

Monitoring Pollution of the Tigris River in Baghdad by Studying Physico-chemical Characteristics

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Abstract

The current study aimed at monitoring, exploring and identifying pollution levels in the Tigris River by studying seasonal variations of the physical and chemical characteristics of the river water in Baghdad. Monthly water samples were collected from four locations along the Tigris River in Baghdad for 12 months period. The studied characteristics of the current study included surface water temperature, pH, turbidity, salinity, electrical conductivity, total suspended solids, total dissolved solids, total hardness, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, phosphate, nitrate, and Sulphate. The results showed that the mean values of all the studied physical and chemical characteristics except pH, temperature, and phosphate were higher than the acceptable limits of the Iraqi river water guidelines and international standards. The current study concluded that the Tigris River water was heavily polluted from untreated sewage discharge and other industrial, agricultural, and domestic activities. The study recommended immediate measures to be taken to end the nonstop inflow of sewage and wastes into the Tigris River water from the residential, commercial, and institutional activities in Baghdad.

Keywords: Seasonal variations, physico-chemical characteristics, Tigris River in Baghdad

Introduction

Physical characteristics such as water temperature, turbidity, and total hardness of the river water can be good indicators for determining pollution. Similarly, chemical characteristics (electrical conductivity, pH, concentrations of K⁺, Na⁺, Cl, and NO³ etc.) represent key parameters in monitoring and identifying pollution in river water [1]. Microbiological contamination is also an important factor with regard to the treatment requirements and safe recycle of effluents of river waters [2].

Pollution levels in the Tigris River in Iraq are on the increase. The river pollution has a serious negative effect on humans, animals, and the way of life. Consequences of such pollution has led to the bioaccumulation of heavy metals in freshwater fishes, increase of heavy metals in river water high levels of heavy metals in river water sediments and increased river water turbidity rise in total salinity increased levels of total hardness (Dabdoob and Ibrahim, 2012), high concentrations of BOD and COD and contamination of river water with microbiological pathogens [3-12].

Most of the domestic and industrial wastes are discharged directly into the Tigris River in Baghdad without any sufficient waste management, which makes the Tigris River water severely polluted specially with organic substances. Quality of the Tigris river water in Baghdad was classified as “very poor” (Khudair, 2013). A more recent study classified the Tigris River as “fair quality” (Ibrahim, Abd Ali, and Hussein, 2018). With the upsurge of industrial activities and the increased anthropogenic processes due to the rise of population in Baghdad, the Tigris River would be more exposed to pollution with effluents and wastes. In the end, this would lead to a serious public health problem in addition to the severe consequences on the environment.

The Tigris River is the only source for potable water supplies, fish consumption and farming, agricultural water supply, and also used for navigation, recreation, and industries in Baghdad. Hence, and according to the recommendations of the World Health Organization it's very important to keep monitoring and evaluating the river water quality by conducting frequent ecological, biological, and physico-chemical assessments and examination of water supplies

[13]. This would involve monitoring at all times, from a public health perspective, over safety and sustainability of water supplies (Okorafor et al, 2012).

The aim of the current study was to monitor seasonal variations in the Tigris River water quality parameters to explore any cause of possible factors affecting river water quality, which could hurt the freshwater biome. Monitoring and evaluating physico-chemical characteristics in the river water will help identify the impact of pollutants on the water quality of the Tigris River. Consequently, a better intervention and solution by the relevant authorities would be taken to help mitigate the problem of Tigris River pollution in Iraq.

Materials and Methods

Study Area

Four sampling locations were selected for the current study. Al-Rashdiya area was the labeled as sampling station. This area is located northern of Baghdad and it marks the entrance of the Tigris River to the city of Baghdad. It is located at the following GPS coordinates (Latitude 33°25'42.0"N and Longitude 44°20'47.7"E). Bab Al-Muwadam labeled as sampling station 2 and it is located at the following GPS coordinates (Latitude 33°20'37" N and longitude 44°22'48" E) in central Baghdad and the third sampling location was the industrial area at Al-Zafaraniya labeled as sampling station 3 and it is located at the following GPS coordinates (latitude 33°17'22.7"N and Longitude 44°27'01.8"E) in the south of Baghdad. The last sampling station was the part of the Tigris River where it merges with the Diyala River southern Baghdad and it is located at the following GPS coordinates (Latitude 33°13'15.9"N and Longitude 44°30'20.9"E). Reasons for selecting those four locations come from the recent and previous official reports and academic studies showing the increase of pollution in these areas [14-16]. Station 2 and 3 were common locations for discharging domestic wastes, effluents from medical and industrial compounds located nearby in addition to the release of municipal wastes. While station 1 and 4 were selected as they represent upstream and downstream of sewage disposal sites. This way, the four selected sampling stations can provide better information and data about the river quality.

