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Evaluation of the Temporal and Spatial Variation of the Tigris River in Baghdad

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Abstract

The Tigris River is the primary source of water for human consumption in Iraq and is the ultimate sink for wastewater generated by activities. This research was conducted between November 2021 and September 2022 using 15 physio-chemical parameters (pH, air and water temperature, EC, salinity, DO, BOD, TH, Ca+, Mg+, SO4, TDS, TSS, turbidity, and Chloride), two heavy metal parameters (Cr, and Al), and biological pollutants to analyze temporal and spatial variation and the effects of pollutants sources on the water quality of the Tigris River from the north to the south of Baghdad city. The results show that some values of the tested parameters were higher than Iraqi and WHO standards for the water river, which call for attention to be paid to the load of pollutants entering the river to avoid risks and future problems. On the other hand, the results presented indicate that biological pollution has been diagnosed at the three southern stations (Shuhada'a Bridge, Al-Za'afarania, and Jisr Diyala) with all the types of bacteria in the four seasons, which indicates that increasing the fecal contamination in the middle and southern sampling stations is due to increasing the wastewater discharge into the river body.

Keywords: Tigris River, water pollutions, physio-chemical parameters, heavy metal parameter.

1. Introduction

Water availability in Iraq exhibits significant spatial and temporal variation. Undoubtedly, the rise in population and the expansion of economic activity are factors in the rising need for water for usage in a variety of ways. Iraq's water resources have been under a lot of stress in the last 20 years, especially when it comes to the amount of water available. This is because of a number of things, such as the building of dams on the Tigris and Euphrates in neighboring countries, changes in the climate around the world, a sharp drop in the amount of rain that falls each year in Iraq, and poor management of how water is used in Iraq [1].

The reach of the Tigris River in Baghdad is distinguished by low concentrations of some variables due to multiple site discharges of effluent. In addition, there is no plan in place to preserve the river's quality [2, 3]. Due to the country's instability and financial shortage, the method for monitoring Iraq's water quality is uncontrolled [4]. Consequently, assessing the water purity of streams and rivers is of paramount significance. The Tigris River deteriorated due to poor management of water resources [5]. The quality of river water fluctuates continuously and is influenced by a variety of variables, including human activity, climate, geology, etc. [6].

Due to the city of Baghdad's growing population, factories built along riverbanks, and reckless usage of water treatment facilities, pollution will affect the area at some point [7]. Many studies were conducted to evaluate the concentrations of pollutants, especially in the Tigris River. The research examined the impact of the city's water quality on the Tigris River's water quality in Baghdad between 2013 and 2014. Eleven physico-chemical parameters were analyzed and compared to CCME Standard Values for the preservation of aquatic life, along with the use of the CCME mathematical model that facilitates the expression of the result and provides a clear picture of the river's health. Findings indicated that the river is highly contaminated for aquatic life, with all stations in both the winter and summer seasons exhibiting unsatisfactory values, suggesting a lack of CCME standard values for aquatic life protection [8]. Another study was done by Abed et al., published in 2019, which discussed analyzing the Tigris River water quality monitoring data within the city of Baghdad for ten stations during the period from December 2016 to November 2017.

The researchers used multivariate statistical methods, including the basic ingredient (PC) test, discriminant analysis (DA), and multiple linear regression analysis (MLRA). Tur, TA, Ca+2, EC, and SO4-2 were the most significant of the study's twenty-five water quality parameters. The PCA found six major components that account for 78.12% of the variance generated by industrial, residential, municipal, and agricultural runoff pollution sources. The MLRA results indicated that BOD5, Na+1, T, DO, and PO4-3 are significant and accurate predictors of the COD value as an indication of organic and inorganic pollution. This study demonstrated the usefulness of multivariate statistical methods as a tool for river water management, control, and conservation [9]. From February 2017 to February 2018, this research assessed the water quality of the Tigris River in Baghdad, Iraq. Four locations were selected from the upreach, reach, and downreach sections of the Tigris River, and fourteen parameters were utilized to measure the river's pollution.

