ASSESEMENT OF WATER QUALITY OF DIYALA RIVER USING OVERALL INDEX OF POLLUTION (OIP) IN IRAQ

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ABSTRACT

The present study was performed to assess the seasonal changes in the water quality of Diyala River (Diyala Governorate, Iraq), from five sites along the river during the period from September 2020 to April 2021, by applying the Overall Index of Pollution (OIP). OIP is one of the reliable indicators in evaluating the quality of surface water. To calculate the value of the OIP, twelve parameters were measured in the water samples, which are (water temperature, pH, electrical conductivity, dissolved oxygen, biological oxygen demand, total hardness, calcium, magnesium, total dissolved solids, total alkalinity, and concentrations of dissolved nitrates and phosphates). The results showed spatial and temporal variation of physicochemical parameters. The obtained values of OIP (1.72-2.72) revealed acceptable water quality in some sites to slight pollution in the others sites. The current study recommends establishing a novel program for the maintenance and control of Iraqi waters. Such program should be based on scientific means to handle changes that occurred during the past years, such as insufficient release of Iraq's water shares by neighboring countries, low-rate precipitation rates, and practices of water abuse committed by the population.

Key words: Over Index of Pollution, Water Quality, Tigris River, Iraq

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مجلة العلوم الزراعية العراقية -2023 :54(3):682-690 السعدون وآخرون

تقييم جودة مياه نهر ديالى باستخدام الدليل الكلي للتلوث (OIP) في العراق

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المستخلص

تم إجراء هذه الدراسة على نهر ديالى (محافظة ديالى, العراق) من خمس مواقع على طول النهر خلال الفترة الممتدة من أيلول 2020 وحتى نيسان 2021، وذلك لتقييم التغيرات الفصلية التي تحدث في نوعية وجودة مياه النهر باستخدام دليل التلوث الكلي (Overall Index of Pollution (OIP)). يعد دليل التلوث الكلي أحد الأدلة التي يتم الاعتماد عليها في تقييم نوعية المياه السطحية. ولحساب الدليل تم قياس أثنى عشر عاملاً وهي: (درجة حرارة الماء والأس الهيدروجيني للماء والتوصيلية الكهربائية للماء والأوكسجين المذاب والمتطلب الحيوي للأوكسجين والعسرة الكلية والكالسيوم والمغنيسيوم والمواد الصلبة الذائبة الكلية والقاعدية الكلية والنترات والفوسفات الذائبة). تبين من خلال نتائج الدراسة الحالية تغيرات موقعية وزمانية للعوامل الفيزيائية والكيمائية. كشفت قيم دليل التلوث الكلي (1.72-2.72) تقييم مقبول في بعض المواقع إلى تلوث قليل في مواقع أخرى. تقترح الدراسة الحالية وضع برنامج جديد لصيانة ومراقبة المياه العراقية يتعامل بشكل علمي مع التغيرات التي طرأت على المياه خلال السنوات الماضية من قلة إطلاق حصة العراق المقررة وكذلك انخفاض معدل الأمطار والتجاوزات الحاصلة من قبل السكان.

الكلمات المفتاحية: دليل التلوث الكلي، نوعية المياه، نهر دجلة، العراق

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INTRODUCTION

Freshwater is the most important water for various human activities, including drinking, irrigation, as well as other ecosystem processes (14, 16). Water pollution can be defined as an alteration in water properties (physical, chemical and biological) and cause a detrimental effect on aquatic organisms and human. This type of environmental degradation occurs through the direct or indirect release of pollutants into water bodies without proper treatment. Surface water is the most vulnerable to pollution because of it is easy to access for purposes of wastewater discharge (13). A growing issue that is facing surface water is the disposal of pollutants resulting from the rapid growth of population and agricultural activities, raising a growing concern in relation to the quality of water worldwide (22). Water quality assessment is the comprehensive evaluation of the physical, chemical, and biological aspects of water in relation to its natural quality as well as the impacts of human uses, particularly those affecting human health and the health of the water system itself (2). The Diyala River Basin is the third largest tributary of the Tigris River, having a length of (445) km and an area of (32,600) km^2. Diyala River is the main source of water supply for Diyala Governorate for domestic, agricultural, and other purposes. Like the other rivers in Iraq, this river is currently suffering from problems of water scarcity and pollution (7). The previous studies on Dialya river reported the impact of anthropogenic sources on water quality of the river (13, 15, 16, 22). OIP is considered as one of the promising and effective indices for testing the impacts of altered water quality along a river. It is also a very useful tool for communicating information related to water quality to the concerned citizens and policy makers. Moreover, it can aid in assessing and solving local and regional issues related to surface water quality (7). The present study aims at calculating the OIP value for Diyala River, within the borders of Diyala Governorate only. To achieve this aim, samples were taken from five locations along the river and tested for values of twelve physical and chemical parameters, which were compared with data from previous studies.