Collection of Samples

Surface water samples from the Tigris River were randomly collected from two different sites for each of the four selected sampling locations. Each sample was labeled with the date of collection and the site of sampling. Collection of the samples was done through wading the surface river water at both sampling stations.

The river water samples were collected in clean and sterile polyethylene bottles every month during the study period from December 2018 to November 2019. 24 water samples for each site were taken (96 samples in total). The samples were taken immediately after collection from the locations to the laboratory for analysis of physical-chemical parameters.

Physical and Chemical Characteristics

The temperature of the water was measured at the sampling locations with a handheld portable thermometer (The Waterproof Thermistor Thermometer - HI93510, U.S.A). A pH meter (HI98108 pHep, U.S.A) was used and it was measured on site. For electrical conductivity (EC), a handheld portable meter (Multi-range EC Meter- HI8733, U.S.A) was used and the test was conducted on site. The total dissolved solids (TDS) and salinity were both measured using a bench-top meter (edge® Multiparameter EC/TDS/Salinity Meter-HI2030-01, U.S.A) and the results of TDS and TSS were expressed in mg/L. The total hardness (TH) was measured using (Water & Wastewater Multiparameter (with COD) Photometer and pH meter-HI83399-01, U.S.A) and the results were expressed in mg/L. The dissolved oxygen (DO) was measured by a bench-top dissolve oxygen meter (HI2400-01, U.S.A) and the results were expressed in mg/L. Biochemical Oxygen Demand (BOD) was measured by Winkler's method and the results were expressed in mg/L. The Chemical Oxygen Demand (COD) was measured according to the APHA (2017) method and the results were expressed in mg/L. Nitrate, phosphate, and sulphate were analyzed by using a bench-top photometer (Multiparameter Benchtop Photometer and pH meter- HI83300-01, U.S.A). All procedures of collecting, preserving, and analyzing the above-mentioned different parameters of water samples were conducted according to the international standard sample collection, preservation, and analysis methods [17-19]. Statistical analysis was conducted using a Windows-based SPSS (version 23).

Results and Discussion

The results of physico-chemical analysis are presented in Table 1. The Tigris River water temperature varied among the 12 months period. But, the values of temperature degrees for the four sampling locations ranged between 11.1 and 30.7. The temperature of the ambient air influenced the variance in water temperature during the 12 months period. The mean values showed that they are within the acceptable range of water temperature of surface river water. Under natural conditions, the temperature of rivers' water varies between 0 °C and 30 °C [1].

Table 1: Mean values of physico-chemical characteristics of the Tigris River in Baghdad during a period of 12 months

Parameter	WHO Standards	Station 1 Min-Max	Station 2 Min-Max	Station 3 Min-Max	Station 4 Min-Max
Temperature (°C)	-	11.1-30.2	11.6-30.2	11.2-30.2	11.2-30.7
pH	6.5-8.5	7.1-8.2	7.1-8.2	7.1-8.2	7.2-8.2
EC (microsems)	1000	620-1210.5	589.2-1220	890-1289	934-1295
TH (mg/L)	<500	240.3-520.5	280.6-530.4	288.6-531.7	360.6-546.9
TDS (mg/L)	500	569-804	550.5-804	755-1219	855-1303
TSS (mg/L)	25	35.5-99.2	40.2-140.8	44.2-141.9	55.6-141.9
DO (mg/L)	4	6.8-8.5	6.9-8.5	6.9-8.5	6.9-8.6
BOD (mg/L)	<5	3.5-5.9	5.5-6.9	5.5-6.9	5.5-6.9
COD (mg/L)	20-200	71.3-562.4	70.8-620.5	99.4-612.9	70.1-502.6
Turbidity(mg/L)	<5	15.3- 30.4	17.5- 34.8	17.5- 35.6	17.5- 35.6
No ³ (mg/L)	≤ 10	3.6-11.3	3.2-11.3	6.9-11.4	8.7-11.9
SO ₄ ²⁻ (mg/L)	200	130.5-420	209.9-470.5	189.9-470.9	188.3-470.8
PO ₄ ³⁻ (mg/L)	5.5	0.12-0.55	0.13-0.55	0.8-0.98	0.41-0.99

pH is a key parameter to establish the suitability of river water for different purposes (Venkatesharaju et al, 2010). pH values ranged between 7.1 to 8.2 for the four stations. These values were also within the permissible WHO standards and these results were similar to previous studies confirming a slight alkalinity of the Tigris River water [20,7]. This alkalinity of the Tigris River surface water could be attributed to the increased disposal of domestic wastes into the river water at different sites along the Tigris river in Baghdad.