All parameter variations over both seasons (wet and dry) resulted in a decline in water quality, as measured by a greater degree of pollution at reach locations. This suggests that the Tigris River in the heart of Baghdad has become more polluted owing to human activities [10]. A study by Ahmed and Gubashi in 2021 analyzed the aquatic environment of the Tigris River inside the city of Baghdad using a weighted arithmetic model. Ten water quality measures were utilized, and statistical analysis, including correlation and regression, was employed to examine the data for five sample sites from August to December 2019. Except for the second station at Al-Muthna Bridge, the results indicated a low to unacceptable quality index in the Tigris River in Baghdad [11]. The present study attempts to assess the current status of the water quality in the Tigris River to determine the impact of pollutants on the ecological life system of the Tigris River in Baghdad, Iraq.

2. Materials and Methods

2.1. The Study Area

One of the longest rivers in the Middle East, the Tigris River, has a catchment area of 235,000 km2 and a length of about 1,900 km, passing through Iraqi land nearly 1415 km. The river shares this role with the Euphrates River as the primary source of water for human consumption, particularly for water supply since it passes through the main cities in the region [1]. The Tigris River flows through Syria, Iraq, and Turkey, beginning in the Toros Mountains in southeast

Turkey. Baghdad, the metropolis of Iraq, relies primarily on the Tigris River for its water provision. Numerous tributaries include the Botmanse, Kessora, A1-Khabur, Greater Zabs, Lesser Zabs, Al-Adhaim, and Diyala Rivers [10]. From the north to the south, the river splits the city of Baghdad into two sides: the right side (Al-Karkh) and the left side (Al-Risafa). The region has a dry, hot, and semi-arid environment with cold winters and an average annual precipitation of about (151.8 mm) [12]. More than eight million residents live in Baghdad, which is regarded as the most populous and developed metropolis in Iraq [13]. Most industrial and municipal waste is dumped into the stream without being properly treated [14].

2.2. Sampling and Analysis

Five locations have been selected for sampling on the reach of the Tigris River, namely: Balad (S1), Al-Ghrai'at (S2), Al-Shuhada'a Bridge (S3), Al-Za'franiya (S4), and Jisr Diyala (S5), as shown in Fig. 1. Data for five water quality monitor locations for the water quality parameters, which were collected by using polypropylene bottles at seasonal intervals from sampling locations between October 2021 and September 2022. For the analysis of several water quality parameters, sampling was used following the recommendation of standard methods [16].

Researchers have utilized the bottles to examine water quality parameters. We have used sampling bottles to collect water samples for BOD analysis in order to prevent unanticipated changes, and we have started analyzing the water samples as soon as possible after collection.

We collected samples of microorganisms in sterile, opaque glass containers. Within approximately 24 hours, the laboratory examined the bottles stored at +4 degrees Celsius. The Department of Water Resource Techniques' biological and chemical laboratory, the Institute of Technology-Baghdad Middle Technical University's, and the Department of Biology's central laboratory, the College of Sciences, University of Baghdad, have both conducted analyses of the collected samples.

The tested Physio-Chemical parameters have included water (pH), air and water temperature (AT) (WT), electrical conductivity (EC), Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), total hardness (TH), Calcium ion (Ca^+), Magnesium ion (Mg^+), sulphate (SO_4), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity (Turb.), and Chloride (Cl). Heavy Metals included Chromium (Cr) and Aluminum (Al) as well as the investigation of biological pollutants by diagnosing the types of bacteria that were found in the study area by using two types of Agars.