MATERIALS AND METHODS

In this study, five water sampling sites were selected on Diyala River within Diyala Governorate. Sampling was conducted once a month over two seasons (wet and dry) for the period from September 2020 to April 2021. Wet and dry seasons identify according to values of percent of humidity (above 50%) is considered as wet season while less than 50% is dry seasons (5). The samples were collected between 8:00 am and 6:00 pm during the fourth week of every month. The samples were transferred to the laboratory to conduct the required measurements. The site map was drawn based on the administrative map of Diyala Governorate and satellite images captured by the American satellite Land Sat + ETM, using the Arc GIS 10.4.1 software. The geographical locations of the sampling sites were determined using a Global Position System (GPS) device (Figure 1 and Table 1). The first site (Al-Sudour area) is located in Diyala Governorate, about (40) km northeast of Baqubah. It is a residential area characterized by the presence of pomegranate, orange, and palm orchards, with fertile agricultural lands. The site contains important facilities, including the Diyala Dam, which is one of the touristic sites in Diyala Governorate. The second site (Al-Salam district) is located north of Baqubah and considered as an agricultural area because it contains a large number of orchards that are distributed along Diyala River. The third site (Baqubah city) is the center of Baqubah/Diyala Baqubah and considered as residential area with restaurants, parks, and one hospital (Al-Batool Teaching Hospital) that is overlooking Diyala River, discharging untreated water directly into the river stream. The fourth site (Buhruz city) is located in the center of the governorate, Buhruz. It is a residential area in addition to being an agricultural area that contains a number of orchards. The area is considered as polluted due to the discharge of the governorate's untreated water directly into Diyala River. The fifth site (Khan Bani Saad district) is located to the south of Baquba city and contains a number of villages, being both a residential and agricultural area. Diyala River passes along the extension of the orchards and agricultural lands inside the district, which are located in the vicinity of the industrial area, where untreated water is discharged from factories and poultry fields directly into the river, affecting its water quality.

