OVERALL INDEX OF POLLUTION (OIP) FOR TIGRIS RIVER, BAGHDAD CITY, IRAQ

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ABSTRACT

This study aimed to identify the pollution extent in the Tigris River within Baghdad city by applying the Overall index of Pollution (OIP). Monthly water samples were collected from five sites along the Tigris River during the wet and dry seasons of 2020-2021. Eleven parameters were selected to conduct the study; Total Dissolved Solids, Turbidity, Chloride, Dissolved Oxygen, pH, Total Hardness, Fluoride, Nitrate, Sulfate, Biochemical oxygen demand, and Total Coliform. The OIP ranges from 2.46 to 1.96 in the dry season and 2.02 to 1.91 in the wet season. Results revealed that Tigris River water is categorized from slightly polluted to acceptable according to OIP classification. The current study's finding lies in a wet season where the values of OIP are less in most of the sites, which may be related to the increased precipitation in the winter months.

Keywords: water pollution, indices, physicochemical parameters, clustering, river.

دليل تلوث المياه لنهر دجلة في مدينة بغداد، العراق

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المستخلص

الهدف من الدراسة الحالية هو التعرف على مدى التلوث في نهر دجلة داخل مدينة بغداد من خلال تطبيق دليل تلوث المياه العام OIP. تم جمع عينات مياه شهرية من خمسة مواقع على طول نهر دجلة خلال الموسم الرطب والجاف لعامي 2020-2021. اخُتير أحد عشر عامل لإجراء الدراسة وهم كالاتي: مجموع المواد الصلبة الذائبة، العكارة، الكلوريد، الأكسجين المذاب، الأس الهيدروجيني، العسرة الكلية، الفلورايد، النترات، الكبريتات، المتطلب الحيوي للأوكسجين، مجموع بكتريا القولون. تراوحت قيم OIP من 2.46 إلى 1.96 في موسم الجفاف و2.02-1.91 في موسم الأمطار. أظهرت النتائج أن مياه نهر دجلة مصنفة من ملوثة قليلاً إلى مقبولة حسب تصنيفOIP. وبينت نتائج الدراسة الحالية ان قيم OIP تكون اقل في معظم المواقع خلال الموسم الرطب، والتي قد تكون مرتبطة بزيادة هطول الأمطار في أشهر الشتاء.

الكلمات المفتاحية: تلوث المياه، دلائل، العوامل الفيزيائية والكيميائية، تحليل عنقودي، النهر

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INTRODUCTION

Surface water bodies have long been the primary source of human needs. Nonetheless, due to various kinds of anthropogenic activity, the water quality of the water resources is under severe environmental stress and risk (33).The water quality of the Tigris River has deteriorated significantly, affecting aquatic life as well as human life due to anthropogenic activities such as wastewater released by industrial activity (15). The decline in the quantity of freshwater coming from Turkey, where dams are being built to hold water for agriculture and recreation, has the most obvious impact on the Tigris River's water quality and global climate change (1).The water pollution index is a quantitative and analytical framework for evaluating the extent of pollution in the aquatic system and gives corresponding details on water pollution. Water pollution indices convert water parameter data into a single numerical value that describes water's condition. The index is particularly helpful to water management agencies in maintaining the health of surface water resources. It could track water quality changes over time at local, regional, national, and global stages (28). Physical and chemical parameters of water samples were used to determine water quality (4). A variety of water pollution indices are available for assessing the pollution state of any river body, Pollution load index (23), overall index of pollution (34), Contamination Index (32), Heavy metal pollution index (HMPI) (39), Geo-accumulation index (*I-geo*) (5), Heavy Metal Evaluation Index (HEI) (26).The majority of scientists utilize these indices to determine whether or not the water is suitable for human consumption. As a result, assessing the quantity and quality of water and providing a database is critical for planning and improving water management approaches (38).The decline in water quality of the main Iraqi water resources is one of the important reasons to use the water quality index in Iraq to simplify the results of many water quality data (30). Some studies used the WPI to assess water quality in Iraq (15, 21, 12, 20) Sargaonkar and Deshpande (31) have designed an Overall Index of Pollution (OIP) for surface water quality based on thirteen variables, including Color, Turbidity, Dissolved Oxygen, pH, BOD, Total Dissolved Solids, Total Hardness, Chloride, Nitrate, Sulfate, Fluoride, Arsenic, and Total Coliforms. According to the Indian standards and other accepted guidelines and standards such as World Health Organization (WHO) and European Community Standards (ECS), each water quality observation was graded as Excellent, Acceptable, Slightly Polluted, Polluted, and Heavily Polluted. An excellent score in OIP means water quality is pristine. The acceptable score needs only disinfection. A slightly polluted score needs filtration and disinfection, a pollution score needs special treatment and disinfection, heavily polluted score cannot be utilized for any purpose (31). In this study, OIP was not calculated based on the weight of parameters but depended on the value of the individual pollution index Pi for each factor. Then these individual indices Pi are gathered to form an OIP score. In contrast, the water quality index depends on the weight of the variable as a determinant, as it is extracted from the sub-index value depending on the local or international standards.The main objectives of this study are to present the use of OIP as an evaluating tool for the Tigris River and to determine the correlations between water parameters.

