MULTIVARIATE ANALYSIS FOR EVALUATION THE WATER QUALITY OF TIGRIS RIVER WITHIN BAGHDAD CITY IN IRAQ

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ABSTRACT

The aim of this study is to evaluate the water quality of Tigris river by measuring the physicochemical parameters of the river within Baghdad city in Iraq from the period of February 2017 to February 2018. Four sites were selected from upreach, reach and downreach. Temperature of air and water, pH, electrical conductivity, salinity and water flow were measured in the field, While, the laboratory measurements included total dissolved substances (TDS), total suspended substances (TSS), turbidity, nutrients (nitrite, nitrate and phosphate), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), organic matter and total organic carbon (TOC), these parameters were used to indicate the pollution of Tigris River ecosystem. The results show that all parameters variation in both seasons (wet and dry), which has led to a deterioration in water quality. A higher level of contamination was recorded at reach sites (Al-Sarrafia Bridge and Al-Shuhada Bridge) in contrast to other sites (Al-Muthanna Bridge and Al-Dora Bridge). This indicates that the Tigris river in the middle of Baghdad city is more polluted due to the anthropogenic impacts.

Key words: Water assessment, physical parameters, chemical parameters, pollution lotic system.

- **Part of Ph.D. dissertation of the 1st author.**

التحليل متعدد المتغيرات لتقييم نوعية المياه لنهر دجلة داخل مدينة بغداد، العراق

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المستخلص

الهدف من الدراسة هو تقييم جودة مياه نهر دجلة من خلال قياس المعلمات الفيزيائية والكيميائية للنهر داخل مدينة بغداد /العراق للفترة من شباط 2017 إلى شباط 2018 ،تم اختيار أربعة مواقع للنهر تضمنت بداية، منتصف ونهاية النهر. بداية شملت القياسات الحقلية درجة حرارة الهواء والماء، درجة الحامضية، التوصيلة الكهربائية، الملوحة وقياس سرعة جريان المياه، اما القياسات المختبرية فقد شملت المواد الذائبة الكلية، المواد العالقة الكلية، العكورة، المغذيات (النتريت، النترات والفوسفات) المتطلب الحيوي للأوكسجين، المتطلب الكيميائي للأوكسجين، الأوكسجين المذاب، المواد العضوية والكاربون العضوي الكلي. استعملت هذه المعلمات للإشارة إلى تلوث النظام البيئي لنهر دجلة. وأظهرت النتائج أن جميع المعلمات قد أعطت تغييرات في كلا الموسمين (الرطب والجاف)، والتي أدت الى تدهور نوعيه المياه. سجلت أعلى نسبة تلوث في مواقع منتصف النهر المتضمنة جسر الصرافية وجسر الشهداء بالمقارنة مع بقية المواقع (جسر المثنى وجسر الدورة). وهذا يشير الى ان نهر دجلة يكون أكثر تلوثاً في منتصف مدينة بغداد بسبب تأثير النشاطات البشرية عليه.

الكلمات المفتاحية: تقييم المياه، المعلمات الفيزيائية، المعلمات الكيميائية، نظام تلوث المياه الجارية.

- **جزء من أطروحة دكتوراه للباحث الاول.**

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INTRODUCTION

Water is one of the most important sources for life. It is used in all countries of the world for municipal, industrial and agricultural uses and is always susceptible to pollution (9). Pressure on existing water resources is increasing due to increasing demands in many sectors of life leading to water scarcity around the world. In Iraq, one of the major important surface water resources is Tigris river, divides the capital city of Baghdad to the right (Karkh) and left (Rusafa) sections with the direction of flow from north to south (6), and there are several river tributaries and number of islands because of the slow speed and sedimentation. Contamination of river water by transmission of toxic pollutants as a result of anthropogenic activities as factories in which discharged their wastewater directly into the river without any real treatments through passing Bagdad city are threatens the ecosystem for plants and living organisms (22). The resulting effects of nature like weathering of bedrock minerals, leaching of organic matter and nutrients from soil, atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, deposition of dust and salt by wind, hydrological factors that lead to runoff, and biological processes within the aquatic environment that can lead to a change in the physicochemical properties of water (42). In the recent years, the assessment of water quality in different countries has become a very important research topic (11). Knowing the physical, chemical and biological characteristics of water is very important before using in different purposes, in which reflects or describes water quality (4, 23, 40). The evaluation various parameters of water are helps to indicate their contamination level. Therefore, any sample of water can show different levels of pollution by different parameters measured (41). Some of physicochemical parameters like pH and dissolved oxygen may define the integrity of water ecosystem by comparison of parameters with water quality standards or guidelines (7, 29). Some of organic pollution indicators such as dissolved oxygen, biochemical oxygen demand and chemical oxygen demand were using to estimate the pollution level of Al-Habbaniya lake in Iraq (38). A continuous monitoring of water quality is very essential to determing the state of pollution in the rivers (35). However, in many cases, monitoring sources do not easily provide a comprehensive view of the spatial and temporal tend of the overall water quality of the watersheds (14). The application of multivariate statistical methods like descriptive analysis, cluster analysis (CA) (temporal and spatial variation), principle component analysis (PCA) and factor analysis (FA) is useful in reducing the complexity of large water quality data (reducing number of variables) without losing original information (17). These techniques were helps to interpret large and complex data to understand the status of water quality, identify pollution sources that effect on ecological of water and give rapid resolution for pollution problems with simple and effective from cost and water quality (18). Therefore, the aim of this research was to assess the physicochemical quality of the Tigris River water in the selected sites within Baghdad city in comparison with Law of Iraqi River maintaining system 25 / 1967 and CCME for aquatic life (12,30,37).