Electrical conductivity (EC) of river water represents a function of the concentration of ions in a solution, the nature of dissolved substance, and the temperature [21]. Results of the current study showed that the values of EC for sampling station 1 ranged between (620-1210.5 $\mu\text{S}/\text{cm}^{-1}$) and (589.2-1220 $\mu\text{S}/\text{cm}^{-1}$) for sampling station 2. While sampling station 3 had EC values ranging

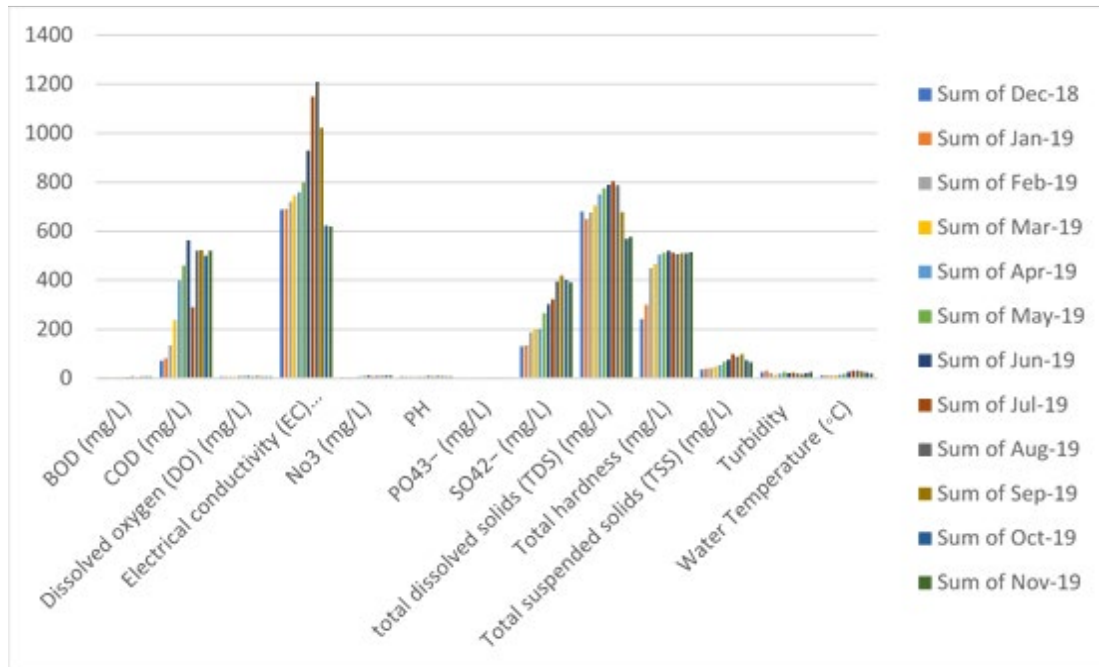
from (890) to (1289) and station 4 had EC values ranging between (934-1295 $\mu\text{S}/\text{cm}^{-1}$). Variance of EC values in the Tigris River is correlated with season and river water temperature. In winter, lower EC values were detected in all sampling stations. On the other hand, higher EC values were registered during summer and during high temperature season. The reason for the decrease of EC values in winter season is due to the increase of rainfall, which may cause the accumulation of ions in river water. Yearly precipitation in Baghdad ranges from 100 to 400 mm/year [22]. The increased values in summer could be caused by the increased agricultural, industrial, and other anthropogenic activities at the sampling stations. The results of the current study confirm results obtained by previous studies regarding the increased EC values in the Tigris River water in Baghdad [23,24]. But, the registered values of EC in the current study especially in the fourth station were higher than the results obtained by some more recent studies [25,26].