MATERIALS AND METHODS

Studying sites

The river's length within Baghdad is almost 50 km, and it divides the city into two parts; Al-Karkh and Al-Rasafa (7). Along the Tigris River, five sites were chosen for this study within Baghdad City and the distance between each site is shown in Figure 1.

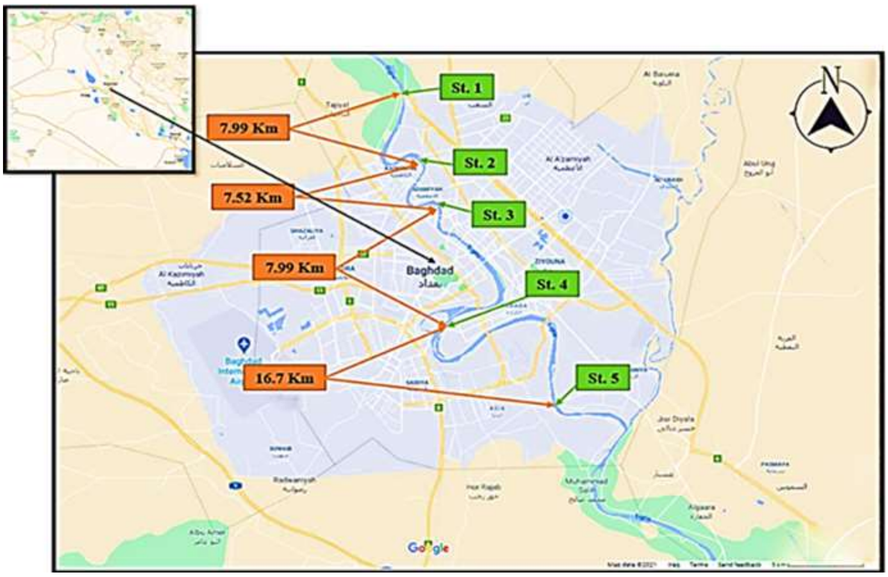

Figure 1. Studied Sites (Google Earth Pro, 2022)

Table 1 represents the Global Positioning System for the sites. Al-Muthanna Bridge, Al-Greaat Bridge, Al-Sarrafia Bridge, Al-Jadriyah Bridge, Al Za'franiya Area. The river is used as the raw water source for eight drinking water treatment plants located on both sides, also used for irrigation purposes and cooling by many facilities, such as the Al-Rasheed Gas Power Plant in the south of the city (35). Most municipal and industrial wastes have been dumped directly into the river without being properly treated (13).

Table 1. The geographical positions (GPS) of the study site

Sites	Position	Longitude	Latitude
St 1	**Al-Muthanna Bridge**	**44°20'43.30"E**	**33°25'42.19"N**
St 2	**Al-Greaat Bridge**	**44°20'55.54"E**	**33°23'26.41"N**
St 3	**Al-Sarrafia Bridge**	**44°22'22.84"E**	**33°21'11.55"N**
St 4	**Al-Jadriyah Bridge**	**44°22'27.69"E**	**33°17'1.39"N**
St 5	**Al-Za'franiya Area**	**44°27'18.95"E**	**33°14'0.08"N**

Sampling

Samples were taken from each site; two from the bank of the Tigris River and one from the middle. The average sampling time was between 7:00 am to 6:30 pm. The samples were collected from the subsurface (20-30 cm below the surface). The bottles are rinsed in river water several times before filling them with the required sample. The sample was preserved in the ice-cool box until it reached the laboratory and conducted the physical and chemical analyses. Laboratory measurements were carried out within 24 hours after sampling at the Environment Research Center, University of Technology-Iraq. Physical and chemical measurements were analyzed according to APHA (17). The Total Coliform Bacterial counts (TCBC) were determined using the Most Probable Number (MPN) method. The analysis was carried out at the Ministry of Sciences and Technology/ Directorate of Environment and Water Baghdad-Iraq. One ml from each dilution was added to each duplicated tube containing 5 ml of luryaltrptose bile broth. These tubes were incubated at 37°C for 48 hours to conduct the total Coliform count. Biochemical tests examined these tubes for identification, where positive results were proved by a gas formation that led to rising derhum tubes and the color of the media changed from purple to yellow. The results of growth were compared according to standard tables (37).