MATERIAL AND METHODS

Study Area: This study was conducted on the Tigris River within Baghdad city in specific locations selected for collection the samples to study the physical and chemical parameters. The period of study was done over two seasons (wet and dry) at once every month, from (February 2017 to February 2018). Samples were collected in the time between 8.30 am to 2.30 pm during the second week of each month. Field measurements, collection, labeling, sampling and transfer to the laboratory were carried out and prepared for regular inspection. The positions of sites were determined by the Global Positioning System (GPS) (Figure 1 and Table 1).

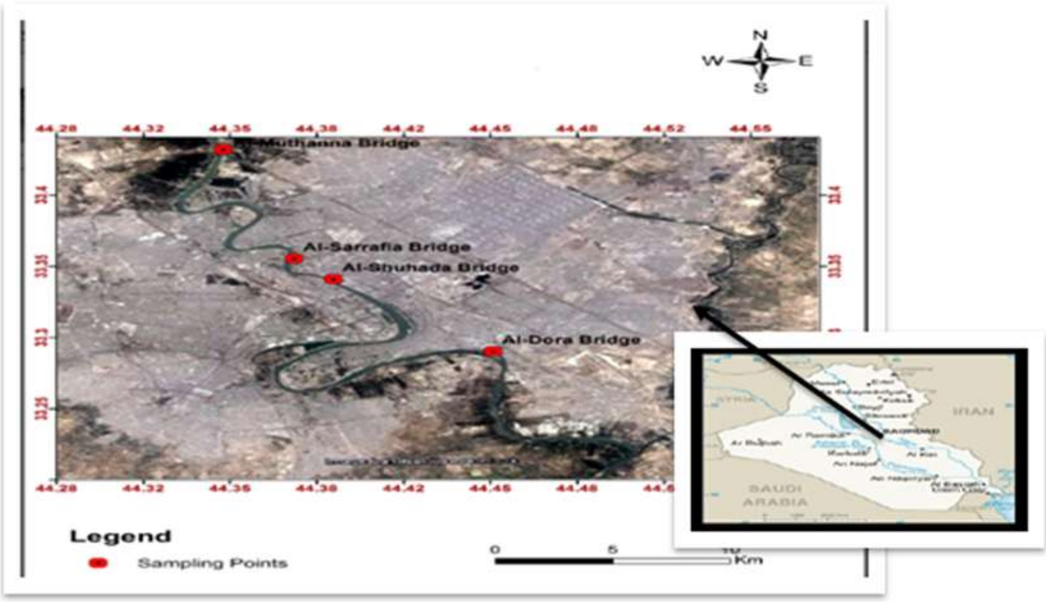

Figure 1. Sampling locations across Tigris River, Baghdad city

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

Site Number	Site Name	Coordinates	
		Longitude (E)	Latitude (N)
1	Al-Muthanna Bridge	44°34'55.50''	33°42'83.22''
2	Al-Sarrafia Bridge	44°37'36.01''	33°35'37.53''
3	Al-Shuhada Bridge	44°38'79.03''	33°33'79.59''
4	Al-Dora Bridge	44°45'02.84''	33°28'96.82''

Samples collection and preservations

The stopper fitted clean polyethylene bottles (1L) that prewashed with distilled water were used to collect the water samples from the surface layer with the depth (20-30) cm. Samples were analyzed for chemical and physical properties immediately after collection.

Sample analysis

Measuring and analysis was carried out on seventeen physical and chemical parameters included (Air Temperature (AT), Electrical Conductivity (EC), Salinity‰, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Turbidity (Tur.), Water Flow (WF), Water Temperature (WT), pH, Nitrite (NO_2), Nitrate (NO_3), Phosphate (PO_4), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Organic Matter present (OM%) and Total Organic Carbon percent (TOC%) for the period from February 2017 to February 2018. These parameters were sampled monthly and determined according to the standard methods (8).