Table 2: Monthly values of physico-chemical characteristics of the Tigris River in sampling station

Parameters	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19
Water Temperature (°C)	11.4	11.1	11.5	14.3	14.8	17.3	24.8	30.1	30.2	26.4	22.6	19.2
PH	7.1	7.3	7.6	7	7.9	7.9	8.1	7.8	8.1	8.2	7.8	7.8
Electrical conductivity (EC) (microsems)	688	690	720	745	760	800	930	1150	1210.5	1022	624	620
Total hardness (mg/L)	240.3	300	450.6	466.6	504.6	512.5	520.5	512.2	505.6	509.3	510.6	514.9
total dissolved solids (TDS) (mg/L)	680.5	650.7	676	705	751	775	789	804	787	678	569	577
Total suspended solids (TSS) (mg/L)	35.5	38.5	42.8	46.9	53.7	67.8	76.2	97.3	88.4	99.2	74.9	65.4
Dissolved oxygen (DO) (mg/L)	6.8	7.1	7.3	7.5	8.2	8.2	8.5	8	8.1	7.9	6.9	7.2
BOD (mg/L)	3.5	4.6	4.4	4.5	4.8	5.1	5.4	5.8	5.3	5.8	5.9	5.9
COD (mg/L)	71.3	82.4	133.9	237.8	399.4	459.5	562.4	290.2	520.1	523.3	501.1	520.8
Turbidity	24.6	30.4	19.8	15.3	18.9	23.9	21.3	22.7	19.1	16.9	19.9	24.9

No3 (mg/L)	3.6	4.1	4.8	5.2	7.4	8.1	10.1	7.2	8.3	9.1	11.3	11.2
SO42- (mg/L)	130.5	133.6	185.9	199.8	201.1	266.5	301.2	322.4	394.9	420	401.1	389.9
PO43- (mg/L)	0.12	0.14	0.22	0.18	0.24	0.35	0.55	0.51	0.49	0.22	0.54	0.36

Fig. 1: seasonal variations of physicochemical characteristics at station 1



Turbidity generally indicates the quantity of non-dissolved materials and substances in water. Turbidity can be seen as a measure of water clarity and it's usually expressed in Nephelometric Turbidity Unit (NTU) [27]. Turbidity values for sampling station 1 ranged between (15.3- 30.4 NTU) and (17.5- 34.8 NTU) for sampling stations 2. Sampling station 3 and 4 had turbidity values between (17.5- 35.6 NTU). These values were significantly higher than the WHO permissible limits of turbidity in freshwaters (<5 NTU). The current results show increased levels of turbidity in the Tigris river water passing through Baghdad and turbidity values registered in this research are higher than the results obtained by previous studies, which indicated the noticeable increase in turbidity in the Tigris River water in Iraq [28,29]. Reasons for such increased turbidity values in the Tigris River could be attributed to the domestic sewage discharge, industrial wastewater discharge, and agricultural activities at the four sampling stations.

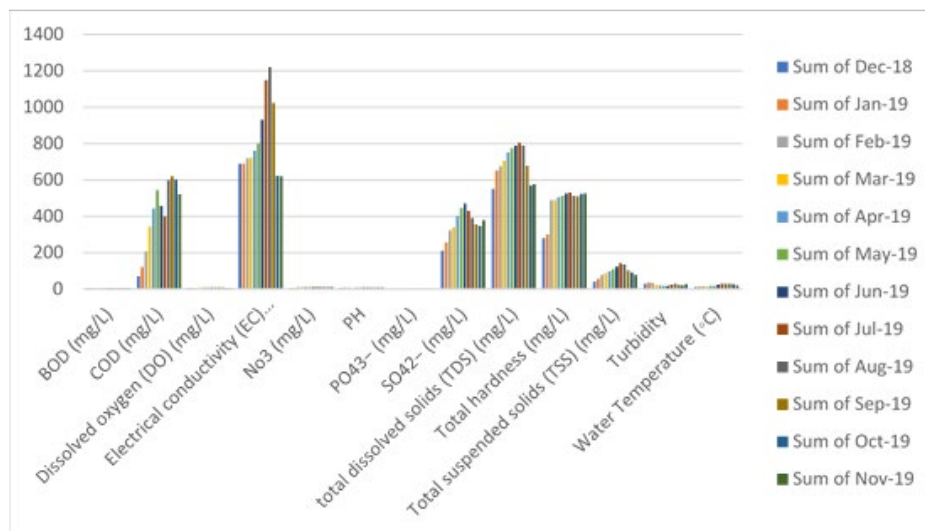
Water hardness is resulted from the presence of calcium (Ca) and magnesium (Mg) compounds, and by different other metals. Hard

water does not pose a danger to the public health, but economically it represents one of the most critical water quality parameters [27]. In fact, hard water helps teeth and bones grow; and lowers toxicity to lead poisoning from lead pipelines. On the other hand, soft waters are believed to be associated with cardiovascular diseases [30]. The total hardness values of the Tigris River in this study were high. Sampling station 1 showed values ranging between (240.3-520.5) and the values of the sampling station 2 were (280.6-530.4). Sampling station 3 and 4 had total hardness values ranging between (288.6 to 546.9). These values were higher than results obtained by previous studies [31]. The current study indicated that the Tigris River has hard water within the city of Baghdad. This result confirms other previous literature that showed the Tigris River was characterized with high total hardness [32, 33]. However, the current study showed higher results of water hardness than any other former study.