Climate of the study area

Seasonal and daily fluctuations characterize the climate of Iraq. Thereby the temperature was highly varied between summer and winter. The climate in the area is arid to semi-arid, with dry, hot summer and cold winter; the average annual rainfall is about 11.02 mm. Table 2 shows the monthly rate of climate factors in Baghdad International Airport/Al-Furat District/Ministry of Transport/Iraqi Meteorological and Seismology from July 2020 to April 2021.

Table 2. Monthly Climate rate during the period of study (Source; International Airport/Al-Furat District/Ministry of Transport/Iraqi Meteorological and Seismology)

Months	Mean Max. Tem .°C	Mean Min. Tem. °C	Mean RH%	Mean wind speed m/Sec	Suspend Dust Storm (No.of days)	Rising Dust Storm (No.of days)	Dust Storm (No.of days)	Monthly Rainfall Totals (mm)	Evaporation Totals (mm)
Jul.	47.4	28.7	21	3.9	10	0	0	0.0	448.7
Aug.	43.8	25.6	24	4.4	2	1	0	0.0	388.7
Sep.	43.9	24.5	27	3.1	20	1	0	0.0	302.7
Oct.	36.1	16.2	34	2.7	12	1	0	0.0	178.7
Nov.	25.1	13.7	60	2.9	10	0	0	84.2	109.6
Dec.	18.9	7.3	69	2.4	1	1	0	2.8	71.3
Jan.	19.7	4.7	55	2.9	6	1	0	1.7	83.9
Feb.	21.2	8	59	2.8	7	0	0	17.9	86.9
Mar.	25.4	11.5	41	4.1	10	4	0	2.8	177.7
Apr.	33.7	23.4	31	3.4	11	2	0	0.8	250.1

Determination of P_i for the chosen parameter and Overall Index of Pollution (OIP): The water quality parameters viz. Total Dissolved Solids (TDS), Turbidity (Turb.), Chloride (Cl^-), Dissolved Oxygen %(DO), pH, Total Hardness (TH), Fluoride (F^-), Nitrate (NO_3^-), Sulfate (SO_4^{-2}), Biochemical oxygen demand (BOD) and Total Coliform (TColi) were considered as the significant indicator parameters of surface water quality to the calculation of P_i in the present study according to Mathematical equations for value function curves suggested by Sargaonkar and Deshpande (31) Table 3, and the final OIP calculated as maintained in equation 1. the OIP classes are: 0–1: Excellent (Class C1), 1–2: Acceptable (Class C2), 2–4: Slightly polluted (Class C3), 4–8: Polluted (Class C4), 8–16: Heavily polluted (Class C5).

Table 3. Mathematical equations for value function curves

Parameters		Mathematical equations	Parameters		Mathematical equations
TDS	≤500	x=1	TH	≤75	x=1
	500–1500	x=exp((y −500)/721.5)		75–500	x=exp(y + 42.5)/205.58
	1500–3000	x=(y − 1000)/125		>500	x=(y + 500)/125
	3000–6000	x= y/375	F	0 –1.2	x=1
Turb.	y ≤5	x=1		1.2 –10	x=((y/1.2) −0.3819)/0.5083
	y5–10	x= (y/5)	NO_3	≤20	x = 1
	y 10–500	x = (y + 43.9)/34.5		20–50	x = exp((y − 145.16)/76.28)
Cl	≤150	x = 1		50–200	x=y/65
	150–250	x=exp((y/50) − 3)/1.4427)	SO_4	≤150	x = 1
	>250	x=exp((y/50) + 10.167)/10.82		150–2000	x=((y/50) + 0.375)/2.5121
DO%	y <50	x=exp(−(y−98.33)/36.067)	BOD	<2	x=1
	50–100	x=(y−107.58)/14.667		2–30	x=y/1. 5
	≥100	x=(y−79.543)/19.054	TColi	≤50	x=1
pH	7	X= 1		50–5000	x=(y/50)**0.3010
	y > 7	x = exp((y − 7.0)/1.082)		5000-15000	x=((y/50)−50)/16.071
	y < 7	x = exp((7− y)/1.082)		>15000	x=(y/15000)+16

$$OIP = \frac{\sum_i P_i}{n} \text{ ………… eq. 1}$$

where Pi = pollution index for ith parameter and n = number of parameters

Statistical analysis

Statistical Package for the Social Sciences

Statistical Package for the Social Sciences (SPSS) was adopted for statistical analysis SPSS Statistics version 25, a statistical software suite developed by IBM for data management, was used to calculate mean, mode, minimum, maximum, standard Deviation, and Hierarchical cluster.

