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Water Quality Assessment of Tigris River Using Overall Index of Pollution (OIP)

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Abstract

This study was performed on the Tigris River (Baghdad city section) during the period between December 2016 and December 2018 to assess seasonal variation in water quality using the Overall Index of Pollution (OIP). The OIP is one of the reliable tools for the assessment of surface water quality. To calculate OIP-values, eight parameters were measured (pH, Dissolved Oxygen "DO", Biological Oxygen Demand "BOD", Total Dissolved Solid "TDS", Total Hardness "TH", calcium "Ca", Sulphate "SO4" and Alkalinity). The results showed the anthropogenic activities impact of Baghdad population that directly discharge of "inadequate treated" waste water to the river. OIP values were acceptable (1>OIP> 1.7) in 2011, 2012, 2013 and 2018. However, in 2014 and 2017,the OIP recorded values that were acceptable and tend to be slightly polluted (1.7>OIP>2.5). The impairment of water quality during 2014 and 2017 might be caused by the decrease in the water share feeding Tigris River from Turkey due to the construction of many dams. Also, markedly reduced rain precipitation rates were recorded in these periods. The study suggests conducting continuous monitoring programs and establishing a reliable Iraqi classification system for water quality by a specialized scientific panel.

Key word: Overall Index of Pollution, OIP, Tigris River, Water quality.

Introduction:

Water is a vital natural resource for all life forms on our planet, so clean water must not contain any concentrations of harmful chemical agents or living microorganisms that cause damage (1). And with the growth of the world communities and development; surface water like rivers were polluted with a wide range of contaminants from numerous sources. Freshwater resources as rivers are important to the welfare and prosperity of society, but during the last decades, these rivers all over the world have suffered from continuous pollution (2).

The quality of water may be defined in terms of physical, chemical, and biological criteria that must be met to attain water quality needs for the specific intended uses such as those of potable, agriculture, recreational, and industrial water (3). Recently, rivers have come under huge load due to human activities such as:(sewage discharge, industrial activity, and mining activity at the bottom of the river) which have led to a marked deterioration of water quality, affecting aquatic and human life (4).

Water quality assessing approaches are considerably based on the comparison of experimental parameter values with the values of the current guidelines. In many cases, the appropriate diagnosis of pollution sources is made through monitoring and may be facing legal subjugation. However, it is not easy to form a general perception of the spatial and temporal trend of total water quality in water bodies (5).

A recent study on Tigris River using water quality index showed that the neither quality of water never reachable to the “Excellent” levels nor fallen to “Unsuitable” score, except in occasional untreated water samples. The effects of the various pollution sources were evident, and extensive studies on water quality index became urgent (6).

Based on that, there should be a strict water monitoring program for Tigris River water quality with the measurement of the extent of pollution level. OIP-water quality is an auspicious and efficient tool to study the effects of changes in water quality along the river. Also, it is a very useful tool for clarifying information on the overall quality of water, which raises concerns among the public and policymakers. This could help to assess and solve local and regional problems related to surface water quality (7). The current study aims to estimate OIP for the Tigris River using eight parameters in comparison to historical data, with sampling from five sites.

Material and Methods:

Study Area

Tigris River is located within Baghdad where five specific sampling sites were selected for testing physical and chemical parameters. Sampling was conducted once a month along two seasons (wet and dry) from December 2016 to December 2018.

Samples were collected in the time between 9.30 am to 2.30 pm during the first week of each month. Field tests, sampling, labeling, and transfer of samples to the laboratory were carried out and samples were prepared for regular laboratory analysis. The locations of sampling sites were determined by the Global Positioning System (GPS) type Garmin e Trex 22X (Fig. 1 and Table 1).