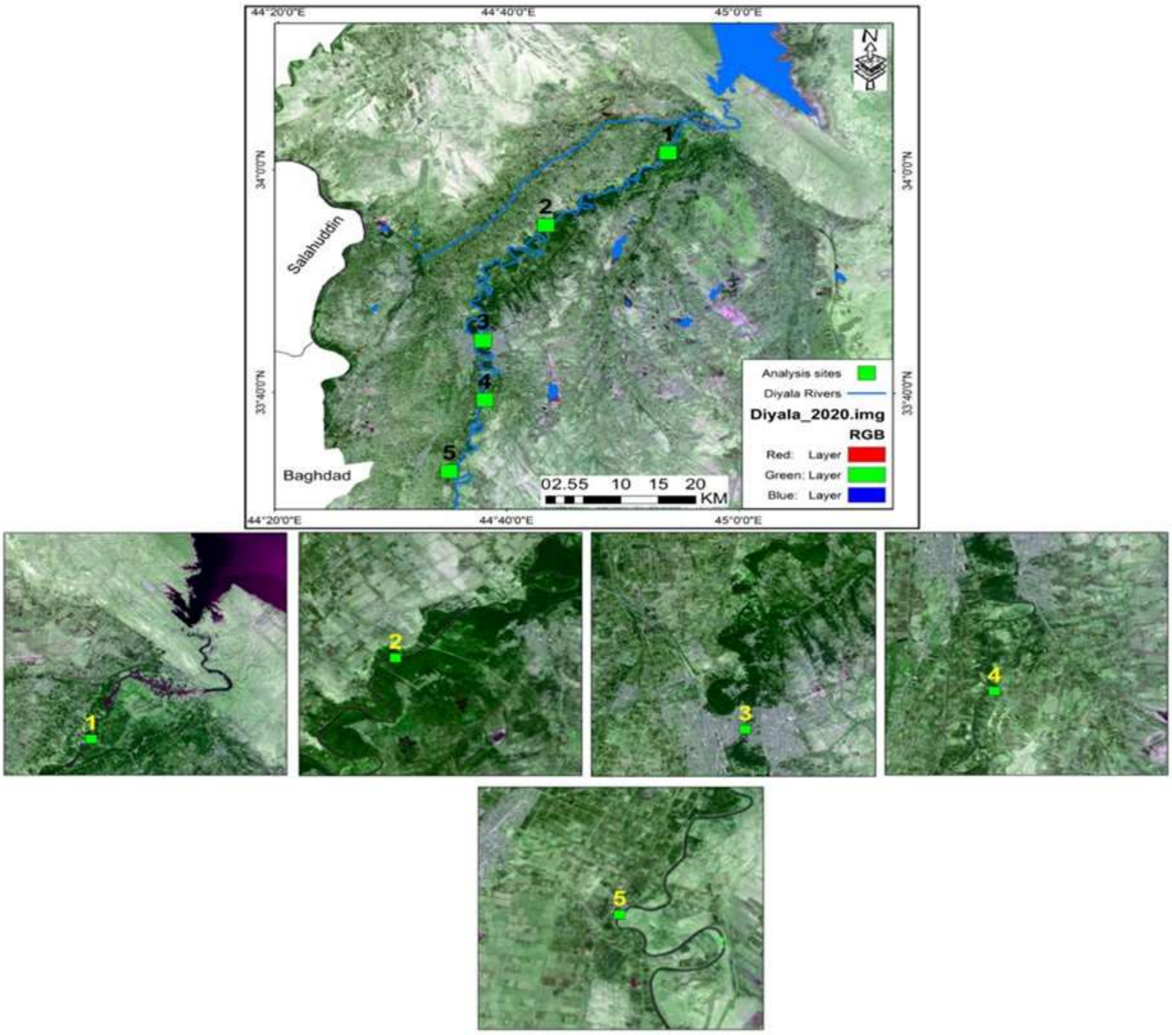

Figure 1. Satellite image of Diyala river with the location of five sampling sites

Table 1. Geographical Locations of sampling sites on Diyala river in Diyala governorate

Sites	Site Name	Coordinates	
		Longitude (E)	Latitude (N)
1	Al-Sudour area	44° 58' 54"	34° 39' 44"
2	Al-Salam district	44° 43' 17"	33° 55' 07"
3	Baqubah city	44° 37' 53"	33° 44' 44"
4	Buhruz city	44° 36' 18"	33° 40' 55"
5	Khan Bani Saad district	44° 35' 01"	33° 32' 58"

Samples collection

Samples were collected from the study sites at a depth of 20-30 cm under water surface (9). Polyethylene plastic containers (1 L) were utilized to collect samples for physical and chemical tests, whereas Winkler bottles (250 ml) were used to collect samples for dissolved oxygen measurement. The samples were kept cooled in a special container until they reached the laboratory.

Samples analysis

Twelve physical and chemical water quality parameters were measured (water temperature, pH, electrical conductivity, dissolved oxygen, biological oxygen demand, total hardness, calcium, magnesium, total dissolved solids, total alkalinity, dissolved nitrate and phosphate). Samples were collected and measurements were conducted monthly according to standard methods (9) and the parameters are checked with the Iraqi standard values (Table 2).