RESULTS AND DISCUSSION

Physical characteristics of Tigris River

1- Descriptive analysis: The descriptive statistics for physical parameters illustrated in Table 2. The results of each parameter were compared with Iraqi River maintaining system Law 25/1967 and CCME for Rivers (12, 37, 30). The air temperature (AT) ranged from 12.55 ºC in wet season (December 2017) to 43.73 ºC in dry season (June 2017). The air temperature (AT) measured was within the weather rates during the study period with limited value for aquatic life (32) (Table 3). The lowest value of electrical conductivity (EC) (580.5 µs/cm) recorded in dry season and the highest was 1108.75 µs/cm in wet season. Electrical conductivity (EC) in the aquatic ecosystem is considered a good indicator for evaluating total dissolved solid materials in water and nature of the purity of water (2, 19). EC is a measure of water's capability to pass electrical flow (15), this ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compound. The results showed that the lowest and highest value of EC war recorded in wet season (Table 2) (March 2017 and January 2018), respectively, in which a higher than the permissible limit of both wet and dry season. The concentration of main ions were slightly higher in wet season than those of dry season due to increasing surface runoff, return irrigation water flow, salinity of soil and increasing human activities. The high value of EC was influence on plant's ability to absorb water. In horticultural applications, monitoring salinity helps manage the effects of soluble salts on plant growth. EC in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge) (31). The salinity (S‰) was ranged (0.2-0.48 ‰) in dry season and wet season, respectively. While TDS ranged from 362.75 mg/l in dry season to 711.75 mg/l in wet season. The results of Salinity (S‰) and Total dissolved solid (TDS) were showed the lower and higher values were recorded in wet season (February 2018, January 2018 and December 2017) (Table 2). These higher values recorded in wet season belong to increasing surface runoff, the geologic formation that the river passes through, increasing in evaporation rate and increasing human activities, which has increased the concentration of ions (10, 35). The highest value for S‰ and TDS were within the permissible values of ISR but its high for CCME. The minimum value of TSS was 3.00 mg/l in dry season and the maximum value was 84.50 mg/l in dry season. While the Turbidity (Tur.) ranged (10.61- 193.75 NTU) in wet season and dry season, respectively. The highest values were recoded for Total Suspended solid (TSS) and Turbidity (Tur.) in dry season (April and July 2017) (Table 2), in which higher than the both limited values. TSS and Tur. indicate to particles present in water. Clarity and Tur. are both visual properties of water based on the light attenuation and scattering. So that the TSS is a specific measurement for all suspended solids, organic and inorganic by mass (34). Growth of phytoplankton in open water may be causes Turbidity. In addition, the human activities that disturb land, as construction, mining and agriculture, can lead to high sediment levels that entering water bodies during rainstorms because of storm water runoff. The suspended sediments that cause turbidity in which can block light to aquatic plants and aquatic organisms and carry pollutants and pathogens, like lead, mercury and bacteria (16, 43). The lowest value of water flow (WF) (0.31 m/s) recorded in wet season and the highest value was 0.71 m/s in dry season. The maximum value for Water Flow (WF) was measured in dry season (July 2017) (Table 2). WF determines the degree and type of deposition and thus the nature of sediment (45). Water flow is an important force that moves the pollutants into region far from their origin. Also the melting snow in summer that caused increase in flow rate, that explains the much lower pollutants were measured in sediment (44). The water temperature (WT) was ranged in this study between 10.36 ºC in wet season to 30.11 ºC in dry season. Water temperature (WT) showed a positive one with air temperature during most seasons (wet and dry) (Table 3). Because the AT plays an important role for the heat budget of the Tigris River (5). The overall range of WT was lowest value in wet season (February 2017) and highest value where in dry season (August 2017), apparently these values followed almost identical seasonal cycles.

Table 2. Physical characteristics of Tigris River during the study period

Parameters	Range		Mean	Standard Deviation	Standard values	
	Minimum	Maximum			Law 25/1967	CCME
AT (ºC)	12.55	43.73	26.27	9.64	-	-
EC (µs/cm)	580.50	1108.75	876.27	148.05	0.5-1.0	-
S ‰	0.20	0.48	0.35	0.08	-	-
TDS (mg/l)	362.75	711.75	563.87	105.47	1000	500
TSS (mg/l)	3.00	84.50	18.58	22.05	60	-
Tur. (NTU)	10.61	193.75	67.83	65.36	5	5
WF (m/s)	0.31	0.71	0.47	0.13	-	-
WT (ºC)	10.36	30.11	21.59	6.83	>35	15

not applicable or available

Table 3. Monthly rates of climate factors (Ministry of Transportation / Iraqi Meteorological organization and Seismology) in Baghdad International Airport 2018)