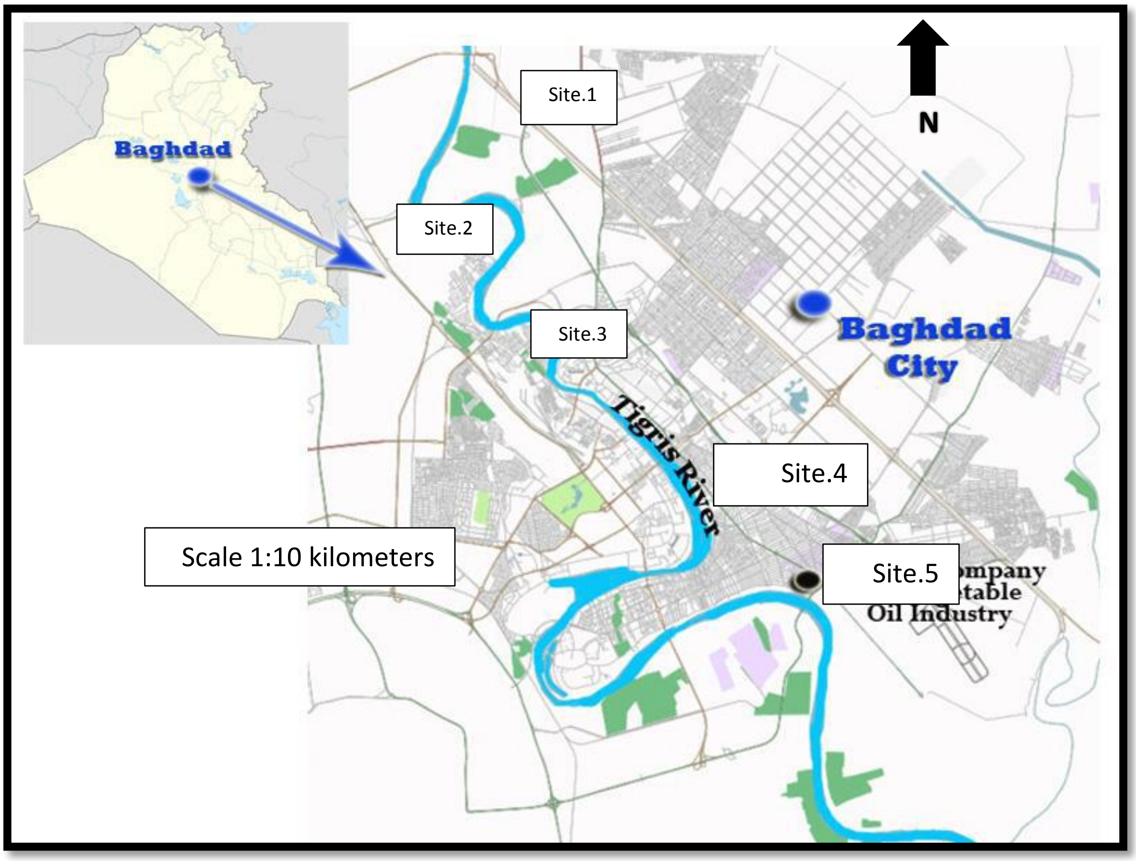

Figure 1. Study sampling sites on the Tigris River

Table 1. Geographical locations of sampling sites on Tigris River section in Baghdad city

Site no.	Site name	Coordinates Longitude (E)	Latitude (N)
1	Al-Muthanna Bridge	44°20'47.35"	33°25'42.49"
2	Al-Ae'ma Bridge	44°21'24.05"	33°22'28.72"
3	Al-Qhadisyia drinking water treatment plant	44°22'13.19"	33°16'55.69"
4	Al-Zuforania drinking water treatment plant	44°28'28.2"	33°13'55.4"
5	Al-Wardia drinking water treatment plant	44°22'55.45"	33°15'44.12"

Samples collection and preservations

Stopper fitted polyethylene bottles (1L) were cleaned and prewashed with distilled water and used to collect water samples from the surface layer with a depth of 20-30 cm, and then the water samples were analyzed immediately after collection for chemical and physical parameters.