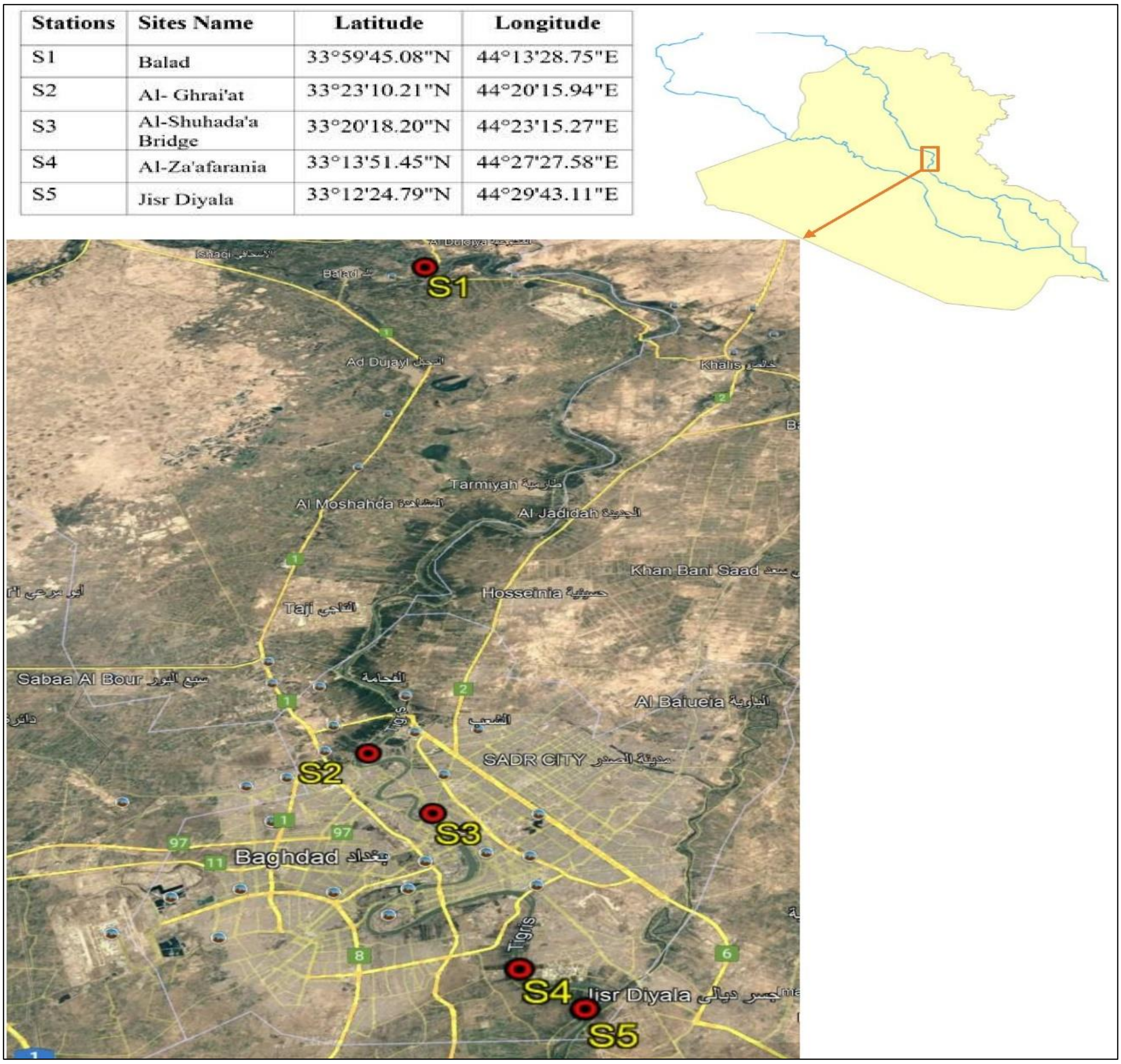
2.3. Statistical Analysis And Presenting Results

The IBM SPSS 25 software has been used to analyze the data that results from the field and laboratory analyses, and the figures presenting the results have been created using MS Excel 2016 by the Microsoft Company.

3. Results and Discussion

3.1. Physio-Chemical Parameters

The findings of the current study presented that the highest value of pH in autumn and winter 2022 was 8.85 at station 3, which was considered slightly alkaline, while the lowest value recorded in spring 2022 was 6.54 at station 2, which was acidic (**Figure 2-a**, **Table 1**).



Stations	Sites Name	Latitude	Longitude
S1	Balad	33°59'45.08"N	44°13'28.75"E
S2	Al- Ghrai'at	33°23'10.21"N	44°20'15.94"E
S3	Al-Shuhada'a Bridge	33°20'18.20"N	44°23'15.27"E
S4	Al-Za'afarania	33°13'51.45"N	44°27'27.58"E
S5	Jisr Diyala	33°12'24.79"N	44°29'43.11"E

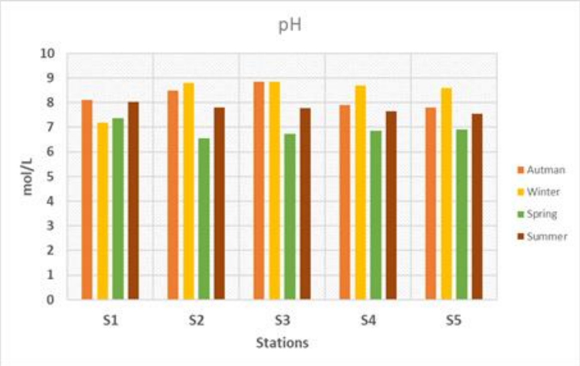
Figure 1. Map of study area and sampling locations [15]