Factors / Months	Mean max Tem.(C°)	Mean min Tem.(C°)	Mean RH%	Mean wind speed (m/s)	Prevailing wind	Suspended Dust (no. of days)	Rising Dust (no. of days)	Dust Storm (no. of days)	Rainfall totals (mm)	Evaporation totals (mm)
Jan./2017	16.1	2.5	70	2.5	NW	11	1	0	9.3	65.0
Feb./2017	18.0	3.0	50	3.0	NW	10	1	0	11.3	89..0
Mar./2017	23.8	3.7	56	3.7	NW	14	2	0	41.8	137.4
Apr./2017	30.4	4.0	41	4.0	NW	14	3	1	7.5	206.1
May/2017	38.1	3.8	26	3.8	NW	23	7	2	0.1	355.6
Jun./2017	42.7	4.5	21	4.5	NW	13	3	0	0.0	415.6
Jul./2017	47.5	4.8	16	4.8	NW	13	2	0	0.0	469.4
Aug./2017	47.4	4.2	18	4.2	NW	9	0	0	0.0	478.5
Sep./2017	43.5	3.4	22	3.4	NW	18	2	0	0.0	358.2
Oct./2017	33.7	2.8	33	2.8	NW	18	2	1	0.0	227.1
Nov./2017	25.4	3.0	48	3.0	NW	13	0	0	1.6	128.0
Dec./2017	21.0	3.4	53	3.4	NW	19	3	0	TR	113.2
Jan./2018	18.7	5.3	53	3.4	NW	18	3	0	0.9	109.4
Feb./2018	20.6	8.4	63	3.0	NW	7	0	0	88.4	86.7

N= North, W= West, TR= Trace (less 0.1 mm)=

2- Temporal variation

Temporal cluster analysis CA generated a dendrogram as shown in Figure 2 grouping 13 months into three clusters. Cluster I included dry season (April and May 2017), cluster II consisted of dry season (June, July, August, September, October and November). Cluster III included wet season (February 2017, March 2017, December 2017, February (dry season) and January 2018 (wet season) were recorded the highest pollution level than the other months have the lowest pollution level. The temporal variation in physical parameters level during the study period illustrated in Figure 3 and showed that the June and July 2017 have the highest value of Turbidity. In addition, January 2018 was recorded the maximum values for EC and TDS. This concluded that these parameters are the main reasons for deteriorated water quality in these months.

Spatial variation: For this study, classification of the sampling site was performed by the use of CA based on eight measured parameters. Figure 4 illustrates two clusters, in which cluster I included sampling sites S2 and S3 whereas the cluster II included S1 and S4. Among the sampling sites, S2 and S3 have the highest pollution level while S1 and S4 have the lowest pollution level. These results are good agreement with the variation in water sampling sites as shown in Figure 5**.** In which at S2 and S3 were recorded highest value for EC and TDS. The results from CA techniques are useful in classification of river water in the study region and the number of sampling sites and associated monitoring costs can be reduced without missing much data or information. This result was in accordance with results of many studies carried out in other rivers. (21, 36).

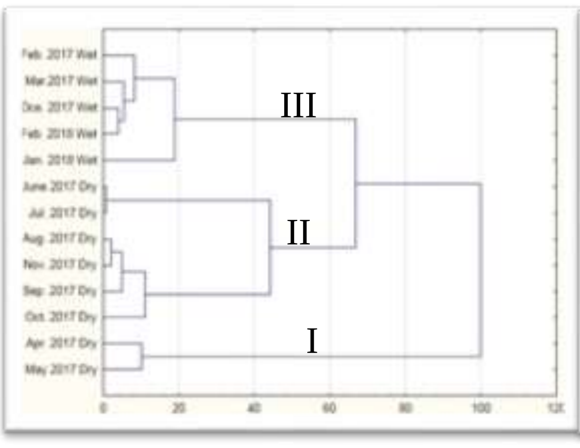

Figure 2. Dendrogram of temporal clustering of sampling period during the study period

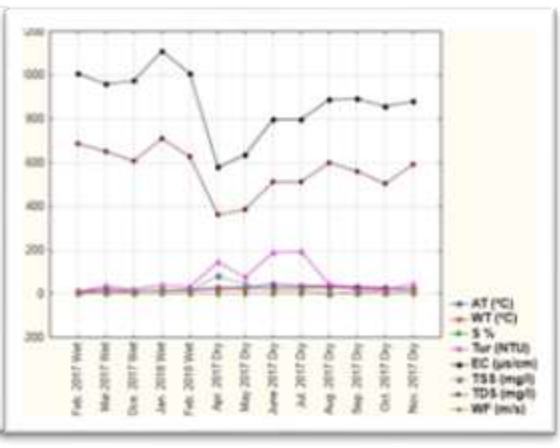

Figure 3. Temporal variations of physical parameters of Tigris River during the study period