Table 2. Iraqi quality standards for River water (25)

Parameter	Standard
Water Temperature (°C)	35
pH	6.5
Electrical Conductivity (µS/cm)	5000
Dissolved Oxygen (mg/l)	5
Biological Oxygen Demand (mg/l)	5
Total Hardness (mg/l)	500
Calcium (mg/l)	75
Magnesium (mg/l)	50
Total Dissolved Solids (mg/l)	500
Total Alkalinity (mg/l)	45
Nitrate (mg/l)	50
Phosphates (mg/l)	0.04

Calculation of the oip

Overall index of Pollution (OIP) was calculated as the average of all pollution indicators (*Pi*) that were considered in the present study. It was calculated on the basis of the following equation (3):

$$OIP = \frac{\sum i Pi}{n} \quad (3)$$

where OIP is Overall Index of Pollution., *Pi* is the pollution index for the *i*th parameter, i = 1, 2, ..., *n* and *n* denote the number of parameters

RESULTS AND DISCUSSION

The OIP reflects the cumulative impacts of the various parameters measured in one clear value, presenting data of the historical health status of a certain water body, as applied here for Diyala River(3). The purpose behind the application of this index is to adopt it as a vital tool for the maintenance and survival of aquatic life in Diyala River, upon which the residents of the province rely to meet their livelihood. For the calculation of OIP value for Diyala River, the model adopted in this study was built using the aforementioned twelve measurements for samples collected from five sites, during the period from September 2020 to April 2021.

Physical and chemical properties

Water temperature: It is an important environmental factor that controls the behavior, functions and distribution of living organisms. It is responsible for regulating physical, chemical, biological, and metabolic processes in aquatic environments (20). Water temperature values in the present study showed clear seasonal variations; the lowest value (9.7 ºC) was recorded in the first location in the wet season, whereas the highest (26.5 ºC) was in the fifth location in the dry season. This variation is due to the difference in the time of sampling, since the temperature is low at the beginning of the morning and then increases in the middle of the day (5). pH of water: pH value indicates the negative logarithm of hydrogen ion concentration (9). The lowest value recorded by the present study (7.3) was in the first location in the dry season, whereas the highest value (8.7) was in the first location in the wet season. The pH values recorded throughout the study period tend to reflect alkaline water, which is one of the main characteristics of the Iraqi rivers, due to the high regulation capacity and high content of carbon and bicarbonate (21). Electrical conductivity: It is a good indicator of aquatic life in an ecosystem, based on the measurement of total dissolved solids in water (14). The electrical conductivity values of water showed the lowest value (631.3 mg/l) in the first location in the wet season, whereas the highest was in the fifth location in the dry season (4231.7 mg/l). The values recorded in this study remained within the acceptable range.Dissolved Oxygen (DO) is the main criterion for the health excellence of the aquatic environment, and it is also used as an indicator of water quality (6). The Dissolved Oxygen values of water showed the lowest value (4.9 mg/l) in the first location in the dry season, whereas the highest was in the fifth location in the dry season (12.5 mg/l). The values recorded in this study remained within the acceptable range. Biological oxygen demand (BOD_5): It is a significant indicator of organic pollution that occurs in water, as it reflects the amount of oxygen consumed by aquatic organisms to oxidize the organic matter in the water body (16). The values of BOD_5 recorded in the present study demonstrated the lowest value (0.03 mg/l) in the second site in the dry season, whereas the highest value (3.7 mg/l) was in the fourth site in the wet season. The values observed in this study remained within the acceptable range. Total hardness: It results from the amount of dissolved calcium and magnesium salts, playing a key role in determining the suitability of water for various purposes (9).