According to the current research, high pH levels were found in the winter and autumn due to the growth of phytoplankton, which is reliant on the presence of carbon dioxide, sunshine, and nutrients. Like other plants, phytoplankton needs varied amounts of nutrients such as nitrate, phosphate, silicate, and calcium, depending on the species. In addition to water temperature and salinity, water depth, wind, and the sorts of herbivores grazing on them, other variables that affect phytoplankton development rates include wind speed and direction. The mean and minimum values of pH are within the Iraqi standard (2009) [20] and WHO guidelines for water quality (2011) [21], which ranged between 6.5 and 8.5 at all seasons, while the maximum pH was higher than the standards in the autumn and winter and below the standard maximum level in the spring and summer.

The results also showed that the minimum value of air temperature was 4 ^{o}C in winter 2022 at station 1, while the minimum value of water temperature was 12.6 ^{o}C in winter 2022 at stations 1 and 5. The maximum value of air temperature was 47 ^{o}C in the summer of 2022 at stations 2 and 3, while the maximum value of water temperature was 32.5 ^{o}C in the summer of 2022 at station 2 (**Figures 2-b and 2-c**, **Table 1**).

Table 1. Minimum and maximum (First Line), mean and standard deviation (Second Line), for physical and chemical characteristics in studied stations during 2021-2022.

Parameters \ Seasons	Autumn	Winter	Spring	Summer
pH	7.8 – 8.85 8.23 ± 0.44	7.2– 8.85 8.43± 0.69	6.54 – 7.38 6.88 ± 0.31	7.5 –8.04 7.76 ± 0.18
Water Temperature (^{o}C)	15.8 – 18.8 17.66 ± 1.17	12.6 – 13.3 12.78 ± 0.29	19 – 21.5 20.36 ± 1.20	30.3 – 32.5 31.16 ± 0.98
Air Temperature (^{o}C)	21– 23 22.2 ± 0.84	4– 7 6.2 ± 1.30	30 – 32 31.2 ± 0.83	44 – 47 46 ± 1.22
EC (μS/cm)	645– 1012 831.8± 159.59	520 – 955 804.2 ± 171.32	407 – 644 570.8 ± 94.03	474 – 976 815.2 ± 199.5
Turbidity (NTU)	8.24– 30.5 17.49±9.49	11.7 – 30.5 18.28 ±8.32	46.1 – 69.2 77.66 ±19.49	6.35 – 41.7 24.5 ±13.7
Total Hardness TH (mg/L)	280– 480 390±81.24	280 – 490 410 ±78.42	280 – 450 332 ±69.78	210 – 460 366 ± 98.64
DO (mg/L)	5.4– 8.5 7.1± 1.48	2 – 7.7 5.36 ±3.07	5.4– 7.8 6.9 ±1.04	3.9– 7.3 5.9 ± 1.37
BOD (mg/L)	1 – 4 2.2 ±1.3	1 –6 2.8 ±2.16	2 –5 3 ±1.22	2 –6 4 ± 1.58
Mg+ (mg/L)	16.8– 38.4 32.64± 8.92	16.8– 60 37.44±17.92	16.8 – 81.6 35.52±26.48	7.2–40.8 26.88±12.96
Ca+ (mg/L)	84 – 128 101.6± 22.38	76 – 136 101.6±29.74	44 – 88 73.6±19.31	72 – 116 101.6±18.46
SO4 (mg/L)	24.96 – 40.32 31.87± 6.45	24.96 – 44.16 37.24±7.38	13.44 – 30.72 22.27±6.87	15.36 – 65.28 34.94±19.5
TDS (mg/L)	234– 384 297.6± 63.90	170 – 348 274.6±66.94	137 – 228 186.2±34.08	155 – 338 277.2±71.83
TSS (mg/L)	200 –400 320± 109.54	200–600 360±167.33	200–1000 520±303.31	600 – 1000 760±167.33
Salinity (ppt)	0.41 – 0.65 0.53± 0.10	0.33 – 0.61 0.51±0.10	0.26 – 0.41 0.36±0.06	0.3 – 0.63 0.52±0.12
Chloride (mg/L)	280–540 376± 102.12	280 – 455 378±67.32	177 – 340 260.96±60.07	177 – 442.5 329.22±99.81
Cr (mg/L)	0.02 – 0.04 0.03± 0.007	0.02 – 0.04 0.02±0.007	0.02 – 0.04 0.03±0.006	0.02 – 0.03 0.02±0.005
Al (mg/L)	2.75 – 4.5 3.358 0.73	6.32 – 7.17 6.82±0.36	3.8 – 4.2 4.08±0.16	4.04– 6.05 4.88±0.91



