-water discharges are a small pollution source that alters water's hydrochemistry. Plus, seasonal variations and non-point sources of pollution caused by urban areas surface-runoffs and underground waters negatively affect the water quality [2]. High amounts of chemical concentrations and nutrients result in various problems such as marine life deaths and loss of biodiversity, increases in algal blooms, and decreases in oxygen [3]. The water quality evaluation is very important for the safety and health of the population [3]. In recent years, the assessment of water quality is becoming an important Burden in many countries that have started taking actions for water shortages that can be faced in their future [4]. Therefore, the water quality evaluation becomes an essential tool in evaluating the pollution extent or otherwise of a water shade and thus applying the appropriate actions to limit the issue of water sources pollution. Water quality is set on by comparing bacteriological, chemical, and physical parameters of water samples with predetermined water quality guidelines. The guidelines are based on scientifically acceptable toxicity levels to either marine life or human health [5]. Sulfate Total dissolve solids Suspended solids Iron Fluoride Nitrite Nitrate Ammonia Silica Orthophosphate and others. WHO Guide-lines are indicated in terms of Action Levels for important organic, inorganic, and bacteriological parameters; toxicity indicator parameters; and radioactive parameters such as gross alpha and beta activity. Action Level is a term that signalized a level above which the reasons for the existence of a substance should be investigated, and proper remedial actions are utilized [6].

II. WATER QUALITY INDEX

The Canadian water quality index Is employed to evaluate the water quality at the three sites and the river's quality as a mullite site index. The Canadian Council of Ministers for the Environment recommends that a WQI should be calculated for a station with no less than four parameters and four sampling visits in a year [7]. The CWQI calculates values over an index period, usually a year or a season. Therefore, the CWQI is designed to evaluate the average quality of water over a given time instead of being utilized as a tool for identifying recent water quality issues, which may be suitable for operating water treatment plants. The Canadian WQI is based on parameters set and objectives limitation for the individual parameter. The index calculates three operators based on the selected objectives: (F1) the number of parameters that did not meet their objective in the index timeline, (F2) the proportion of tests that failed the objectives in the index timeline, and (F3) the relative intensity of any failures in the index timeline. Combining these operators gives the overall rating. Therefore, two main environmental aspects, the severity and frequency of adverse conditions, are both included in the CWQI calculation. Depending on the geographical location and application, the number of parameters and the parameters objectives can easily be regulated in the index calculations [8].

III. STUDY AREA

The Tigris River is the primary source for drinking and irrigation water for Baghdad, the largest city in Iraq "with about 7,216,000" [9]. It is also the only river which passes through Baghdad. Although it is the most crucial water source in Iraq, monitoring and obtaining the necessary quantity and quality of this river delivers a significant issue [10]. The water is tested at the intakes of a Three water treatment plants were listed in Table.1 The sites were selected to ensure that the quality of water at intakes of the treatment plants represents the Tigris river water in Baghdad city for drinking purposes. Because Sharq Dijla project intake is near the Tigris river entrance, and within Baghdad municipal jurisdiction, and Al-Wathba project is at the last portion of the Tigris river flows in Baghdad city south of Baghdad figure 1. And because these sites locations and characteristics meet the study, plan, objectives, requirements, and logistics. And because of large numbers of the population these projects serve, and their health related to the water they consume from these projects. And to ensure that samples from these sites are met with quality control measures taken as part of the study plan.

Table 1. Water Treatment plants.

Project	Design capacity (m^3/day)	Production (m^3/day)	Location	Coordinates
Sharaq Dijla	544,000	544,000	AL kurayat	33.416355 N 44.345392 E
Al-Wathba	80,000	62,000	AL waziria	33.351478 N 44.373772 E
Al-Wahda	70,000	50,000	AL karrada	33.292488 N 44.444440 E

IV. MATERIALS AND METHODS

➢ *Sampling routine*

Samples were collected every two weeks for the period of seven months from January 27, 2019 to August 28,2019 at the intakes of each of the three water treatment plants and tested for the chemical, physical, and Biological parameters. Following the EPA SESDPROC-201-R3, Surface Water Sampling guide, the water is collected using a plastic bucket and then the containers filled in the bucket by dipping them in the water, to avoid contamination, containers are washed in distilled water and alcohol and dried the night before, the bucket and the cool-box are decontaminated also. The samples then are set in a cool-box with ice and kept at 4 degrees Celsius. The entire operation is done wearing medical gloves. After documentation, the box then transported to the lab for testing. The samples box was transported to the lab within approximately one hour.