Table 3: Monthly values of physico-chemical characteristics of the Tigris River in sampling station

Parameters	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19
Water Temperature (°C)	11.6	12.2	14.7	15.4	18.5	18.9	24.9	30.2	30.2	29.6	25.2	20.3
PH	7.1	7.4	7.6	7.1	7.9	7.6	8	7.8	8.2	8	8.1	7.7
Electrical conductivity (EC) (microsemens)	689.2	690	720	721	760	800	930	1150	1220	1022	624	620
Total hardness (mg/L)	280.6	300.5	489.4	490.7	504.6	512.5	524.7	530.4	512.7	509.3	523.6	525.9
total dissolved solids (TDS) (mg/L)	550.5	650.7	676	705	751	775	789	804	787	678	569	577
Total suspended solids (TSS) (mg/L)	40.2	56.8	77.9	86.8	97.7	110	123.4	140.8	133.5	104	89.5	77.7
Dissolved oxygen (DO) (mg/L)	7.1	7.2	7.3	7.5	8.2	8.2	8.5	8	8.1	7.9	6.9	7.2
BOD (mg/L)	5.6	5.5	5.8	5.9	5.9	6.2	6.4	6.3	6.5	6.1	6.9	6.8
COD (mg/L)	70.8	120.7	206.3	343.6	443.7	544.6	455.8	399.8	598.9	620.5	601.2	520.8
Turbidity	29.6	35.6	34.8	22.1	19.8	18.9	17.5	23.6	27.9	22.7	19.9	25.6
No3 (mg/L)	3.2	6.9	8.9	10.2	11.3	11.1	11.2	11	10.8	10.9	11.1	10.9
SO42- (mg/L)	209.9	255.8	324.8	340.9	401.8	444.4	470.5	430.5	389.9	355.8	346.7	378.3
PO43- (mg/L)	0.13	0.15	0.22	0.18	0.24	0.35	0.53	0.55	0.49	0.22	0.54	0.37

Fig. 2: seasonal variations of physicochemical characteristics at station 2



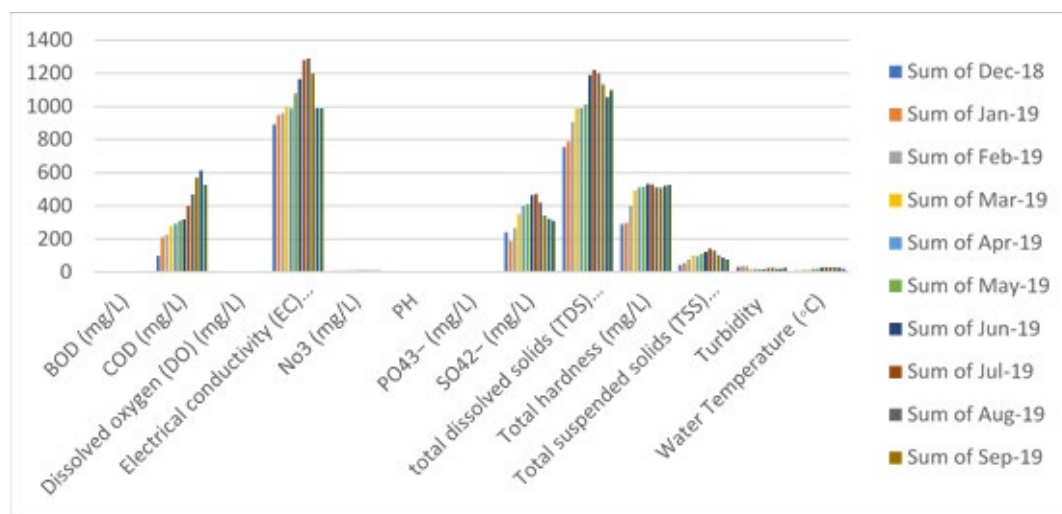
Values of total dissolved solids (TDS) for sampling station 1 ranged from 569 to 804 mg/L and for the second sampling station were (550.5-804 mg/L). While sampling station 3 and 4 had values ranging between (755 to 1303 mg/L). These values were within the WHO acceptable limits of total dissolved solids in river waters (1000 mg/L). However, the increased values could be attributed to higher concentrations of discharged effluents nearby the sampling stations since the four sampling locations are considered heavily populated and industrialized areas. These results are higher than the results obtained by some previous studies that indicated the Tigris River is characterized with increased values of TDS and that the river water is more saline in the central and southern areas of Iraq (Al-Shujairi, Sulaiman, and Najemaldin, 2015; Ali and Shaban, 2014). Moreover, high concentrations of