The total hardness in the present study demonstrated the lowest value in the first location in the dry season (273.3 mg/l), whereas the highest value was in the fifth location in the dry season (1323.3 mg/l). One possible explanation for the high value of total hardness in the dry season can be the disposal of waste materials by the residents into the river. These materials might contain calcium and magnesium ions. Another reason might be the dredging of salts from the lands located in the vicinity of to the river. In addition, the obtained higher values of hardness versus the alkalinity rates indicate the presence of ions other than bicarbonate and carbonate, such as chlorides and sulfates, which results in non-carbon hardness (26). Calcium is an essential element for animal and plant life forms, being the major component of dissolved substances in natural water (17). Calcium values was recorded in the present study the lowest value in site 1 in the dry season (61.5 mg/l), whereas the highest value was in site 5 in the dry season (231.1 mg/l). The reason for the decrease in calcium in the dry season might be the increase in the numbers of algae, since calcium is an important element that enters into the composition of its cell wall (27). However, the high calcium values in the fifth site can be attributed to the exposure of the river to sewage water, which contains large amounts of organic matter. Sewage is decomposed by microorganisms, leading to the release of CO_3^-, which can react with calcium, forming calcium carbonate in large quantities. Magnesium is an essential element in the synthesis of chlorophyll in aquatic plants and algae. Magnesium deficiency was reported to lead to a decrease in the density of algae (29). The present study showed that the lowest magnesium concentration was in the first site in the dry season (48.2 mg/l), whereas the highest value was in the fifth site in the dry season (265.4 mg/l). The reason for the increase in magnesium level in the fifth site in the dry season is the high temperature and, consequently, the increase in water evaporation and deposition of magnesium ions. Another reason can be the agricultural nature of the site, which causes the deposition of magnesium ions into the water from agricultural land. Total dissolved solids reflect salts dissolved in water and cannot be removed via conventional filtration (4). The outcomes of the measurement of total dissolved solids in the present study revealed that the lowest value was recorded in the first site in the dry season (423 mg/l), whereas the highest value was in the fifth site in the dry season (3106.3 mg/l). The study values exceeded the permissible range, which might possibly be related to the sources of dissolved solids, which are soil pollution leaching, residential and agricultural runoff, and water pollution discharge from sewage or industrial treatment plants (11). Total alkalinity is an essential measure in determining the ability of water to neutralize acidity to a certain extent (11). The total alkalinity values showed the lowest value in the first site in the dry season (105.3 mg/l), whereas the highest value was in the fifth site in the dry season (256.7 mg/l). The study values exceeded the permissible range, which may be related to wastewater and pollutants resulting from population sources near the banks of the river. Nitrates represent the inorganic form of nitrogen in aquatic ecosystems (28). Nitrate values in this study showed the lowest value in the first site in the dry season (0.8 mg/l), whereas the highest value was in the first site in the wet season (8.2 mg/l). The values in this study remained within the acceptable range. Phosphate is an essential nutrient in water bodies. It is the only soluble inorganic form of phosphorous that is used directly by aquatic organisms (29). Phosphate value in this study was the lowest value in the fourth site in the dry season (0.4 mg/l) and the highest in the fourth site in the wet season (0.7 mg/l). The reason behind the slight increase in phosphate concentrations can be the higher precipitation rate in the winter. Another factor can be the erosion of phosphate-containing compounds as a result of the washing of lands near the river (24).

Table 3. The Diyala river water physio-chemical parameters and OIP

Site 1. Al-Sudour area										
	Dry Season					Wet Season				
Parameters	Min	Max	Mean	SD	Pi	Min	Max	Mean	SD	Pi
Water Temperature	16	25.2	19.8	3.94	0.57	9.7	16.5	12.6	2.84	0.36
pH	7.3	8.6	8.2	0.6	1.26	8.3	8.7	8.6	0.18	1.32
Electrical Conductivity	679.3	963	809.7	134.63	0.16	631.3	750.3	671.5	53.57	0.13
Dissolved Oxygen	4.9	8.6	6.5	1.7	1.3	6.5	8.5	7.9	0.92	1.58
Biological Oxygen Demand	1	1.7	1.3	0.32	0.25	0.1	0.7	0.3	0.28	0.07
Total Hardness	273.3	410	340.8	74.26	0.68	296.7	370	339.2	32.13	0.68
Calcium	61.5	94.9	79.2	14.36	1.06	69.5	93.5	79.8	10.37	1.06
Magnesium	48.2	78.9	63.6	15.17	1.27	55.2	67.2	63	5.57	1.26
Total Dissolved Solids	423	788.3	595.6	150.97	1.19	455.7	606.3	528.4	69.27	1.06
Total Alkalinity	105.3	141	122.3	17.58	2.72	116.7	133.3	124.9	6.84	2.78
Nitrate	0.8	5.3	2.6	2.03	0.05	1.4	8.2	5.3	2.91	0.11
Phosphates	0.4	0.4	0.4	0.01	10.15	0.4	0.5	0.5	0.03	11.6
∑ Pi					20.66					22.01
OIP					1.72					1.83