Fig 1:- Selected sampling sites

➢ *Parameters setting*

Eleven parameters are selected for testing the river water, these parameters are ranging in importance and impact on health, and present an image of the water quality. Some parameters shear the same sampling procedure and preserving, but each parameter has its own test. The parameters' selection is based on the recommendations and the guidelines of the health and environmental organizations excluding parameters that may compromise the overall study due to complexity of their sampling, handling, and most importantly testing those parameters, Setting the plan part of selection the parameters should consider the availability of laboratories that have the capability to test the samples within a reasonable distance of the sampling sites, thus delivering the samples at its best condition in the shortest period possible.

➢ *Testing methods*

Tests conducted on samples are based on the standard method for examining *water and waste-water,* Al samples have been tested simultaneously to collect the samples in deferent labs. For each sampling site, the nearest lab was chosen Sharq Dijla lab, Wathba lab, Wihda lab, and laboratories of the water and food departments of the science and technology ministry departments. The parameters selected and the testing method are shown in Table 2.

parameter	Testing Method	Measured as
Ammonia	Phenate method	mg/L NH_3
Nitrite(no2)	Colorimetric method	mg/L NO_2
Nitrate(no3)	Ultraviolet spectrophotometric method	mg/L NO_3
Turbidity	Nephelometric method	NTU
Sulfate	Turbidimetric method	mg/L SO_4^{-2}

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Total Hardness	EDTA titration method	mg/L $CaCO_3$
TDS	Conductivity meter	
PH		
Fluoride	Spadns method	mg/L F
Iron	phenanthroline method	mg/L Fe
Fecal coliform	9222 MEMBRANE FILTER TECHNIQUE FOR MEMBERS OF THE COLIFORM GROUP	Number of colonies / 100 ml

Table 2. Parameters selected and the method of testing

➢ *CCMEWQI Model*

It has been proposed in the last few years that mathematical calculations are employed to calculate the index for water quality for better understanding of the water quality in water bodies. As the water parameters that analyzed different studies are diverse, water resources comparisons can be hard, to resolve this, a mathematical formula has been proposed in past years to calculate the WQI when defining water bodies' water quality [11]. The Council of Ministers of the Environment in the Canadian government proposed a Water Quality Index (CCME WQI) a very remarkable index, intending to create a method of integrating water quality issues to stakeholders, decision-makers, and scientists. The Canadian WQI serves divers advantages over other methods, including freedom in selecting criteria, an indulgence for missing data, compliance with multiple legal requirements and different uses of water, and eligibility for assessing the quality of water in specific areas (Yan, F. 2016). The water quality index value categorizes the water into five categories; Poor (0 to 44); Marginal (45 to 64); Fair (65 to 79); Good (80 to 94); Excellent (95 to 100) [8].

The index permits measurements of the extent and frequency to which parameters surpass their respective guidelines at each testing station [8], the Canadian water quality index is calculated by the following equation Were F1, F2, F3 are Scope, Frequency, Amplitude. And there are calculated as follow. F1 and F2 are computed directly by the following equations [11],

- F1: represents the proportion of parameters that didn't meet their guideline limits at least once during the assessment timeline, relative to the total number of parameters measured under consideration ("failed variables") [11]:

$$F1 = \left(\frac{Nuber\ of\ failed\ variables}{Total\ number\ \ of\ variables}\right) \times 100$$

- F2: represents the percentage of each tests that didn't meet objectives ("failed tests") [11]:

$$F2 = \left(\frac{Nuber\ of\ failed\ tests}{Total\ number\ \ of\ tests}\right) \times 100$$

- F3: takes additional steps and is calculated as follow

$$F3 = \left(\frac{nes}{0.01nes + 0.01}\right)$$

- excursion: The number of times in which each test concentration is greater than the objective. When the test value must not surpass the guideline limit, the extrusion is calculated as bellow [11]:

$$excursion\ i = \left(\frac{failed\ tests\ Value\ i}{Objective\ j}\right) - 1$$

- nes: the normalized sum of excursions, is the collective amount by which individual tests that did not comply with the setted objectives. it is the sum of excursions of each test from their objectives and dividing it by the total number of tests (tests that comply with objectives and those that don't). [11]:

$$\mathrm{nes} = \frac{\sum_{i=1}^{n} \mathrm{excursion\ i}}{\mathrm{number\ of\ tests}}$$

- The Canadian Council of Ministers of the Environment WQI [11]:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1 \cdot 732}\right)$$

The CCMEWQI is calculated by developing a MATLAB code. The code developed have the advantage and flexibility to calculate the water quality index for any chosen parameters and guidelines.