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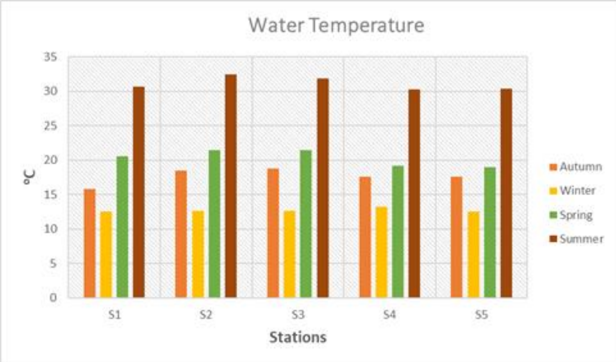

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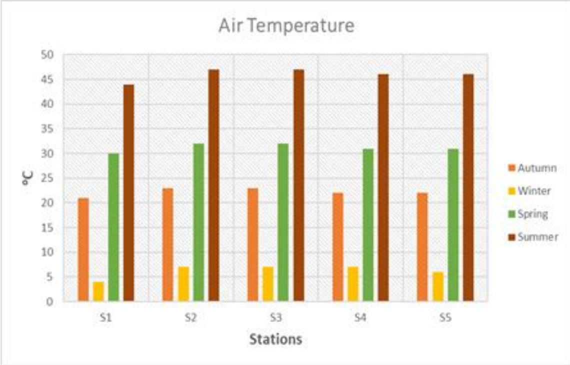
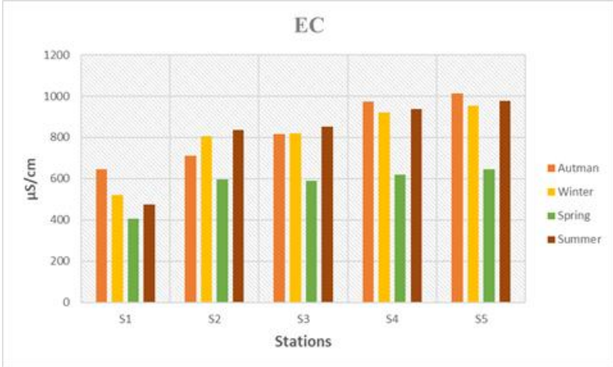
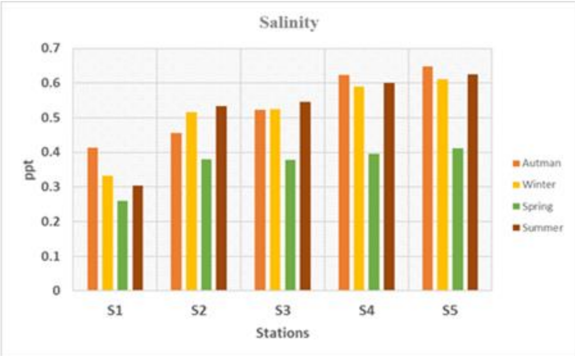