Table 3. Continuum

Site 2. Al-Salam district										
	Dry Season					Wet Season				
Parameters	Min	Max	Mean	SD	Pi	Min	Max	Mean	SD	Pi
Water Temperature	18.4	24.4	20.8	2.59	0.59	11.9	16.3	13.6	2.06	0.39
pH	7.8	8.3	8.1	0.23	1.24	8.1	8.4	8.3	0.14	1.28
Electrical Conductivity	1374	1681.7	1538.2	131.68	0.31	1000.7	1338.3	1157	145.91	0.23
Dissolved Oxygen	5.2	8	6.5	1.28	1.3	7.2	8.4	7.7	0.51	1.54
Biological Oxygen Demand	0.03	1.8	0.7	0.79	0.13	0.6	0.8	0.7	0.09	0.13
Total Hardness	453.3	670	587.5	103.01	1.18	440	590	516.7	74.39	1.03
Calcium	113.6	159	132.9	19.07	1.77	100.2	138.9	122.2	16.56	1.63
Magnesium	79.3	130.7	110.5	22.72	2.21	77.7	111.9	95.8	15.4	1.92
Total Dissolved Solids	835.7	1156.3	979.8	135.35	1.96	747.3	958.3	858.1	111.82	1.72
Total Alkalinity	158	216.7	186.6	27.23	4.15	152	199.3	178.8	19.67	3.97
Nitrate	1.6	6.7	4.2	2.07	0.08	4.2	6.5	5.7	1.06	0.11
Phosphates	0.4	0.4	0.4	0.02	10.53	0.4	0.5	0.5	0.03	11.43
∑ Pi					25.45					25.38
OIP					2.12					2.12

Table 3. Continuum

Site 3. Baqubah city										
	Dry Season					Wet Season				
Parameters	Min	Max	Mean	SD	Pi	Min	Max	Mean	SD	Pi
Water Temperature	17.7	25.7	21	3.38	0.6	11.8	15.9	13.4	1.95	0.38
pH	7.4	8.3	8	0.43	1.23	8.3	8.5	8.4	0.1	1.29
Electrical Conductivity	1844.7	2426.3	2217.8	256.16	0.44	1241.3	2020.7	1601.4	332.47	0.32
Dissolved Oxygen	5.3	8.8	6.7	1.64	1.33	7.1	8.7	7.9	0.67	1.58
Biological Oxygen Demand	0.3	2.6	1.3	1.06	0.25	0.8	1.6	1.2	0.3	0.24
Total Hardness	626.7	880	748.3	128.6	1.5	583.3	783.3	672.5	101.23	1.35
Calcium	122.9	171	144	24.79	1.92	106.9	153.6	137.9	21.5	1.84
Magnesium	122.4	172.3	146.9	25.26	2.94	109.3	153.7	129.9	20.89	2.6
Total Dissolved Solids	1245.7	1753	1491.3	271.93	2.98	983.3	1471.3	1255	221.3	2.51
Total Alkalinity	174	249.7	217.2	31.82	4.83	173.7	214.7	196.3	17.44	4.36
Nitrate	1	6.9	3.2	2.78	0.06	2.8	5	3.5	1.03	0.07
Phosphates	0.4	0.5	0.4	0.03	10.55	0.4	0.5	0.5	0.04	11.63
∑ Pi					28.64					28.17
OIP					2.39					2.35