V. RESULTS AND DISCUSSION

Table 3 contains A summary of Physical and chemical parameters for all samples. The tests results are compared to Iraq and world Health Organization Drinking water standard since the Canadian, Australian, EPA, standards shear the same health-based standard of drinking water except for few parameters deference in limits for Aesthetic purposes for example WHO and EPA did not set a mandatory limit for silica in regard for human health.

Parameter	MAX	MIN	AVE	IQR	WHO
Turb	431	20	77.57	5	5
T.H	394	216	296.7	500	200
Cl	103	29	57.46	250	250
PH	8.15	7.82	7.983	6.5-8.5	6.5-8.5
SO_4	250	114	165.7	250	250
TDS	771	371	526.8	1000	600
Fe	4.3	0.11	1.822	0.3	0.3
F	0.15	0.01	0.087	1	1.5
NO_2	1.71	0.005	0.762	3	3
NO_3	1.8	0.047	0.758	50	50
NH_3	3.3	0.047	0.729	NGV	1.5

Table 3:- The maximum, minimum, average for physical and chemical parameters

The tests results gave a good understanding of the river condition throughout the testing period. For the selected 13 parameters a 195 test is conducted for each site, 63 tests exceeded the WHO limits in sharq Dijla site, 70 in Al Wathba

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site, and 64 in Al Wihda site. The equation of the WQI contains an evaluation of both range and size of excursions from the WHO guidelines see figure 2. Rickwood, and Carr, as in [8] have shown that the extension by which each parameter surpassed the guideline has a significant impact on the index, and lesser influence of the number of failed parameters and the failure times of each parameter, thus parameters influencing F3 have a substantial impact on the index. Furthermore, F2 has a small impact; in other words, the failure times of a parameter are not a significant factor in the index value determination. To better understand which parameter has the impact on the index and the percentage of testes that failed for each parameter, see figure 3.