Samples Analysis

The analysis was carried out on eight physical and chemical parameters (pH , Dissolved Oxygen "DO", Biological Oxygen Demand "BOD", Total Dissolved Solid "TDS", Total Hardness "TH", Calcium "Ca", Sulphate "SO4" and Alkalinity) between December 2016 and December 2018. Sampling and analysis were performed monthly according to the standard methods (Table 2) (8).

Table 2. Iraqi drinking water quality standards (417-2001)(9)

Parameter	Standard
Ph	6.5-8.5
Dissolved Oxygen (mg/l)	5
Oxygen Biological Demand (mg/l)	3
Total dissolved solid (mg/l)	500
Total Hardness (mg/l)	100
Calcium (mg/l)	100
Sulphate (mg/l)	250
Alkalinity (mg/l)	100

OIP-Estimating

The calculation of the OIP was performed as previously described (7). This index was originally developed to assess the health status of water resources in India. The index was calculated based on the following equation (1):

$$\mathrm{OIP} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{Pi} \qquad (1)$$

Where P_i = pollution index for the i^{th} parameters and n = number of parameters.

$$P_i = \frac{Vn(observed\ Value\ of\ parameter)}{Vs(Standard\ value\ of\ parameter)} \qquad (2)$$

Results and Discussion:

An Overall Index of Pollution represents the accumulative impacts of diverse parameters in a single clear score, displaying data of the historical health situation of a water body, as used here for the Tigris River. These data are used in the present study as a vital tool for the maintenance and survival of aquatic life in the Tigris River where the population of Baghdad and many Iraqi cities depend on it in fulfilling their daily needs. In order to support decision makers with a clear picture of the river health and the proper decision, data of Tigris river monitoring program from 2011, 2012, 2013 and 2014 were compared with the results from the current two-years study (2017, Table 3; 2018 , Table 4). All data were computed to produce an OIP value. The current study model was built up with eight parameters (pH, TDS, DO, BOD5, SO4, Ca, Total Hardness and Alkalinity) for samples that were monthly collected from five sites.

Physio-chemical Properties

pH is a useful scale to quantify the acidity or alkalinity of water. River water tends to be alkaline, because of the natural existence of the carbonates and bicarbonates, and that is typical for Iraqi rivers (9). Our results show a pH range of 6.5-8.5, which indicates that Tigris water samples are almost neutral to sub-alkaline in nature.

Dissolved oxygen values during all times of the current study stayed within the acceptable range, demonstrating a good water quality. The average DO value observed was 6 -10.1 mg/l during the two years, in accordance with a previous report (10) which suggested that DO for healthy water must be 5 mg/l . Also, our results agree with another study (11) which showed that the dissolved oxygen range of the Gharraf River (6–10 mg/l) was still within the acceptable range.

BOD_5 is the quantity of oxygen used by microorganism to break down water organic compounds in 5 days (9). In the present study, BOD_5 showed a range of (1.10-5.00 mg/l) that was occasionally higher than the quality standard of the WHO 3 mg/l (1). But the Iraqi standards consider (3mg/l) as better value (Table 2). Our results from 2017 showed that BOD_5 had acceptable values in most of the monitoring sites within Baghdad city, especially the two downstream stations of site 4 (Al-Zuforania drinking water treatment plant) and site 5 (Al-Wardia drinking water treatment plant) which had BOD_5 values that reached 5 mg/l during the dry season (table3,4) . Our observed results agree with those previously reported (11), which found that station 6 of Gharraf river did not reach the criteria, especially in summer and early autumn.

TDS values in the water are a direct estimate of dissolved particulates in the water column. The desirable limit of TDS for drinking water is 500 mg/l according to the Iraqi drinking water standards (Table 2), but our results show that the lowest value (502 mg/l) was close to the upper limit in site 3 (Al-Qhadisyia drinking water treatment plant) during the dry season of 2018, while the highest value exceeded that limit to reach 500 mg/ l in site 5 (Al-Wardia drinking water treatment plant) during the dry season of 2017. The results showed that TDS values were slightly higher than the permissible levels. High TDS may arise through natural weathering of certain sedimentary rocks or may have an anthropogenic source, e.g. industrial and sewage effluent (1). Similar findings were reported in Rawanduz River and Gali Ali Beg stream (13).