Air Temperature
°C
S1
S2
S3
S4
S5
Stations
Autumn
Winter
Spring
Summer

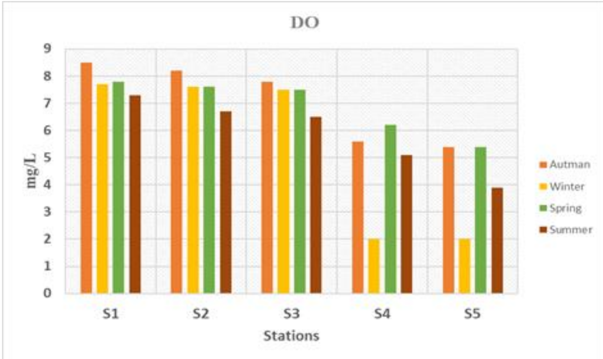
c


EC
µS/cm
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

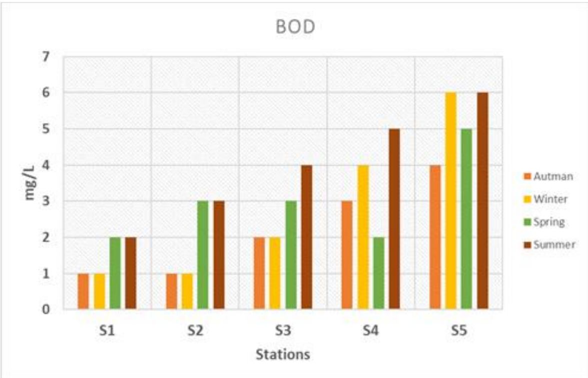
d


Salinity
ppt
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

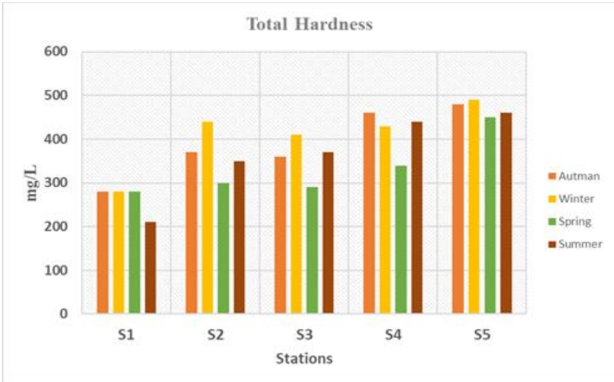
e


DO
mg/L
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

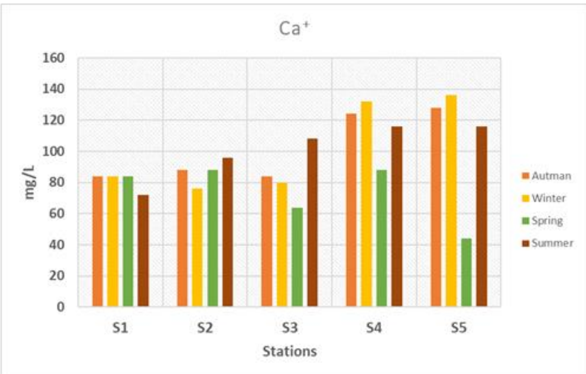
f


BOD
mg/L
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

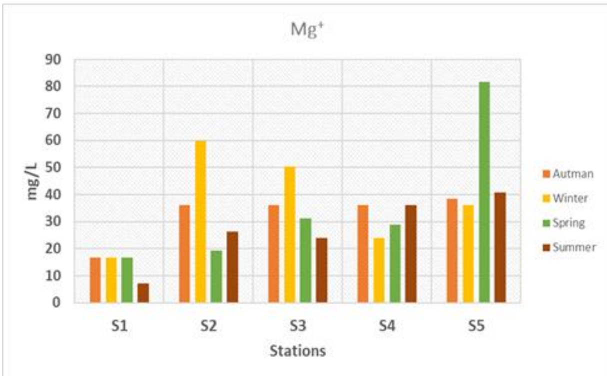
g


Total Hardness
mg/L
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

h


Ca+
mg/L
S1
S2
S3
S4
S5
Stations
Autman
Winter
Spring
Summer

i


Mg+
mg/L
S1
S2
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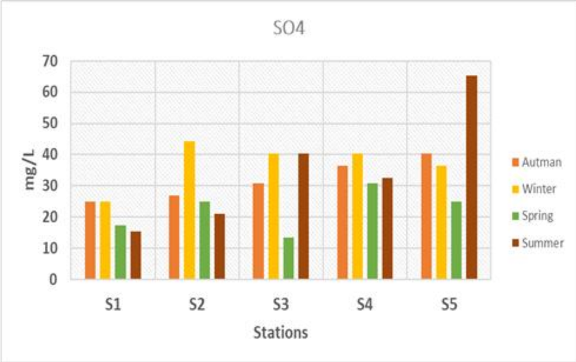
Stations
Autman
Winter
Spring
Summer

j



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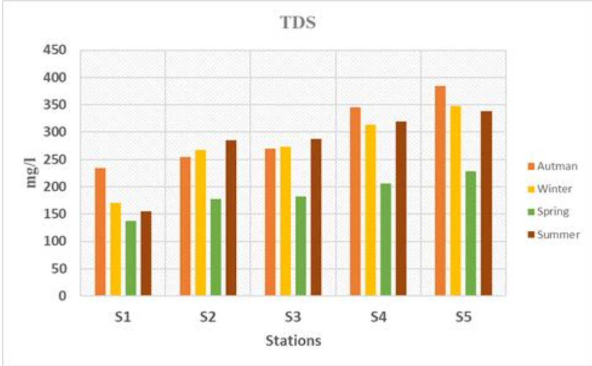