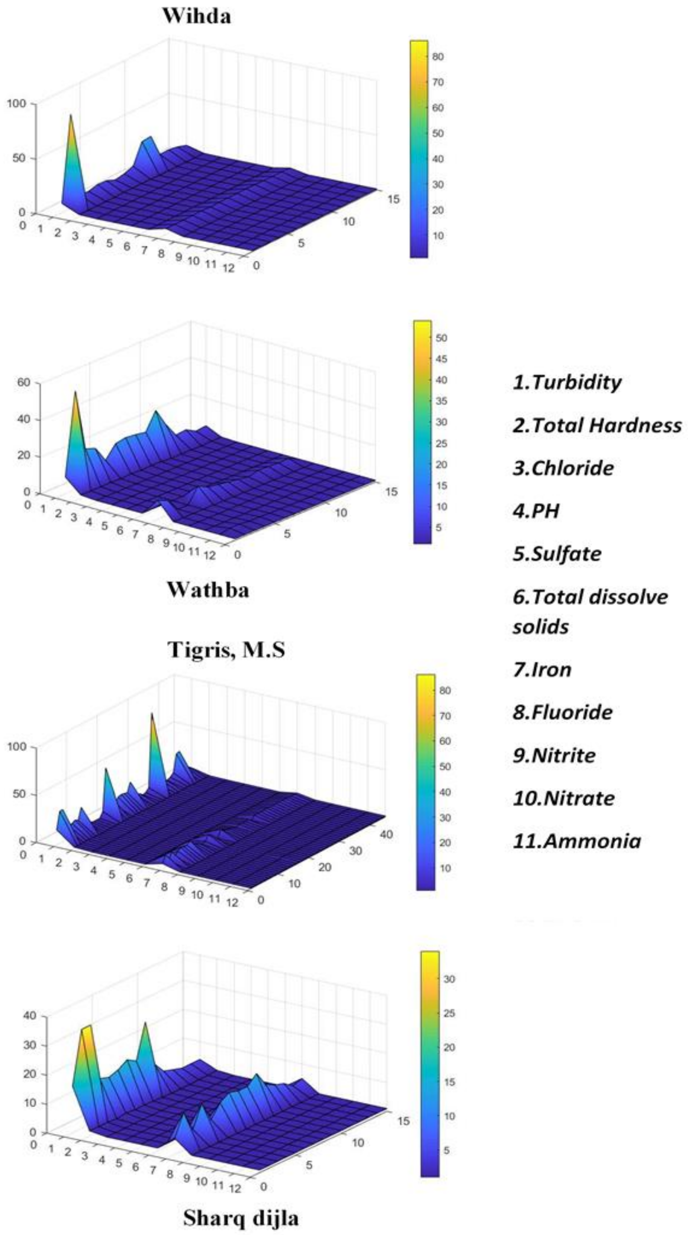

Fig 2:- Surface plot of the Excursions without Faecal coliform for the three sites and the Tigris River within Baghdad. (M.S: multi stations)

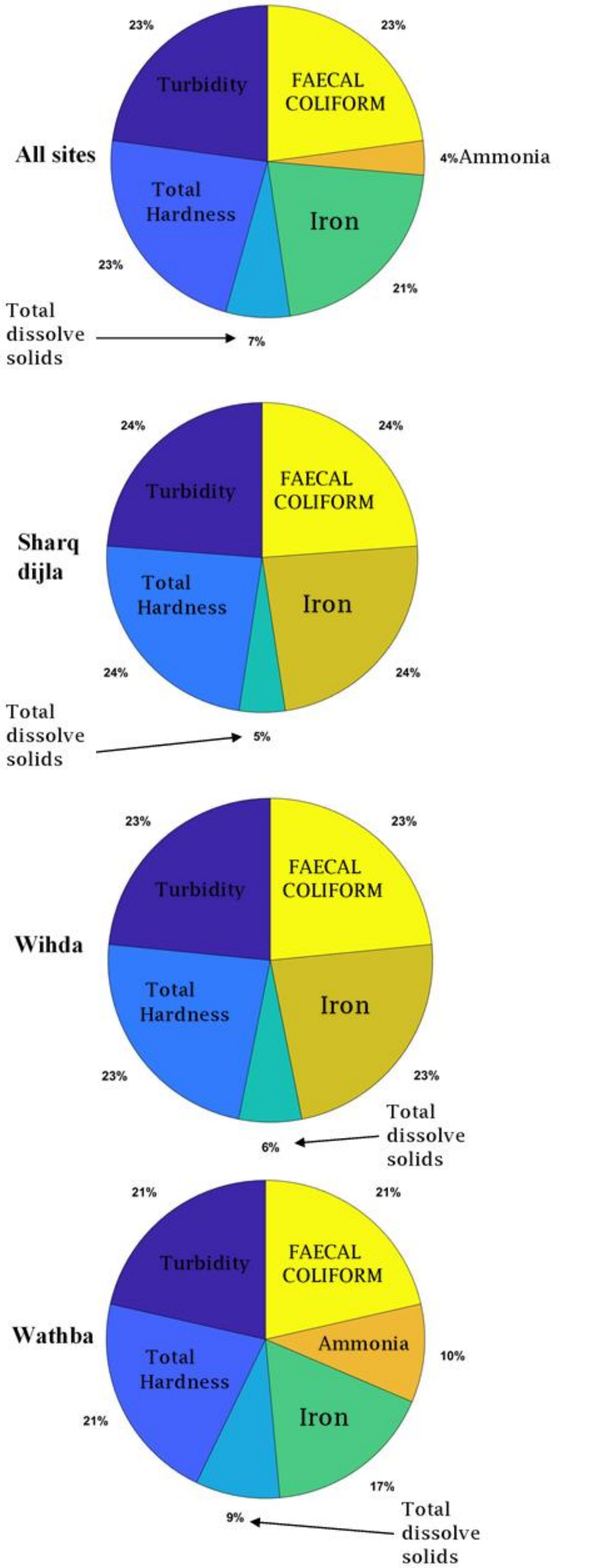

Fig 3:- Pie chart of the percentages of the failed tests for the parameters evaluated at three sites and the river as multi-stations.