Total Hardness (TH) is also an important water parameter that is primarily caused by the presence of cations such as calcium, magnesium and anions such as carbonates and chloride in water. Our results show that TH values were often higher than the minimal permissible level recommended by the WHO for drinking water. The results show that the range of TH was between 230 mg/l in site 5 (Al-Wardia drinking water treatment plant) during the dry season of 2018 and 500 mg/l for the same site in the same season.

This finding complies with a study on Rawanduz River and Gali Ali Beg stream (13). Water hardness is known to negatively affect human health. Several authors indicated that if a man consumes 2L /day of water with a hardness of 150-300 mg/l and above, this might result in stone formation in the kidneys (14).

Calcium is one of the most common constituents present in Iraqi inland water. The increase in calcium concentration causes hardness in water and incrustation in boilers. Our results show that calcium range was 166 mg/l in site 3 (Al-Qhadisyia drinking water treatment plant) during the wet season of 2018 to 430 mg/l in site 5 (Al-Wardia drinking water treatment plant) during the dry season 2017. Our results comply with those of a previous study (15) on the Shatta AL-Arab River in Basra southern Iraq (downstream of Tigris River).

Sulphate exists naturally in surface water as SO_{-4}. Our results show that the lowest concentration (175 mg/l) was recorded in site 1 (Al-Muthanna Bridge) during the dry season of 2017 while the highest was 280 mg/l in site 5 (Al-Wardia drinking water treatment plant) during the dry seasons of 2017 and 2018. Our findings agree with those previously published on the Shatta Al-Arab River (15). Most of sulphate values during 2017-2018 exceeded the acceptable range, which could be due to discharge from waste disposal, domestic waste and untreated sewage.

Alkalinity is caused by various sources (hydroxides, bicarbonate, carbonates) and shows the capability of the aqueous solution to neutralize an acid. Alkalinity values during 2017 were above the permissible limits in all study sites, ranging from 147 during the wet season in site 2 (Al-Ae'ma Bridge) and 156 during the dry season in site 4 (Al-Zuforania drinking water treatment plant), while the range during 2018 was 124 in wet season site 3 (Al-Qhadisyia drinking water treatment plant) and 150 in site 5 (Al-Wardia drinking water treatment plant). All water samples during our study showed increasing alkalinity values, which may partially agree with the values of water samples from Rawanduz River and Gali Ali Beg stream, they attribute this to geological formation of the area (13).

Table 3. The Tigris River water Physio-chemical parameters and OIP values during 2017

	Site 1 (Al-Muthanna Bridge)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	8.30	8.10	8.20	0.14	1.17
D.O	8.40	10.30	9.35	1.34	1.87
B.O.D	2.20	3.20	2.70	0.71	1.35
T.D.S.	570.00	636.00	603.00	46.67	1.21
T. hardness	338.00	401.00	369.50	44.55	3.70
Ca	301.00	345.00	323.00	31.11	2.15
Sulphate	175.00	243.00	209.00	48.08	0.84
Alkalinity	156.30	150.60	153.45	4.03	1.53
Total OIP value					1.73
	Site 2 (Al-Ae'ma Bridge)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	7.40	8.40	7.90	0.71	1.13
D.O	8.00	10.10	9.05	1.48	1.81
B.O.D	3.70	2.70	3.20	0.71	1.60
T.D.S.	555.00	630.00	592.50	53.03	1.19
T. hardness	330.00	402.00	366.00	50.91	3.66
Ca	296.00	361.00	328.50	45.96	2.19
Sulphate	178.00	247.00	212.50	48.79	0.85
Alkalinity	151.60	147.00	149.30	3.25	1.49
Total OIP value					1.74
	Site 3(Al-Qhadisyia drinking water treatment plant)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	8.43	8.40	8.42	0.02	1.12
D.O	7.50	9.00	8.25	1.06	1.65
B.O.D	3.30	3.00	3.15	0.21	1.58
T.D.S.	586.00	610.00	598.00	16.97	1.20
T. hardness	332.00	415.00	373.50	58.69	3.74
Ca	304.00	365.00	334.50	43.13	2.23