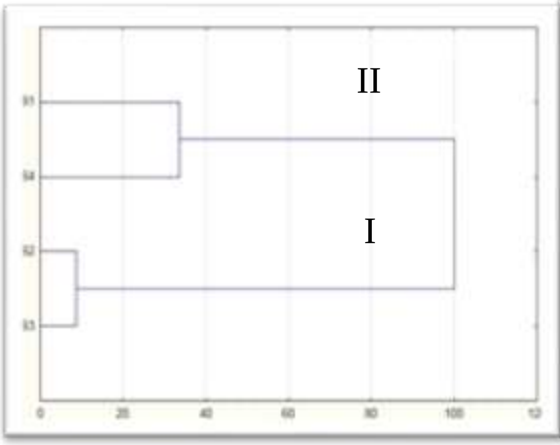

Figure 4. Dendrogram of spatial clustering of sampling sites during the study period

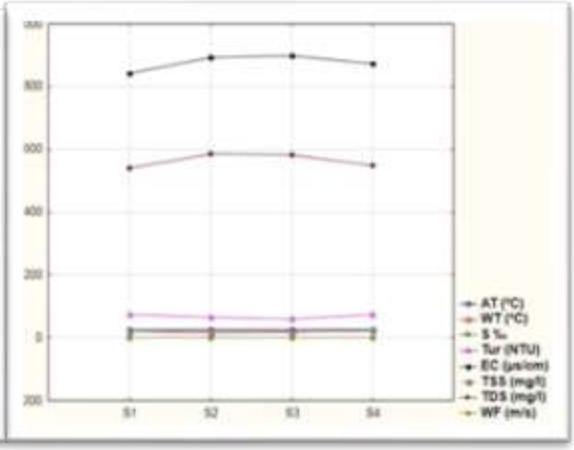

Figure 5. Spatial variation of physical parameters of Tigris River during the study period

4- Person's correlation coefficient

A significant positive strong correlation ($P<0.05$) were observed between AT-WT (r= 0.949), AT-Tur. (r= 0.718), AT-WF (r= 0.853), WT-WF (r= 0.790), S‰-EC (r= 0.954), S‰-TDS (r= 0.934), Tur.-WF (r= 0.843) and EC-TDS (r= 0.973) (Table 4) during the study period. In addition, a strong negative significant correlation were observed for S‰-TSS (r= -0.785), EC-TSS (r= -0.769) and TSS-TDS (r= -0.760).

Table 4. Person's correlation coefficient of physical parameters of Tigris River during the study period

Parameters	AT (°C)	WT (°C)	S ‰	Tur (NTU)	EC (µs/cm)	TSS (mg/l)	TDS (mg/l)	WF (m/s)
AT (°C)	1.000							
WT (°C)	0.949	1.000						
S ‰	-0.537	-0.418	1.000					
Tur (NTU)	0.718	0.534	-0.641	1.000				
EC (µs/cm)	-0.631	-0.552	0.954	-0.604	1.000			
TSS (mg/l)	0.205	0.058	-0.785	0.465	-0.769	1.000		
TDS (mg/l)	-0.606	-0.542	0.934	-0.562	0.973	-0.760	1.000	
WF (m/s)	0.853	0.790	-0.459	0.843	-0.521	0.180	-0.506	1.000

r= >0.75 strong correlation, r= 0.75-0.5 moderate correlation, r= 0.5-0.3 weak correlation

5-Principal component analysis (PCA) and factor loading analysis (FA)

The results of PCA during the study period were generated two significant factors in which the cumulative variance for them was 89.026% and the cumulative variance of the first component (Factor 1) was 67.448% (Table 5). Whereas a strong positive loading ($P<0.05$) for TSS (r= 0.942). A strong negative loading ($P<0.05$) of EC (r= -0.882), S ‰ (r= -0.913) and TDS (r= -0.877). The total variance of the second component (Factor 2) was 21.578% and a strong negative loading ($P<0.05$) of AT (r= -0.939), Tur. (r= -0.706), WF (r= -0.923) and WT (r= -0.925).