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Faecal coliform bacteria, turbidity, total hardness and iron has the most impact on the overall index with ammonia has the least roll. Scatterplots for each index against its respective parameter's excursions can be seen in Figure (3). It was obvious that Faecal coliform influences the overall index and outweighs the parameters' role in the index. It is Attributed to the significant value by which Faecal coliform exceeded the WHO guideline limit for all samples of the three sites. This was a reason to be hesitant when including Faecal coliform parameter in the index in the first place, because of the guideline restrict the limit to 0 counts/100 mL. Because of this strict guideline limit no matter what Faecal coliform will always exceed the limit and multiple factors of pollution in the Tigris Faecal coliform exceeds the limit in huge margins, it makes it the index's main driver. Table 3 shows the CCMEWQI model results with Faecal coliform included in the index. Table 4 contains results without the Faecal coliform including in the index.

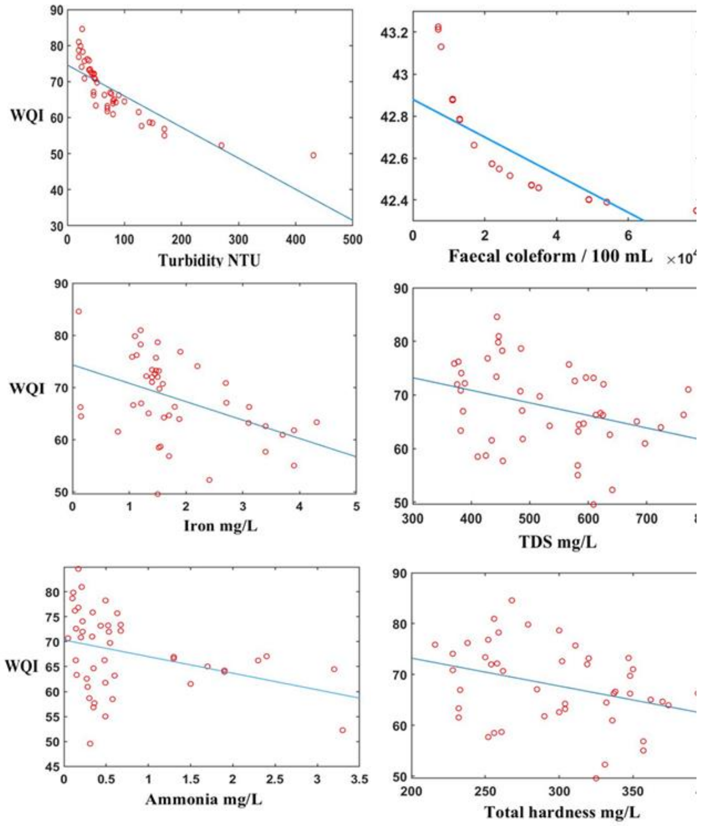

Fig:- Sums of excursions scatterplot for the individual parameters the exceeded the guideline limit vs the WQI.

	Tigris, M.S	Sharq dijla	Wathba	Wihda
NFV	6	5	6	5
NFT	197	63	70	64
nes	308.78803	398.95245	198.74646	328.665
F1	0.5	0.4166	0.5	0.4166
F2	0.3648	0.35	0.3888	0.355
F3	99.677198	99.749970	99.49936	99.6966
WQI	42.448	42.406	42.551	42.437
WQS	Poor	Poor	Poor	Poor

Table 3. WQI including Faecal coliform for the period of 27 January to 19 August. NFV: number of failed variables, NFT: number of failed tests, WQS: water quality status, M.S: multi stations

	Tigris, M.S	Sharq dijla	Wathba	Wihda
NFV	6	5	6	5
NFT	152	48	55	49
nes	1.839474	1.978434	1.7537	1.78627
F1	0.454	0.363	0.45	0.36
F2	0.307	0.29	0.333	0.296
F3	64.7822	66.425313	63.68544	64.10975
WQI	62.5955	61.647260	63.22866	62.98413
WQS	Marginal	Marginal	Marginal	Marginal

Table 4. WQI without Faecal coliform for the period of 27 January to 19 August. NFV: number of failed variables, NFT: number of failed tests, WQS: water quality status, M.S: multi stations

VI. CONCLUSION

The assessment of the water quality at the intakes of the water treatment plants revealed that although industries in Iraq is at its minimum levels thus minimum contamination from industries sector is discharged into rivers, it is still apparent that the quality of the water in the river within Baghdad wasn't at its best condition. in this study, it was concluded that

- The tests were conducted during the hot and cold seasons, so a good and comprehensive view of the river condition is obtained.
- Among the 12 tested parameters turbidity, total hardness and Faecal coliform have exceeded WHO's upper limit for all the tested samples.
- Faecal coliform high levels indicate that might be improperly treated sewage effluents.