Hierarchical cluster analysis

Multivariate data analysis includes clustering by measuring distances and identifying each cluster, this method groups items into clusters. Euclidean distance and Manhattan distance are two distance measures that can be employed. The shape of the resulting cluster is determined by the metrics chosen. This is because clusters which are close together according to one metric can be distant from each other according to another metric. Objects with a high degree of similarity will be placed together in a cluster, while objects with low similarity will be grouped in separate clusters. In other terms, the homogeneity between clusters is low while the homogeneity within the same cluster is high (8). Each object is handled as a separate cluster, which is subsequently combined or aggregated into cluster pairs successively until all clusters have been grouped into a single cluster containing all objects. In other words, the hierarchical technique starts by joining the two most similar objects. When these two objects were combined, they will form a new object with one or more other similar objects. This clustering process will finally agglomerate into a single huge cluster containing all the objects (36).

RESULTS AND DISCUSSION

Overall Index of Pollution Determination

The current study established 11 water quality parameters, viz. TDS, Turb., Cl, DO%, pH, TH, F, NO_3, SO4, BOD, and Total Coliform are the significant indicator parameters of surface water quality to calculate the overall pollution index. For each parameter concentration level, mathematical formulas were fitted to get a numerical value called an index (Pi) for individual pollutants, reflecting the degree of pollution for that parameter. The mathematical equations are revealed in Table 3. Descriptive statistics for all properties examined are shown in Table 4. All constituents have mean values over median values and high standard deviation reflecting positively skewed distribution and variation. An explanation of the observed characteristic follows in the following sections, with the term concentration referring to the median concentration employed. The OIP was calculated for each site during dry and wet seasons by taking the median of all the pollution indices (Pi) for individual water quality parameters (Table 4). The site 1, the overall water quality ranged from Acceptable in the dry season to Slightly polluted in the Wet Season (1.09 > OIP> 1.28), respectively. In all other sites, the OIP was slightly polluted, 2.16 > OIP> 2.21 for the wet and dry season in site 2, respectively, 2.36> OIP> 2.38 for the wet and dry season in site 3, respectively, 2.22 > OIP> 2.32 and 2.29 > OIP> 2.30 for dry and wet season in site 4 and 5, respectively. Tigris River suffers from a serious water shortage and annual variations in water quantity and quality. Climate change and dam development in neighbouring countries have caused the discharge variation. The water upstream is polluted with dark organic debris during the summer and autumn (drought seasons), causing WQ changes (9). This is so due to the effect of pollutants that come from municipal wastes, industrial wastes, human activities, and runoff from agricultural lands located in the city that deteriorates the water quality of the Tigris River day by day, where there are more than 17 stations (pumping + rain) located on Tigris River in Baghdad that were monitored by the Baghdad Environment Directorate/ The Ministry of Environment, which discharge sewage directly to water sources (river, drain, canal) without treatment. Some of these stations were established primarily as rainwater pumping stations. Still, because of population growth and the increase in the amount of sewage water, and the failure to absorb the pipes transporting the sewage treatment projects, which in turn are not sufficient to absorb the quantities generated from the city of Baghdad, some areas near these stations have been connected to them so that sewage is discharged directly to the water sources without treatment and treatment into the Tigris River in the city of Baghdad (Figure 2).

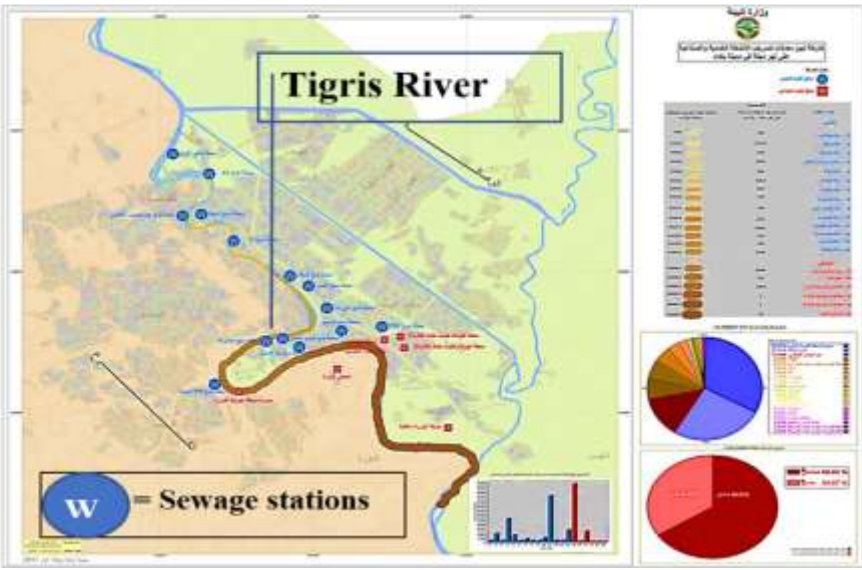

Figure 2. Sewage stations for the city of Baghdad (source; Baghdad Environment Directorate/ The Ministry of Environment)