Table 3. Continuum

Site 4. Buhruz city										
	Dry Season					Wet Season				
Parameters	Min	Max	Mean	SD	Pi	Min	Max	Mean	SD	Pi
Water Temperature	18.5	25.1	21	2.97	0.6	10.8	15.4	12.9	2.42	0.37
pH	8	8.3	8.2	0.14	1.26	8.2	8.4	8.3	0.09	1.28
Electrical Conductivity	1829.3	2328	2101.4	216.73	0.42	1269.7	2001	1584.9	314.3	0.32
Dissolved Oxygen	5.1	8.7	6.5	1.68	1.3	5.5	8.1	7.3	1.22	1.47
Biological Oxygen Demand	1.6	2.7	2.2	0.5	0.43	1.7	3.7	2.6	1.04	0.52
Total Hardness	670	910	775.8	122.76	1.55	606.7	833.3	720.8	96.85	1.44
Calcium	120.2	176.4	151.3	24.96	2.02	106.9	168.3	144.6	28.75	1.93
Magnesium	128.1	178.3	151.8	24.34	3.04	121.4	161.6	140.02	17	2.8
Total Dissolved Solids	1118	1840.7	1507.8	326.45	3.02	1023	1563	1275.8	246.85	2.55
Total Alkalinity	176.7	239.3	216.6	28.44	4.81	178	239.7	212.9	26.97	4.73
Nitrate	2.2	4.1	3.3	0.78	0.07	3.3	4.4	3.8	0.61	0.08
Phosphates	0.4	0.5	0.4	0.04	11.05	0.5	0.7	0.6	0.09	14
∑ Pi					29.56					31.48
OIP					2.46					2.62

Table 3. Continuum

Site 5. Khan Bani Saad district										
	Dry Season					Wet Season				
Parameters	Min	Max	Mean	SD	Pi	Min	Max	Mean	SD	Pi
Water Temperature	19.2	26.5	21.6	3.44	0.62	11.6	15.6	13.7	2.04	0.39
pH	8.1	8.7	8.3	0.25	1.28	8.2	8.5	8.3	0.12	1.28
Electrical Conductivity	1752.7	4231.7	2895.2	1063.1	0.58	1712.3	2744	2131	476.18	0.43
Dissolved Oxygen	5.1	12.5	7.8	3.31	1.56	7.1	9.2	8.2	0.87	1.64
Biological Oxygen Demand	0.9	3.6	2.5	1.23	0.5	0.1	1.3	0.8	0.54	0.15
Total Hardness	703.3	1323.3	968.3	287.13	1.94	716.7	1036.7	849.2	152.57	1.7
Calcium	108.2	231.1	167.3	60.88	2.23	128.3	193.7	164	29.07	2.19
Magnesium	144.6	265.4	194.6	55.34	3.89	140.9	204.8	166.5	30.53	3.33
Total Dissolved Solids	1428	3106.3	2151.9	774.34	4.3	1440	2221.3	1754.3	371.56	3.51
Total Alkalinity	177	256.7	221.8	33.23	4.93	183	234.7	216.3	23.76	4.81
Nitrate	1.3	3.7	2.5	1.09	0.05	2	2.9	2.3	0.43	0.05
Phosphates	0.4	0.4	0.4	0.01	10.7	0.4	0.5	0.5	0.03	11.73
∑ Pi					32.58					31.19
OIP					2.72					2.6

Overall index of pollution

OIP was previously applied in various geographic regions with the goal of assessing the quality of surface water. These regions included India (19, 30), Chile (12), and the Himalayas (23). This index was also utilized in different areas of Iraq, including the assessment of water quality of Gharraf River in southern Iraq (7), which revealed an acceptable value to severe pollution. Moreover, it was applied for water quality assessment of Tigris River (8), which showed an acceptable value to slight pollution. In the present study, which was performed to assess water quality of Diyala River (strictly Diyala governorate only), the OIP ranged from acceptable values in some sites to low pollution in other sites. The Indian water quality classification system (19) was adopted to evaluate the results of this study, due to the lack of a classification system for Iraqi waters Table (4).

Table 4. Indian classification system of water quality according to (18)

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

According to the outcomes of the present study and based on the Indian water classification system, the water quality of Diyala River (within Diyala Governorate only) was found to be acceptable to slightly polluted (C2-C3). The water quality of the Diyala River was found to be significantly affected by the reduction in water releases from Iran (where the source point of the river is located). Other impacts included the low precipitation rate, not to mention the violations practiced by the residents and the disposal of solid and water waste directly into the river without treatment.

CONCLUSIONS

1. Diyala River is under the pressure of water scarcity, in addition to pollution impact, which caused alteration in river water characteristics.
2. According to OIP values the river water quality ranged from acceptable to slight pollution. These results were showed need to use more parameters to calculate the index to accurate picture of the quality of Diyala River water.
3. It has become necessary to establish a classification system for the quality of Iraqi water instead of relying on other classification systems.

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