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- The levels of iron that exceeded the upper limit at Al wathba and al wihda might result from Al Sarafya Bridge debris form the terrorist attack on the bridge in April 12, 2007. The bridge debris still at the bottom of the river to this day and it could reach up to a thousand tons or more of steel that is getting oxidized, thus iron is transferred along the river in Baghdad.

- At sharq dijla, iron levels could be the result of fish iron cages spread along the river north Baghdad city. The territories north Baghdad are mainly farmlands on both sides of the river and fish cages are common.

- The three sites' water quality index was marginal and also for Tigris river as multi-station WQI within Baghdad.

- The CCMEWQI scores during the assessment period is a matter of concern in a way that small change in the river water characteristics due to Multiple reasons (e.g. river discharge decrease, runoff, inadequate river bed cleaning, etc.…) might lower the water quality index to the poor category.

- Faecal coliform is excluded from the water quality index calculation because it was out casting other parameters, and it might not be appropriate to use the index for both chemical and biological parameters.

- The MATLAB code developed to calculate the CCMEWQI was very sufficient and easy to use and it will be transformed into an application to be used as water quality assessment and reporting tool.

- The code is not constrained by a certain number or kind of parameters or guidelines.

VII. ABBREVIATIONS

TDS	Total Dissolved Solids
Turb	Turbidity
T.H	Total Hardness
Cond	Conductivity
S.S	Suspended Solids
Set.S	Settleable Solids
IQR	Iraq water Quality Standard
WHO	World Health Organization
EPA	Environmental Protection Agency
UIR	Undetected in River Water
APHA	American Public Health Association
EDTA	Ethylenediaminetetraacetic acid
WQI	Water quality index

REFERENCES

[1]. Schwarzenbach, R.P., Egli, T., Hofstetter, T.B., Von Gunten, U. and Wehrli, B., 2010. Global water pollution and human health. Annual review of environment and resources, 35, pp.109-136.

[2]. Sophocleous, M., 2002. Interactions between groundwater and surface water: the state of the science. Hydrogeology journal, 10(1), pp.52-67.

[3]. Ouyang, Y., Zhang, J.E. and Ou, L.T., "Temporal and spatial distributions of sediment total organic carbon in an estuary river". Journal of environmental quality, 35(1), pp.93-100, 2006.

[4]. Corvalan, C., Hales, S., McMichael, A.J., Butler, C. and McMichael, A., 2005. Ecosystems and human well-being: health synthesis. World health organization.

[5]. Al-Janabi, Z.Z., Al-Kubaisi, A.R. and Al-Obaidy, A.H.M.J., 2012. Assessment of water quality of Tigris River by using water quality index (CCME WQI). Al-Nahrain Journal of Science, 15(1), pp.119-126.

[6]. Sargaonkar, A. and Deshpande, V., 2003. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. Environmental monitoring and assessment, 89(1), pp.43-67.

[7]. Saffran, K., Cash, K. and Hallard, K., "Canadian water quality guidelines for the protection of aquatic life, CCME water quality Index 1, 0, User's manual", Excerpt from Publication, 1299, 2001.

[8]. Rickwood, C.J. and Carr, G.M., 2009. "Development and sensitivity analysis of a global drinking water quality index. Environmental monitoring and assessment" 156(1-4), p.73.

[9]. Al Murib, M., "Hydrodynamic and water quality modeling of the Tigris River system in Iraq using CE-QUAL-W2", 2018.

[10]. Hamad, S.H., Schauer, J.J., Shafer, M.M., Abed Al-Raheem, E. and Satar, H., "The distribution between the dissolved and the particulate forms of 49 metals across the Tigris River, Baghdad, Iraq", The scientific world journal, 2012.

[11]. Duncan, A.E., Oti, J. and Potakey, M.E., 2019. "Impacts of Human Activities on the Quality of River Water: A Case Study of River Densu in Nsawam Adoagyiri of the Akwapim South District, Eastern Region of Ghana" Open Access Library Journal, 6(12), pp.1-13.