To identify the specific parameters that are responsible for pollution, which can be obtained by referring to the ranges of concentration shown in Table 6 that are provided by (31), where **TDS** values ranged between 849.67 mg/l in site 5 during the wet season to 366 mg/l in site 2 during the dry season, as it is clear in Table 5 where spatial distribution for increasing of TDS concentration from north to south due to the agricultural lands along the Tigris River that were characterized with high salt content and higher concentrations of discharged effluents nearby the sampling stations since all sites were considered heavily populated and industrial wastes were directly disposing of the river without treatment (25), the increasing pattern was previously recorded in other studies (25, 3). Hence, the TDS was categorized in class 2 (Acceptable) in all sites for both seasons (Table 5).

Turbidity values ranged between 10.24-55.77 NTU in site 2 during the dry and wet seasons, respectively, and according to the pollution index (p*i*) classification (Table 5), turbidity lay in class 3 (Slightly Polluted) in all sites. The turbidity of the Tigris River water depended on the inorganic plankton represented by the components of the soil washing from the banks into the water and melting snow coming from the north, as well as the presence of floating algae (24). However, the dumping of the waste effluent into the Tigris River without treatment has contributed to increasing turbidity in the first place in Baghdad city. The high values of turbidity in the Tigris River were documented by many researchers (3, 2, 9, 14).

Cl^- concentration ranged from 297.99 mg/l at site 5 to 121.96 at site 3 during the dry season, categorized in class 2 (Acceptable) in all sites for both seasons. According to Iraqi river maintenance, their concentration was below the limits of 200 mg/l (33) for most of the study period.

DO% The presentation DO for saturation was categorized in class 2 (Acceptable) throughout the study. The highest percentage recorded was 93.2 in the wet season in site 1, and the lowest percentage was 65 in site 5 during the dry season. This pattern follows the ability of water to hold oxygen is influenced by temperature, where water temperature decreases in wet seasons (14.73 °C) and increases in dry seasons (22.38 °C). Since warm water holds less DO than cold water, a temperature increase causes a reduction in DO concentrations; increasing the activity of different microorganisms during a hot climate also leads to the consumption of Oxygen (19). Dissolved oxygen is considered an essential indicator of the water quality of any river. It has gained tremendous attention in recent decades, and so many studies show that the Tigris River is well-aerated (9, 18, 27).

pH concentration is a way to express the activity of the hydrogen ion in water. The pH value ranged from 8.44 in site 4 to 7.55 in site 3 during the dry season and was categorized under class 2 (Acceptable) to class 3 (Slightly

Polluted). The results of pH recorded in this study sustained in the alkaline side at all stations and in both seasons (never below pH 7.0). Tigris River water has a high buffering capacity due to carbon dioxide-bicarbonate balance. This agrees with the general water properties of Iraqi inland waters (9,16, 18,19).

Total Hardness concentration ranged from 420.00 in the dry season to 270.00 during the wet season in site 4 located in class 4 (polluted) in the individual classification system due to untreated pollutant waste discharged into the Tigris River, which causes a rise in parameter concentrations, primarily calcium and magnesium, where their concentrations reach 125.58 mg/l and 101.3 mg/l in site 4 respectively, this resulted in a rise in total hardness (3).

NO_3 and F^- concentration were categorized in class 1 (Excellent) enter the study, and also their values (14.60-0.0 and 0.2-0.0, respectively) were within the Iraqi river maintenance standards, which are 15 mg/l and 0.2 mg/l, respectively (29).

Sulfate highest value recorded in this study was 296.0 mg/l in site 3 during the wet season, and the lowest value was 126.0 mg/L in site 1 during the dry season. According to the pollution index classification (Table 5), sulfate SO_4 lies between class 2 and class 3 (Acceptable-Slightly Polluted) and also above the Iraqi River maintaining a standard which is 200 mg/l (29). Different factors that increase SO_4 are; Rocks (gypsum) close to the water body, and the biochemical effect of anaerobic microbes represents the principal sulfate source (22). Many industrial activities may also produce this ion when their wastes reach the river through the sewage drain pipes. At present, wet battery repair using sulfuric acid could be assumed as the main source of sulfate (18).