Table 5. Factor loadings of physical parameter of Tigris River during the study period

Parameters	Factor loading for all period study	
	Factor 1	Factor 2
AT (°C)	0.254*	-0.939***
EC (µs/cm)	-0.882***	0.420*
S ‰	-0.913***	0.329*
TDS (mg/l)	-0.877***	0.399*
TSS (mg/l)	0.942***	0.041*
Tur (NTU)	0.450*	-0.706***
WF (m/s)	0.192*	-0.923***
WT (°C)	0.129*	-0.925***
Eigenvalue	5.396	1.726
Total variance %	67.448	21.578
Cumulative variance,%	67.448	89.026

Significant factor loadings are boldfaced (*strong, >0.75; **moderate, 0.50–0.75; *weak, 0.50–0.30).**

Chemical characteristics of Tigris River

1- Descriptive analysis

Descriptive statistics of chemical parameters in Tigris river were illustrate in Table 6. The pH ranged from 7.43 in dry season to 8.25 in wet season. The pH of the aquatic systems is an important indicator of the water quality and the extent pollution in the watershed areas (51). pH is a measure of the amount of free hydrogen and hydroxyl ions in the water. In which high free hydrogen ions is acidic, while high free or hydroxyl ions is basic (33). The pH value in dry and wet season are within the permissible limit (Table 6), suggest that the river water is often slight alkaline (1, 49). pH can effected by photosynthesis and respiration in the water. The change depends on the alkalinity of water, in which carbon dioxide is the most common cause the acidity in water. While released hydrogen ions decrease the pH of water. Lowest value of pH might be due to the presence of pollution, or the degradation organic materials, which produced dissolved carbon dioxide because of low temperature (50). Nutrients were including nitrite (NO_2), nitrate (NO_3) and phosphate (PO_4) and the minimum concentration of NO_2 was 0.01 mg/l in dry season and the maximum concentration was recorded to 0.45 mg/l in dry season. The lowest value of NO_3 (0.64 mg/l) whereas the highest value was 8.97 mg/l recorded in dry season. While the PO_4 were ranged (0.07-1.52 mg/l) in wet season. Nutrients include nitrite (NO_2), nitrate (NO_3), and phosphate (PO_4). NO_2 and NO_3 are naturally ions present in water due to it are a part of nitrogen cycle. Results showed that NO_2 increased from the standard in which the highest value was recorded in dry season (September 2017), while NO_3 is a highly decreased from the permissible limits for both wet and dry season (Table 5). NO_3 is a stable form of N_2, which can be decreased by nitrification while NO_2 is unstable oxidation (24). The reasons for decrease the concentration of nitrate in Tigris River for both sites and months are due to uptake process by microbial activity especially during the summer season where most of biological processes take its place during the hot season (48). For the concentration of PO_4, it is a higher than the permitted level of aquatic life for all sites and months and the highest value was recorded in wet season (August 2017). PO_4 is an important nutrient in water body and only the soluble form inorganic phosphorus directly was utilized by aquatic biota (46). High concentration of phosphorus leads to algal blooms that the excessive growth of aquatic plants leads to "Eutrophication", which cause anoxic condition in water body (13, 25). Phosphorus occurs as for naturally or by anthropogenic activities. For naturally occurs from atmospheric deposition, natural dissolution of rocks and minerals, weathering of soluble inorganic materials, decomposition of biomass, runoff, and sedimentation. Anthropogenic source includes: fertilizers, detergents, animal wastes, wastewater and septic system effluent, industrial discharge (20). Organics in this study includes BOD, COD, DO, OM% and TOC%. The results of analysis show that the BOD ranged from 0.53 mg/l in wet season to 3.67 mg/l in dry season. Also the minimum concentration of COD was 3.75 mg/l in wet season and the maximum concentration was 88.25 mg/l in dry season. The lowest value of DO (4.63 mg/l) in dry season and the highest value was 11 mg/l in wet season. BOD is a measure of the amount of oxygen consumed by the bacteria that are decomposing organic matter to both waste and surface water. BOD is an indication of poor water quality. The results of present study were showed that the BOD value is within limited value (37). COD is a measure of the amount of chemicals (usually organics) that consume dissolved oxygen. The COD value was lowest the limited value, which corresponds to low of residues because of human activities. All values in wet and dry season were within the limited values which agreement to those found by Al-Hiyaly *et al.* (3). The fluctuations depend on temperature and algal populations were supported the biological life in water by DO (26). Increasing of the flow rate of a water body will increase the amount of dissolved oxygen in the water, because the flow rate increases the diffusion or movement of oxygen into water from atmosphere. The amount of organic matter in the water affects dissolved oxygen levels by lowering it. DO is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self-purification capacity which is a major indicator of water quality (47). In the present study, DO level was within permissible limit (Table 5). In this study OM % was ranged (0.43-5.55 %) in dry season. While TOC % ranged from 0.27 % in dry season to 2.24 % in wet season. Estimation of TOC% in sediment and soil samples is an important parameter for assessment the quality of the environment. Organic matter (OM%) is present in soil land and aquatic sediment of environment. The presence of these compounds in the sediment leads to bind with ions of metals that lead to formation soluble or insoluble complexes. Thus, these complexes interact with minerals, which are present in the sediment to form particles that can be absorbed to other pollutants (27). Due to the proportionality between TOC content and organic matter which has affinity for trace anionic and nonionic surfactants contaminants, which should be conducted in the area to use TOC as an indicator of river pollution (28). The highest values was recorded for OM% in dry season (July 2017) and TOC% in wet season (March 2017) (Table 6).