TDS are common in freshwaters in arid climates, as the case in Iraq, which is considered an arid region (Boyd, 2015). Al-Saady and Abdullah (2014) indicated that the registered increased TDS values along the Tigris river in Baghdad and the southern areas resulted from several factors such as: the agricultural lands along the Tigris river that are characterized with high salt content. In addition, there is a noticeable reduction in levels of the Tigris river water in Baghdad. Moreover, the high evaporation of river water that lead to increasing salt in river water. It's noteworthy that the increase of TDS downstream the Tigris River is resulted from the extensive agricultural activities in the area between Baghdad and Umara city. However, runoff and return flow from agricultural land that contain fertilizers can also lead to high TDS value (Saady and Abdullah, 2014).

Table 4: Monthly values of physico-chemical characteristics of the Tigris River in sampling station 3

Parameters	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19
Water Temperature (°C)	11.2	12.3	14.6	16.9	21.2	21.2	27.9	30.1	30.2	29.7	25.8	20.8
PH	7.3	7.1	7.6	7.2	7.9	7.6	8.1	8.2	8	7.9	8.1	7.8
Electrical conductivity (EC) (microsemens)	890	950	960	998	987	1079	1167	1280	1289	1199	990	988
Total hardness (mg/L)	288.6	300.5	399.4	490.9	509.6	514.5	531.7	530.4	512.7	509.3	523.6	525.9
total dissolved solids (TDS) (mg/L)	755	789	906	987	989	1013	1188	1219	1202	1133	1056	1098
Total suspended solids (TSS) (mg/L)	44.2	56.8	77.9	98.9	97.7	112.6	123.4	141.9	133.5	104	89.5	77.7
Dissolved oxygen (DO) (mg/L)	7.1	7.2	7.3	7.5	8.2	8.2	8.5	8	8.1	7.9	6.9	7.2
BOD (mg/L)	5.6	5.5	5.8	5.9	5.9	6.2	6.4	6.3	6.5	6.1	6.9	6.8
COD (mg/L)	99.4	210.5	225.8	277.9	292.5	310.2	321.2	398.7	469.9	569.7	612.9	527.9
Turbidity	32.7	35.6	34.8	22.1	19.8	18.9	17.5	23.6	27.9	22.7	19.9	25.6
No3 (mg/L)	6.9	9.4	10.2	11.2	11.4	10.3	9.5	10.5	9.9	9.8	10.8	10.6
SO42- (mg/L)	240.5	189.9	266.8	349.7	399.6	412.6	464.9	470.9	420.4	341.9	322.7	311.3
PO43- (mg/L)	0.45	0.48	0.66	0.88	0.8	0.98	0.91	0.83	0.79	0.92	0.81	0.9

Fig. 3: seasonal variations of physicochemical characteristics at station 3



Total suspended solids (TSS) represent a measure of the weight of relatively insoluble materials in the ambient water. Suspended solids can include both organic (detritus and biosolids) and inorganic (sand or finer colloids) constituents [30]. The WHO does not have a limit for TSS, but the European Union set (25 mg/L) as a limit for fisheries and aquatic life in rivers [1]. TSS values for the 1st sampling station ranged between (35.5-99.2 mg/L). TSS values for the 2nd station were (40.2-140.8 mg/L). While TSS values for the third and fourth sampling stations ranged between (44.2 to 141.9 mg/L). The current high TSS results shown in this study come in consistency with the ones obtained by [38, 39]. Though, the current study had much higher results than the previous studies.

Dissolved oxygen is a very important water characteristic. DO is necessary to preserve most forms of aquatic life and to allow the decomposition of organic matter, including organic wastes [40]. The current study showed the average value of dissolved oxygen (DO) in the Tigris river water was ranging from (6.8 mg/L to 6.8 mg/L) at all the four sampled stations. These values are acceptable according to the Iraqi and international standards where DO values must not be less than 4 mg/L. The current results agree with previous studies confirming that the dissolved oxygen levels in the Tigris River water are within the acceptable international standards [39,12].