BOD indicates poor water quality and measures the amount of oxygen consumed by the bacteria decomposing organic matter to both waste and surface water (6). The results of BOD5 in the present study ranged from 2.8 mg/l in site 1 to o.5 mg/l in site 5 during the Dry season. According to the classification system of the individual index (Table 5), BOD_5 was categorized in class 1 (Excellent) throughout the study, and their concentration is within the limited value of Iraqi river maintenance, which is low than 5 mg/l (29).

Coli (Total Coliform counts) ranged between 1600-0.0 MPN/100ml. According to the Proposed Classification (Table 5), TColi ranged from class 1 (Excellent) and class 2 (Acceptable) in the dry season to class 3 (Slightly Polluted) in the dry season. This could be attributed to the high quantities of suspended solids and nutrients in the drainage water, which affected the aquatic microflora's survival, or to the positive relationship between temperature and bacterial growth, where higher temperatures increase bacterial activity (10).

Table 4. Spatial and temporal variation of water quality parameters (mean, standard deviation, minimum and maximum) and OIP of Tigris River. All parameters in mg/l, except for DO in percentage, turbidity in NTU and TColi in MPN/100ml

SITE 1	DRY SEASON					WET SEASON				
	Median	SD	Mini	Maxi	P_i	Median	SD	Mini	Maxi	P_i
Turbidity	32.98	13.13	14.1	51.2	2.23	19.58	7.36	12.77	29.37	1.84
pH	7.72	0.37	7.6	8.4	0.51	8.05	0.23	7.87	8.33	0.38
DO	75.52	2.03	73.2	77.7	2.19	78.95	8.38	74.08	93.25	1.95
BOD	1.07	0.77	0.7	2.8	1.00	1.23	0.45	1.07	2.07	1.00
TDS	623.83	129.04	366.0	670.0	1.19	640.83	91.64	622.5	816.67	1.22
TH	346.33	40.97	284.0	380.0	6.63	363.67	40.06	317.5	400.00	7.21
Cl	165.78	31.85	129.3	213.3	1.24	202.02	27.36	159.95	218.27	2.06
NO_3	7.85	4.50	0.0	10.7	1.00	5.92	2.36	3.90	8.95	1.00
SO_4	204.00	43.05	126.0	226.7	1.77	230.67	14.65	226.00	258.00	1.99
TColi	883.33	536.02	0.0	1183.3	5.32	405.00	375.09	126.67	956.67	2.44
F	0.16	0.04	0.1	0.2	1.00	0.08	0.04	0.00	0.09	1.00
OIP					2.18					2.007
SITE 2	DRY SEASON					WET SEASON				
	Median	SD	Mini	Maxi	P_i	Median	SD	Mini	Maxi	P_i
Turbidity	32.63	14.53	17.50	55.77	2.22	23.51	15.64	10.24	46.23	1.95
pH	7.77	0.35	7.69	8.37	0.49	8.09	0.25	7.87	8.35	0.37
DO	75.20	4.70	69.11	80.80	2.21	79.63	3.62	73.35	81.69	1.91
BOD	1.20	0.26	0.90	1.57	1.00	1.15	0.09	1.05	1.23	1.00