Sulphate	182.00	230.00	206.00	33.94	0.82
Alkalinity	154.00	148.00	151.00	4.24	1.51
Total OIP value					1.73
	Site 4 (Al-Zuforania drinking water treatment plant)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	8.43	8.10	8.27	0.23	1.12
D.O	7.40	9.20	8.30	1.27	1.66
B.O.D	4.00	3.20	3.60	0.57	1.80
T.D.S.	600.00	617.00	608.50	12.02	1.22
T. hardness	350.00	414.00	382.00	45.25	3.82
Ca	314.00	372.00	343.00	41.01	2.29
Sulphate	190.00	235.00	212.50	31.82	0.85
Alkalinity	156.00	147.00	151.50	6.36	1.52
Total OIP value					1.88
	Site 5 (Al-Wardia drinking water treatment plant)				
	Dry	Wet	Mean	Std.	Single-OIP value
Parameters	8.47	8.30	8.39	0.12	1.20
pH	7.50	9.30	8.40	1.27	1.68
D.O	4.00	3.30	3.65	0.49	1.83
B.O.D	850.00	750.00	800.00	70.71	1.60
T.D.S.	500.00	470.00	485.00	21.21	4.85
T. hardness	430.00	403.00	416.50	19.09	2.78
Ca	221.00	280.00	250.50	41.72	1.00
Sulphate	160.00	143.00	151.50	12.02	1.52
Alkalinity	8.47	8.30	8.39	0.12	1.20
Total OIP value					2.06

Table 4. The Tigris River water Physio-chemical parameters and OIP values during 2018

	Site 1 (Al-Muthanna Bridge)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	7.90	7.50	7.50	0.30	1.07
D.O	6.3	6.60	6.45	0.21	1.29
B.O.D	4.5	1.70	3.10	1.98	1.55
T.D.S.	529	620.00	574.50	64.35	1.15
T. hardness	370	260.00	315.00	77.78	3.15
Ca	335	228.00	281.50	75.66	1.88
Sulphate	200	225.00	212.50	17.68	1.42
Alkalinity	137	145	141.00	5.66	1.41
Total OIP value					1.61
	Site 2 (Al-Ae'ma Bridge)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	7.60	7.70	7.65	0.07	1.09
D.O	6.90	8.50	7.70	1.13	1.54
B.O.D	2.00	1.40	1.70	0.42	0.85
T.D.S.	521.00	600.00	560.50	55.86	1.12
T. hardness	350.00	260.00	305.00	63.64	3.05
Ca	310.00	235.00	272.50	53.03	1.82
Sulphate	187.00	193.00	190.00	4.24	1.27
Alkalinity	135.00	136.00	135.50	0.71	1.36
Total OIP value					1.51
	Site 3(Al-Qhadisyia drinking water treatment plant)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	8.10	7.80	7.95	0.21	1.06
D.O	8.00	7.60	7.80	0.28	1.56
B.O.D	2.60	1.80	2.20	0.57	1.10
T.D.S.	502.00	590.00	546.00	62.23	1.09
T. hardness	372.00	284.00	328.00	62.23	3.28
Ca	325.00	166.00	245.50	112.43	1.64
Sulphate	205.00	200.00	202.50	3.54	1.35
Alkalinity	124.00	140.00	132.00	11.31	1.32
Total OIP value					1.55
	Site 4 (Al-Zuforania drinking water treatment plant)				
Parameters	Dry	Wet	Mean	Std.	Single-OIP value
pH	6.80	7.60	7.20	0.57	1.02
D.O	7.00	6.50	6.75	0.35	1.35