Biochemical Oxygen Demand (BOD) is the amount of oxygen microorganisms use to decompose organic wastes that are present

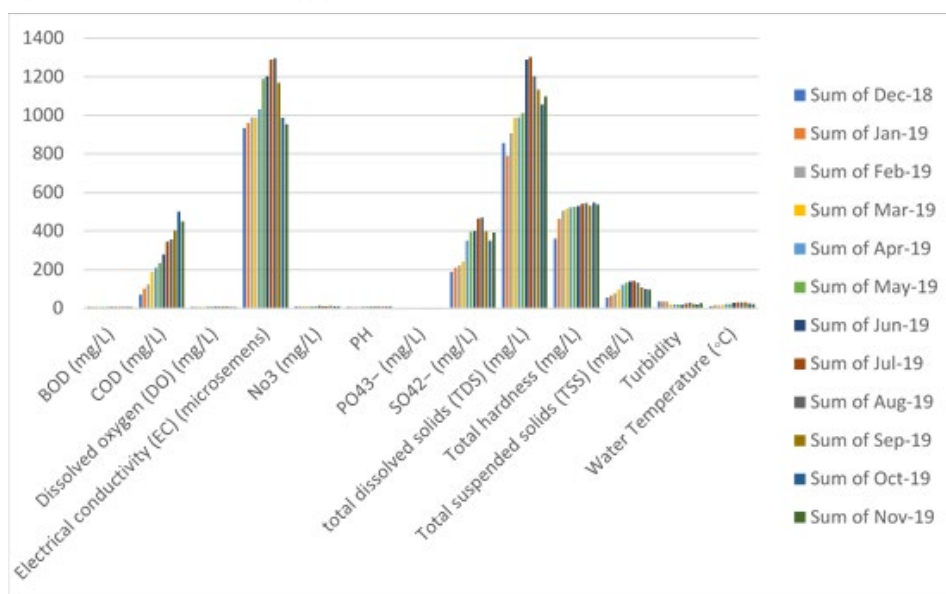
in water [41]. BOD is a very commonly used environmental test and considered as the most important marker of river water organic pollution [40]. BOD values ranged between (3.5-5.9 mg/L) at sampling station 1 and (5.5-6.9 mg/L) at the second sampling station. While sampling station 3 and 4 registered BOD values ranging between (5.5-6.9 mg/L). The increased BOD range detected at the four sampling stations exceeds the international standards for BOD levels in river waters (<5 mg/L). The current results are much higher than the ones obtained by indicating an increase in the BOD concentrations in the Tigris River water in Baghdad[42, 9]. High BOD concentrations in the Tigris River water indicate an increase in pollution caused by organic sources.

Chemical Oxygen Demand (COD) is the mass of oxygen needed for the complete oxidation of an organic compound present in water [43]. For this reason, COD is an important indicator of organic contamination in surface water. COD values for the 1st sampling station ranged between (71.3-562.4 mg/L) while the 2nd sampling station had values ranging from (70.8-620.5 mg/L). Sampling stations 3 and 4 had COD values ranging between (70.1 to 612.9 mg/L). These results show the Tigris river water is heavily polluted with organic matter coming from the sewage discharged directly into the river without any treatment. Previous studies had similar results showing an increase in the COD values of the Tigris River water in Baghdad [44, 45].

Table 5: Monthly values of physico-chemical characteristics of the Tigris River in sampling station

Parameters	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19
Water Temperature (°C)	11.2	14.4	14.9	17.4	21.9	21.2	27.8	30.7	30.4	29.9	23.7	20.5
PH	7.2	7.4	7.6	7.1	7.9	7.9	8.1	8.2	8.1	8.2	8.1	8.1
Electrical conductivity (EC) (microsemens)	934	960	988	990	1033	1190	1203	1290	1295	1168	987	955
Total hardness (mg/L)	360.6	463.9	505.4	514.5	523.4	525.9	528.2	539.8	544.4	533.7	546.9	539.3
total dissolved solids (TDS) (mg/L)	855	789	906	987	989	1013	1289	1303	1202	1133	1056	1098
Total suspended solids (TSS) (mg/L)	55.6	66.9	75.9	97.9	121.1	133.5	140.2	141.9	133.5	107.9	99.5	96.5
Dissolved oxygen (DO) (mg/L)	7.1	7.2	7.3	7.5	8.2	8.2	8.6	8	8.1	7.9	6.9	7.2
BOD (mg/L)	5.6	5.5	5.8	5.9	5.9	6.2	6.4	6.3	6.5	6.1	6.9	6.8
COD (mg/L)	70.1	102.4	123.5	188.5	208.6	234.7	278.9	344.4	356.5	402.3	502.6	450.4
Turbidity	35.7	35.6	34.8	22.1	19.8	18.9	17.5	23.6	27.9	22.7	19.9	25.6
No3 (mg/L)	8.7	10.2	10.3	10.6	9.9	10.9	11.9	11.7	11.3	11.9	11.2	10.9
SO42- (mg/L)	188.3	208.9	222.6	240.8	350.7	397.5	401.8	466.9	470.8	398.7	349.9	391.8
PO43- (mg/L)	0.41	0.55	0.45	0.65	0.56	0.51	0.76	0.84	0.99	0.91	0.98	0.92