TDS	622.67	80.90	444.0	639.0	1.19	601.67	89.88	580.6	773.3	1.15
TH	343.33	54.22	264.00	410.00	6.53	387.58	32.02	331.33	400.0	8.10
Cl	174.95	36.89	124.63	206.60	1.41	186.61	23.58	158.2	204.94	1.66
NO_3	5.97	5.28	0.00	14.60	1.00	4.21	1.85	2.47	6.93	1.00
SO_4	192.00	26.63	148.00	222.00	1.68	203.00	9.46	190.0	213.0	1.77
TColi	540.00	619.11	0.00	1373.33	3.25	210.75	267.3	95.00	665.67	1.27
F	0.14	0.03	0.11	0.19	1.00	0.11	0.07	0.00	0.17	1.00
OIP					1.99					1.92
SITE 3	DRY SEASON					WET SEASON				
	Median	SD	Mini	Maxi	P_i	Median	SD	Mini	Maxi	P_i
Turbidity	35.97	15.45	10.60	50.00	2.31	23.28	7.76	17.77	34.10	1.95
pH	7.74	0.38	7.55	8.41	0.50	8.16	0.37	7.57	8.40	0.34
DO	78.69	3.41	73.06	82.86	1.97	80.15	2.60	79.24	84.98	1.87
BOD	0.97	0.31	0.70	1.53	1.00	1.37	0.21	1.22	1.65	1.00
TDS	621.67	119.21	423.00	732.00	1.18	654.17	105.45	622.67	849.0	1.24
TH	355.00	44.65	274.0	400.0	6.91	358.35	29.60	342.0	410.0	7.03
Cl	197.44	49.11	121.96	264.91	1.93	204.52	32.89	158.28	226.60	2.13
NO_3	4.52	3.37	0.00	8.90	1.00	7.01	2.35	2.83	8.13	1.00
SO_4	206.00	32.78	146.00	220.67	1.79	241.67	43.75	206.0	296.0	2.07
TColi	1246.67	801.32	5.00	1600.0	7.50	440.08	743.19	23.67	1600.0	2.65
F	0.17	0.02	0.14	0.19	1.00	0.11	0.07	0.00	0.15	1.00
OIP					2.46					2.03
SITE 4	DRY SEASON					WET SEASON				
	Median	SD	Mini	Maxi	P_i	Median	SD	Mini	Maxi	P_i
Turbidity	29.60	15.77	16.20	49.87	2.13	17.00	8.58	13.95	32.50	1.77
pH	7.76	0.41	7.64	8.44	0.50	8.33	0.23	7.95	8.47	0.29
DO	72.85	6.47	71.39	85.30	2.37	80.23	5.56	77.20	89.81	1.86
BOD	1.23	0.38	0.50	1.40	1.00	1.62	0.26	1.48	2.07	1.00
TDS	652.00	115.34	449.00	769.00	1.23	664.92	88.56	622.00	815.67	1.26
TH	353.33	40.56	270.00	370.00	6.86	342.00	44.10	321.40	420.00	6.49
Cl	179.94	41.12	154.95	259.90	1.51	199.10	22.15	166.62	214.93	1.98
NO_3	7.30	5.51	0.00	12.83	1.00	3.05	3.11	1.47	8.38	1.00
SO_4	218.00	36.20	140.00	227.33	1.88	242.83	42.08	164.00	256.00	2.08
TColi	350.00	595.65	5.00	1210.00	2.11	516.50	621.68	24.67	1373.33	3.11
F	0.15	0.02	0.14	0.20	1.00	0.08	0.05	0.00	0.11	1.00
OIP					1.96					1.99
SITE 5	DRY SEASON					WET SEASON				
	Median	SD	Mini	Maxi	P_i	Median	SD	Mini	Maxi	P_i
Turbidity	33.87	12.56	18.00	51.60	2.25	17.82	11.29	10.94	37.13	1.79
pH	7.65	0.39	7.61	8.43	0.55	8.35	0.33	7.70	8.37	0.29
DO	73.28	9.11	65.33	87.53	2.34	76.48	2.67	74.73	80.82	2.12
BOD	1.08	0.45	0.40	1.53	1.00	1.37	0.25	1.13	1.70	1.00
TDS	635.00	106.62	445.00	753.00	1.21	644.92	113.69	608.00	849.67	1.22
TH	357.33	40.39	276.00	383.33	6.99	355.67	30.85	329.30	403.33	6.94
Cl	199.10	39.78	164.94	279.99	1.98	199.94	17.87	168.28	208.27	2.00
NO_3	4.08	6.66	0.00	14.6	1.00	5.83	3.22	2.60	9.00	1.00
SO_4	209.00	32.52	149.00	228.00	1.81	250.33	19.73	232.00	276.00	2.14
TColi	350.00	693.99	0.00	1600.0	2.11	264.83	606.52	30.67	1373.33	1.59
F	0.18	0.01	0.16	0.19	1.00	0.16	0.03	0.12	0.18	1.00
OIP					2.02					1.92

Table 5. Proposed Classification of Water Quality

Classification	Excellent	Acceptable	Slightly Polluted	polluted	Heavily polluted
	C1	C2	C3	C4	C5
Class Index	1	2	4	8	16
parameters			Concentration limit		
Turbi.	5	10	100	250	>250
pH	6.5-7.5	6.0-6.5 and 7.5-8	5-6 and 8-9	4.5-5 and 9-9.5	<4.5 and >9.5
DO%	88-112	75-125	50-150	20-200	<20 and >200
BOD_5	1.5	3	6	12	24
TDS	500	1500	2100	3000	>3000
Cl	150	250	600	800	>800
NO3	20	45	50	100	200
SO4	150	250	400	100	>1000
TColi (MPN)	50	500	5000	10000	15000
F	1.2	1.5	2.5	6	>6
TH	75	150	300	500	>500