Table 6. Chemical characteristics of Tigris River during the study period.

Parameters	Range		Mean	Standard Deviation	Standard values	
	Minimum	Maximum			Law 25/1967	CCME
Chemical properties (standard unit)						
pH	7.43	8.25	7.75	0.22	6-9.5	6.5-9
Nutrients (mg/l)						
NO_2	0.01	0.45	0.11	0.12	0.06	0.06
NO_3	0.64	8.97	4.18	2.82	15	13
PO_4	0.07	1.52	0.66	0.43	0.4	0.1
Organic						
BOD (mg/l)	0.53	3.67	1.5	0.79	>5	-
COD (mg/l)	3.75	88.25	36.73	34.9	>100	-
DO (mg/l)	4.63	11	6.18	2.06	<5	5.5-9
OM %	0.43	5.55	1.7	1.44	-	-
TOC %	0.27	2.24	0.88	0.56	-	-

-= not applicable or available.

2- Temporal variation

Figure 6 illustrates the Temporal CA was generated a dendrogram, in which grouping eight months into three clusters. Cluster I was begin from June to September 2017(dry season), cluster II included November 2017 whereas Cluster III included wet season (February 2017, March 2017, January 2018, February 2018 and December 2017) and dry season (April, October and May 2017). Through the monitoring months, the month from June to September 2017 have the highest pollution level than the rest months that have the lowest pollution level. Figure 7 shows the temporal variation of the chemical parameters, that demonstrated the high pollution level from June to September 2017, which are referred to the highest level of COD, BOD, nutrients (NO_2, NO_3) and OM%. This concluded that theses parameters were caused retrogradation water quality in these months.

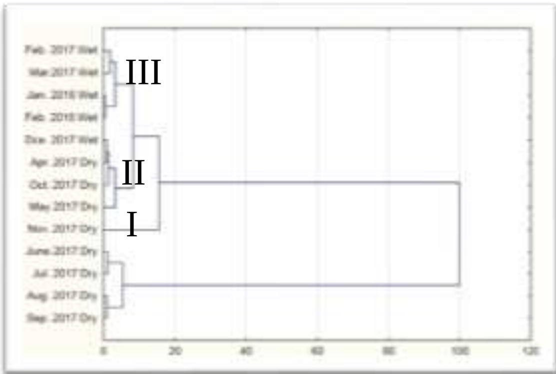

Figure 6. Dendrogram of temporal clustering of sampling period for all period study

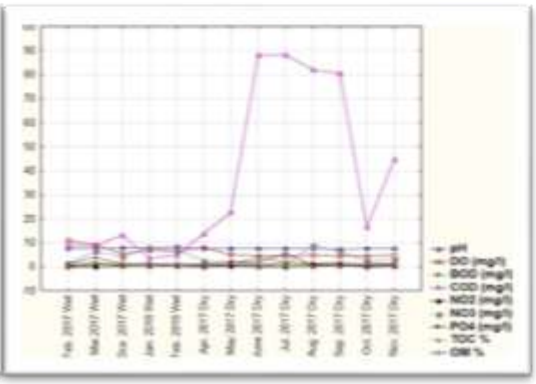

Figure 7. Temporal variation of chemical parameters of Tigris River during the study period

3- Spatial variation

Sampling sites was performed by the use of CA. Figure 8 illustrates the two clusters, in which the cluster I included sampling site S4 and the Cluster II included S1, S2 and S3. Among the sampling sites, S4 have the highest pollution level while S1, S2 and S3 have the lowest pollution level. These results are a good agreement with the variation in water quality parameters that measured in the sampling sites as shown in Figure 9. The S4 was recorded a highest value for COD, BOD, NO_2 and NO_3

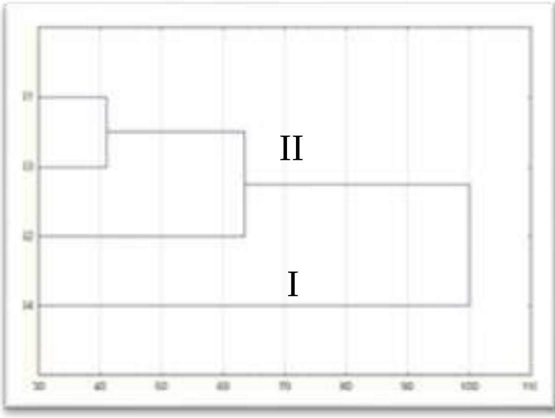

Figure 8. Dendrogram of spatial clustering of sampling sites for all period study