B.O.D	1.70	2.70	2.20	0.71	1.10
T.D.S.	510.00	620.00	565.00	77.78	1.13
T. hardness	380.00	280.00	330.00	70.71	3.30
Ca	325.00	227.00	276.00	69.30	1.84
Sulphate	192.00	187.00	189.50	3.54	1.26
Alkalinity	130.00	138.00	134.00	5.66	1.34
Total OIP value					1.88
	Site 5 (Al-Wardia drinking water treatment plant)				
	Dry	Wet	Mean	Std.	Single-OIP value
Parameters	7.40	7.60	7.50	0.14	1.07
pH	7.50	6.00	6.75	1.06	1.35
D.O	5.00	4.00	4.50	0.71	2.25
B.O.D	540.00	650.00	595.00	77.78	1.19
T.D.S.	374.00	230.00	302.00	101.82	3.02
T. hardness	340.00	250.00	295.00	63.64	1.97
Ca	224.00	205.00	214.50	13.44	1.43
Sulphate	132.00	150.00	141.00	12.73	1.41
Alkalinity	7.40	7.60	7.50	0.14	1.07
Total OIP value					1.71

Overall Index of Pollution (OIP)

Many attempts were made to assess surface water quality using OIP in different geographical areas, including India (7, 16 and 17), Chile (5) and the Himalayas (10). Only one attempt was made to apply the OIP in Iraq (18) and showed that water quality of Al-Garraf River, southern Iraq was close to poor and partially not good for drinking without proper treatment.

OIP results show two temporal patterns of water quality, one with a range of (1.7 > OIP > 2.5) during 2017 (1.73, 1.74, 1.73, 1.88, 2.06) for site-5 (Table 3), while the other pattern was with a range of (1> OIP >1.7) during 2018 (1.61, 1.51, 1.55, 1.88 and 1.71) for the same site (Table 4). OIP values are usually used to express the extent of water contamination. The Indian of water quality classification system (4,7) was adopted to evaluate our results due to the lack of an Iraqi water quality classification system (Table 5).

Table 5. Indian classification system of water quality according to (4)

Water quality status	Class	Class index (OIP score)
Excellent	C1	1
Acceptable	C2	2
Slightly polluted	C3	4
Polluted	C4	8
Highly polluted	C5	16

According to these results, water quality of Tigris River is classified as acceptable to slightly polluted (C2-C3) during 2017, yet it slightly improved to be acceptable during 2018 (C2).
Analysis of historical data from 2011, 2012, 2013 and 2014 collected by the Ministry of Health and Environment staff shows fluctuations in OIP values; the trend showed decreases in water quality from 2011, 2012 (1>OIP>1.5) but an increase during 2013 (1> OIP > 1.7), lying within C2 class; OIP values reached values of (2> OIP > 4)during 2014, lying within C3 class (Fig.2).