Hierarchical cluster analysis

The dendrogram in Figure 3 shows two clusters of OIP during the Dry season. The first cluster consists of a pair of sites 1 and 2, where they are similar in characteristics, and the similarity is higher. The two sites are located north of the city of Baghdad, and therefore the water quality was equal or similar, and the impact of pollutants was low. Site 3 was associated with them, and they formed the first sub-cluster. The second cluster consisted of a pair of sites 4 and 5. This suggests the increase of pollution in these two sites during the Dry season, where the OIP classification ranges from Acceptable pollution to slight pollution respectively, due to higher wastewater discharged from all human activities were both sites located in the south of Baghdad's characterized by heavily discharging from many wastewater and industrial facilities located on both sides of the river (9, 11). The tree dendrogram in Figure 4 shows two clusters of OIP in the Tigris River during the wet season. The first cluster included Pairs of sites 4 and 5, and at a distance, site 1 joined with them and formed a sub-cluster. As a result, the three sites have the same water quality, which may be due to an increase in the Rainfall in the winter months (Table 2). Sites 2 and 3 pair in a sub-cluster that may return to the nature of these two sites as characterized by the presence of tourism activity and fisheries. The difference in water quality between the north and south parts of the city may be due to the river's self-purification, one of the known features Tigris River (13). This factor greatly influences improving water quality, where the values of OIP were less in the Wet Season than in the Dry Season (Table 4).

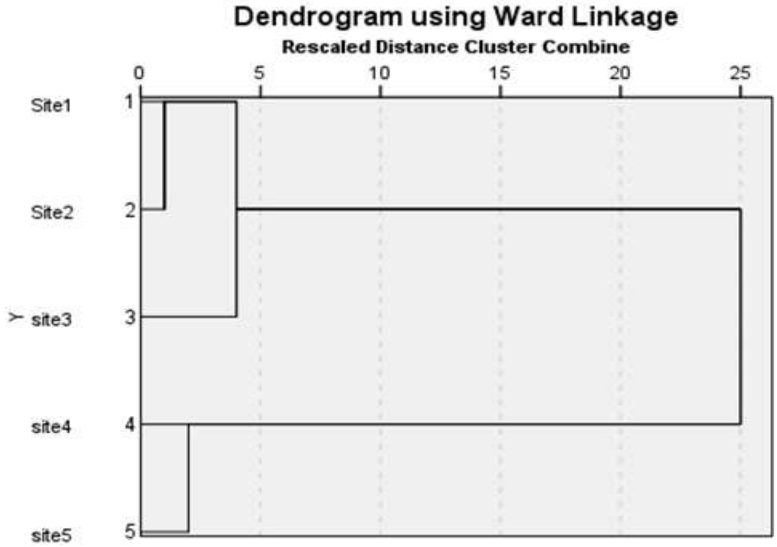

Figure 3. Dendrogram of clustering of sampling sites during Dry season

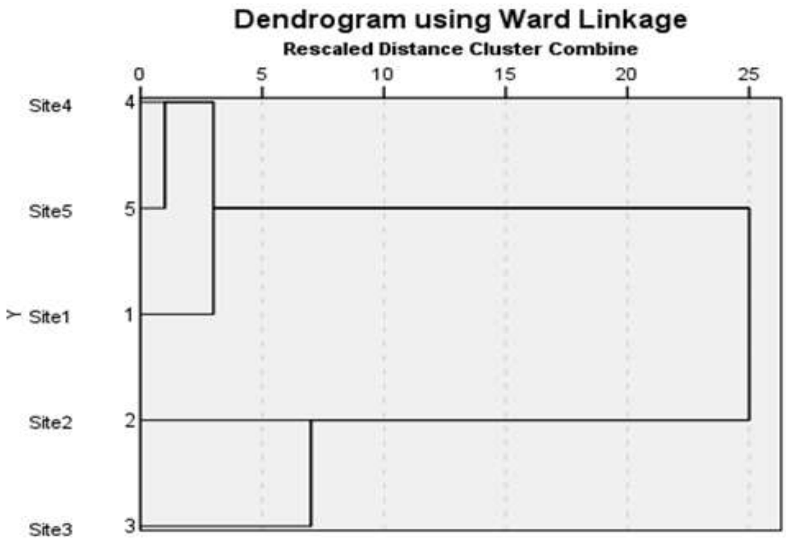

Figure 4. Dendrogram of clustering of sampling sites during Wet season

CONCLUSION

1. The Tigris River receives a constant inflow of sewage and wastewater from residential, institutional, agricultural, and commercial activities.
2. As the river moves from north to south, its water becomes more detritus because of the effect of population and the increase in human activities.
3. It is necessary to ask for the development of local environmental laws and regulations in Iraq. Thus, applying any index will be suitable for the Iraqi environment

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