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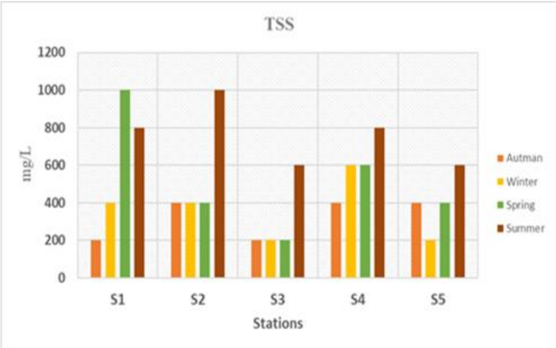

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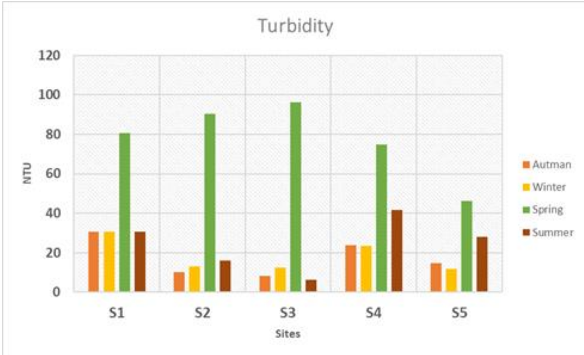

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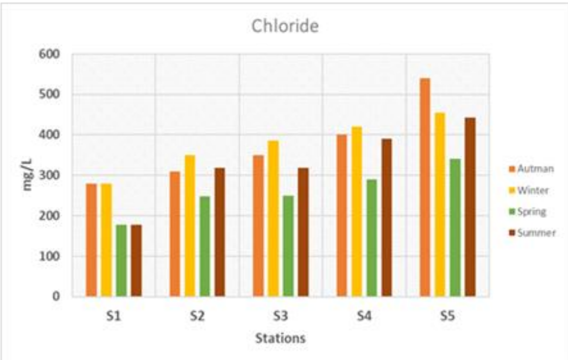

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Figure 2. Seasonal variation of physio-Chemical Parameters in Tigris River during Nov.2021-Sep.2022.

The measured values for air and water temperature in this study related to the time of measurement do not reflect the variation throughout the whole day; higher temperatures in dry seasons than in wet seasons could be due to longer photoperiods and higher sun light intensity, and it is obvious that water temperature is affected by the air temperature in the surrounding area [22].

The study results showed that the highest value of EC in the autumn at station five was 1012 µS/cm and the highest value of salinity in the winter at station one was 0.648 ppt., respectively. The lowest value of EC recorded at station one in spring was 407 µS/cm, while the lowest value of salinity was recorded at 0.261ppt (**Figure 2-d and e, Table 1**). The spring season had the lowest recorded EC and salinity readings, which may be attributable to the fact that the conductivity of water is affected by several factors, including the concentration of dissolved ions, the temperature of the water, and the presence of impurities or pollutants. Generally, the higher the concentration of ions, the greater the conductivity of the water. Additionally, as the temperature of water increases, its conductivity also tends to increase. Impurities and pollutants can also affect the conductivity of water, as they can introduce additional ions into the water. The recorded values of EC are below the maximum level that is limited by the Iraqi standard of water quality (2009) [20] and WHO Guideline (2011) [21].

The result showed that the highest value of DO was in the autumn, with a concentration of 8.5 mg/L at station one, while the lowest value was recorded in the winter, with a concentration of 2 mg/L at stations four and five (**Figure 2-f, Table 1**). The DO value is below the standards in winter due to the reduction the water level of the river [23] and the discharge of pollutants, which causes an increase in salt in the water. The salinity of the water also has an effect on the concentration of dissolved oxygen in the water; oxygen levels are low in extremely salty environments, and vice versa [18]. On the other hand, the non-agreed DO values that were recorded in the summer due to the high temperature in it and the amount of any gas, including oxygen, that is dissolved in water is inversely proportional to the temperature of the water. As the temperature of the water rises, the dissolved gas content in the water decreases [24].