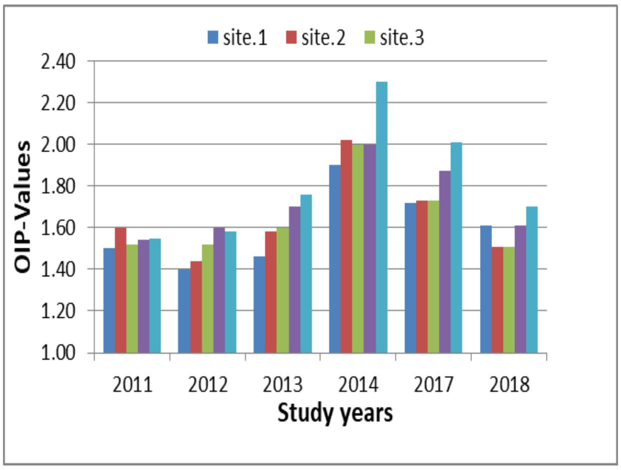

Figure 2. Temporal and spatial variation in OIP values in study sites

The water quality of the Tigris River is most obviously affected by the decrease in the quantity of freshwater coming from Turkey, where dams are being established to store water for agriculture and recreation. One of the most famous dams is Aliso, which started operation in 2017. Annual rate of precipitation also plays an important role in diluting rivers water; Iraqi meteorological data show that 2017 was the driest in 10 years with an annual precipitation rate of 71.6 mm; however, the annual precipitation rates were (96.0, 184.4, 296.7 and 107.5 mm) during 2011, 2012, 2013 and 2014, respectively, while the rate increased during 2018 to reach 366.4 mm (19). This might be considered as a cause of slightly improved water quality during 2018.

Our current study agrees with a previous study on Rawanduz River and Gali Ali Beg stream in 2019 (13), which showed that water quality was subjected to "rapid" decline. Degradation of surface water quality may be the result of human activities and easy accessibility to the river. Also, another study (20) reported that the water of Tigris2017 was polluted by anthropogenic activities, especially at the downstream sampling site near a vegetable oil factory. The authors attributed this to factory wastes discarded into the river without adequate treatment.

Conclusion:

1. Tigris River is subjected to pressure due to anthropogenic activities, while the preventative measures taken by stakeholder authorities are still not sufficient.
2. The parameters contributing in our OIP model need to be improved by adding new important variables to show a more expressive picture of river health.
3. Developing an Iraqi expressive classification system for water quality by an experienced scientific panel is an urgent matter.

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Author's declaration:

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are mine. Besides, the Figures and images, which are not mine, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in AL-Karkh University of Science.

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تقييم نوعية مياه نهر دجلة باستخدام دليل التلوث الكلي OIP

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جامعة الكرخ للعلوم، كلية علوم الطاقة والبيئة، بغداد، العراق .

الخلاصة:

اجريت الدراسة الحالية على نهر دجلة (مقطع مدينة بغداد) للفترة من كانون الاول 2016- كانون الاول 2018. لتقييم التغيرات الفصلية في نوعية مياه النهر باستخدام دليل التلوث الكلي OIP. يعتبر دليل التلوث الكلي احد الادوات المعتمدة لتقييم نوعية المياه السطحية. ساهم في حساب الدليل ثمانية عوامل هي (الدالة الحامضية pH، الاوكسجين المذاب D.O، المتطلب الحيوي للاوكسجينBOD، المواد الذائبة الكلية TDS، العسرة الكلية T.H، تركيز الكالسيوم Ca، تركيز الكبريتات So4، القاعدية AlKalanity). اظهرت نتائج الدراسة الحالية تاثيراً واضحاً للانشطة البشرية لسكان مدينة بغداد على نوعية المياه لنهر دجلة من خلال الطرح المباشر للفضلات المنزلية (الغير معالجة بشكل كافي) الى مياه النهر. اظهرت قيم دليل التلوث الكلي تقييم مقبول (1.7 > OIP >1) لسنة 2011و 2012 و 2018 في حين كانت قيم الدليل تشير الى ان نوعية مياه النهر كانت مقبولة وتميل الى التلوث القليل (2.5 > OIP > 1.7). ان تردي نوعية المياه خلال السنوات 2014- 2017 ربما يكون بسبب انخفاض حصة العراق المائية في نهر دجلة القادمة من الاراضي التركية بسب بناء السدود التي تحتجز مياه نهر دجلة من منبعه. كما ان هناك انخفاض في كمية الامطار الساقطة خلال سنوات الدراسة. تقترح الدراسة الحالية الاستمرار في برامج المراقبة وضرورة اعتماد نظام عراقي لتصنيف المياه من خلال فريق من الخبراء.

الكلمات المفتاحية: دليل التلوث الكلي ، OIP ، نهر دجلة ، نوعية المياه.