Fig. 4: seasonal variations of physicochemical characteristics at station 4



Nitrogen is present in the river water in the form of nitrate (NO_3). Presence of Nitrate in the water indicates that the river is polluted with sewage. Nitrate in river water can be a serious public health danger to both human and animal infants. High concentrations of nitrate in drinking water can even cause death [46]. Agricultural activities are considered the main source of nitrate pollution [47]. Values of nitrate detected at the 1st sampling station ranged from (3.6-11.3 mg/L) and (3.2-11.3 mg/L) for the 2nd sampling station. Sampling station 3 had nitrate (NO_3) values ranging from (6.9-11.4 mg/L) and (8.7-11.9 mg/L) for sampling station 4. The high concentrations of nitrate in the four sampling locations are caused by the continuous wastes discharge, agricultural fertilizers, and domestic garbage dumps. Similar previous results obtained by indicated the presence of high nitrate levels in the Tigris River water in Baghdad [48, 49]. However, the current study showed higher nitrate (NO_3) values at the fourth sampling station. Previous studies did not register such higher values in that location. This shows that the sampling station 4 is being polluted heavily over the past few years.

There are two forms of sulfur (S) common in water and wastewater: sulfate (SO_4^{2-}) and hydrogen sulfide (H_2S). Sulphate (SO_4^{2-}) in high concentrations can cause a laxative effect and a bitter taste and is considered a nuisance in drinking water [27]. The 1st sampling station had mean values ranging from (130.5-420 mg/L) and the 2nd sampling station had values ranged from (209.9-470.5 mg/L). Sampling station 3 had values ranged from (189.9-470.9 mg/L) and (188.3-470.8 mg/L) for the fourth sampling station. Previous studies (Hashim, 2018) showed similar high Sulphate concentrations indicating that the Tigris River water in Baghdad had increased levels of Sulphate and that those concentrations had exceeded the permissible international limits for Sulphate in freshwaters [50].

Phosphate (PO_4^{3-}) is the ideal form of phosphorus (P) for plant growth. It is a major cause of excessive algae growth and degraded water quality especially in lakes [27]. Phosphate values at the four sampling stations ranged between (0.8-0.99 mg/L). The detected concentrations are within the acceptable WHO for phosphate in freshwaters.

Conclusion

Surface river water of the Tigris River seems to deteriorate starting from the north of Baghdad to the south of Iraq. The results of the current study concluded that the Tigris River water at the four sampling stations characterized with high level of TDS, TSS, TH, turbidity, BOD, COD, NO_3 , and SO_4^{2-} . Mean values of these parameters exceeded the WHO limits in river waters. The current research confirmed previous studies, which had similar results showing the increase of pollution in the Tigris River water. Sources of the Tigris River water pollution mainly come from the continuous industrial influents that are discharged into the river without prior treatment. This will lead to the deterioration of the Tigris River water quality and increased levels of pollution with different chemicals.

The current study indicated that the primary source of the Tigris River water pollution comes from sewage effluents that are directly discharged into the river water without proper treatment. Previous studies [51,52] showed the current waste management methods applied in Iraq need further investigation and review to better handle the increasing pollution levels coming from the sewage. The consequences of such pollution would include the Tigris River water quality impairment, drop in fish abundance, and will have a severe effect on water usage for recreation (swimming, wading, and boating), industrial, and domestic purposes. The increased municipal and agricultural wastes that are directly discharged into the Tigris River water without proper treatment remain a major environmental challenge and a public health threat to the Tigris River water. In general, the Tigris River water quality is poor and this result is consistent with the findings of previous studies confirming the deterioration of the Tigris River water quality in Iraq [53-60].

Recommendations:

Immediate measures are required to be taken to end the nonstop inflow of sewage and wastes into the Tigris River water from the residential, commercial, and institutional activities in Baghdad. It's very important to call for speeding up drafting local environmental legislations and laws in Iraq as soon as possible. Rehabilitating and renovating waste management methods adopted by the local authorities is a key step towards improving water quality in Iraq. Moreover, further detailed studies covering more sampling stations along the Tigris River in Iraq should be conducted so that we can better compare results. Finally, a nation-wide media campaign would be necessary to help educate officials and citizens about the public health, environmental, and economic dangers of the Tigris River pollution in Iraq.

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