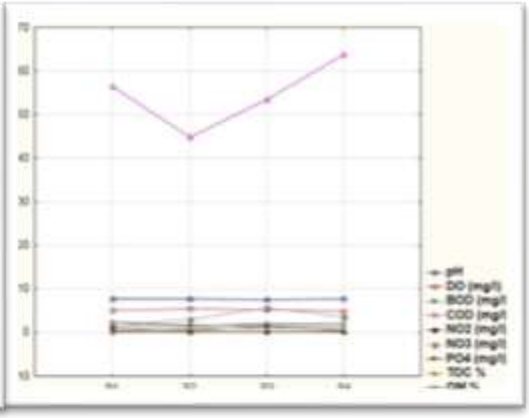

Figure 9. Spatial variation of chemical parameters of Tigris River during the study period

4- Person's correlation coefficient

A significant positive strong correlation (P<0.05) were observed between BOD-COD (r= 0.739) during the study period Table 7. In addition, a moderate positive significant correlation were observed for NO_2-NO_3 (r= 0.515) and TOC%-OM% (r= 0.697). While a moderate negative significant correlation was shown between pH-COD (r= -0.526), pH-PO_4 (r= -0.613), DO-BOD (r= -0.676) and DO-COD (r= -0.618).

Table 7. Person's correlation coefficient of chemical parameters in Tigris River during the study period

Parameters	pH	DO (mg/l)	BOD (mg/l)	COD mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)	TOC %	OM %
pH	**1.000**								
DO (mg/l)	**0.151**	**1.000**							
BOD(mg/l)	**-0.217**	**-0.676**	**1.000**						
COD(mg/l)	**-0.526**	**-0.618**	**0.739**	**1.000**					
NO_2 (mg/l)	**-0.120**	**-0.388**	**0.066**	**0.391**	**1.000**				
NO_3 (mg/l)	**0.310**	**-0.001**	**-0.360**	**-0.111**	**0.515**	**1.000**			
PO_4 (mg/l)	**-0.613**	**-0.174**	**0.042**	**0.475**	**0.286**	**0.380**	**1.000**		
TOC %	**-0.326**	**0.206**	**-0.041**	**-0.064**	**-0.448**	**-0.182**	**0.489**	**1.000**	
OM %	**-0.297**	**0.015**	**0.164**	**0.277**	**-0.440**	**-0.296**	**0.393**	**0.697**	**1.000**

r= >0.75 strong correlation, r= 0.75-0.5 moderate correlation, r= 0.5-0.3 weak correlation

5- Principal component analysis (PCA) and factor loading analysis (FA).

PCA results during the study period were generated two significant factors, in which the cumulative variance for them was 61.198% while the accumulative variance of the first component (Factor 1) was 33.649% (Table 8). A strong positive loading (P<0.05) for BOD (r= 0.730) and COD (r= 0.939). While a strong negative loading (P<0.05) for DO (r= -0.756). The total variance of the second component (Factor 2) was 27.548%. And a strong positive loading (P<0.05) of OM% (r= 0.833) and TOC% (r= 0.865). The reason of using PCA and FA are to extract the important information as a set of uncorrelated variables. Principle components, factors and eigenvectors or loadings are called variables. The importance of each component is expressed by the variance (eigenvalue) of its projection or by the proportion of the variance explained (39). From this study can conclude that: The cluster analysis and temporal variation can concluded the highest parameters that cause deterioration of water quality with similarity in high degree of EC, S‰, TSS, Tur., TDS, NO_2, PO_4, OM% and TOC%. From CA and spatial variation can conclude the sites that have highest pollution level during the wet and dry season are S2, S3 (midstream of Tigris River within Baghdad city, which refer to site of high human activities. Moreover, S4, which represent the downstream of Tigris River that found in this site, located near the Rasheed thermal power station as well as the vegetable oil plant where it was seen that the dump of liquid waste is thrown directly to the river. The Person's correlation was recorded strong positive and negative correlation between some of physicochemical parameters of Tigris River.=

Table 8. Factor loadings of chemical parameter of Tigris River during the study period

Parameters	Factor loading for all period study	
	Factor 1	Factor 2
pH	-0.606**	-0.434*
NO_2 (mg/l)	0.473*	-0.685**
NO_3 (mg/l)	-0.039*	-0.503**
PO_4 (mg/l)	0.582**	0.319*
BOD (mg/l)	0.730***	0.021*
COD (mg/l)	0.939***	0.016*
DO (mg/l)	-0.756***	0.286*
OM %	0.231*	0.833***
TOC %	0.020*	0.865***
Eigenvalue	3.028	2.479
Total variance,%	33.649	27.548
Cumulative variance,%	33.649	61.198

Significant factor loadings are boldfaced (*strong, >0.75; **moderate, 0.50–0.75; *weak, 0.50–0.30)**

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