On the other hand, the highest value of BOD recorded at station five was 6 mg/L in the winter and summer, whereas the lowest values measured in autumn and winter were 1 mg/L at stations one and two (**Figure 2-g, Table 1**). The results of the present study refer to high concentrations of BOD values in winter and summer that exceed permissible limits (5 mg/l) recommended by WHO (2011) [21] and Iraqi standards (2009) [20]. These factors likely contribute to the high concentrations of BOD values in winter and summer, exceeding the permissible limits (5 mg/l) recommended by WHO (2011)[21] and Iraqi standards (2009)[20]. Comparable results were obtained by other authors [25, 26].

The results showed that the highest value of total hardness was in winter 2021 at station 5, which was 490 mg/L, while the lowest was in summer 2022, when it was 2010 mg/L at station 1 (**Figure 2-h, Table 1**). Hardness is a natural property of water, and it has the potential to improve the water's flavor and the degree to which consumers would drink it for drinking reasons [27]. According to Chapman (1996) [28], seasonal changes in the hardness of river water are common, with the greatest values occurring during low flow circumstances and the lowest values occurring during floods. The findings of this study agree with those of Chapman's study. The TH values in this study are approximately near the allowable limits of Iraqi standards for drinking water No. 417 in 2009 [20] and WHO (2011) [21], whose maximum value was 500 mg/L.

The result showed that the highest value of calcium ion (Ca+) was recorded in winter 2022 with a concentration of 185 mg/L at station 5, while the lowest value was recorded in spring 2022 with a concentration of 44 mg/L at station 5 too (Figure1-i; Table 1). The results of the present study refer to high concentrations of Ca+ in all seasons that do not exceed the permissible limits recommended by the WHO (2011) [21], but more than the limitations of the Iraqi standards (2009) [20]. The lower levels of calcium ions in some seasons may be due to the consumption of this element by aquatic organisms for their biological activities, whereas calcium ion is considered the main component of the cell wall in aquatic plants [29].

The results of the study showed that the highest value of magnesium (Mg+) was found in autumn 2021 at station four with a value of 104 mg/L, while the lowest concentration of magnesium was found in autumn 2021 at station two with a value of 32 mg/L (Figure 2-j; Table 1). The results show that the value of Mg+ exceeds the permission limits of WHO (2011) [21], while some values in the winter and spring exceed the Iraq standard (2009) [20] due to the rainy seasons in Iraq [30] and that the rain pulls soil that contains Mg+ which is a relatively abundant element in the earth's crust and hence a common constituent of natural water. Water bodies associated with granite or siliceous sand may contain less than 5 mg of magnesium per liter [31].

The highest value of SO4 indicated at station five was 65.28 mg/L in summer, and the lowest one was 13.44 mg/L in spring at station 3 (**Figure 2-k, Table 1**). The finding shows the value of SO4 is below the permission limits of both the WHO and the Iraqi Standard in all seasons [20, 21]. The concentration of sulfate showed variation among the study months, and a higher concentration was recorded at some sites. This is possibly due to the geological nature of the area, which is common in gypsum [32], as well as the climatic conditions and erosion processes, in addition to the high concentration of SO4 in the sewage water, which discharges without treatment into the Tigris River [33].

The results showed that the highest value of TDS was found in winter 2021 at station five with a value of 384 mg/L, while the lowest concentration of TDS was found in spring 2022 at station one with a value of 137 mg/L (**Figure 2-l, Table 1**). The current study showed that the value of TDS is less than the permission limits of both the WHO (2011) and the Iraqi Standard (2009) in all seasons [20, 21]. The high value in winter may be due to the increase in rainfall, which increases the amount of dissolved salts. On the other hand, the results tend to show a decrease in TDS in spring, which may occur due to low rates of rainfall and soil erosion that is adjacent to the river [34]. Then the results return recorded high values toward the summer and autumn seasons, as may be due to the increasing number of dust storms and the increase in the rates of dry fallout into the resources of surface water [35], as well as the increase in salt concentrations, especially calcium and chloride salts, which increase TDS values [36].

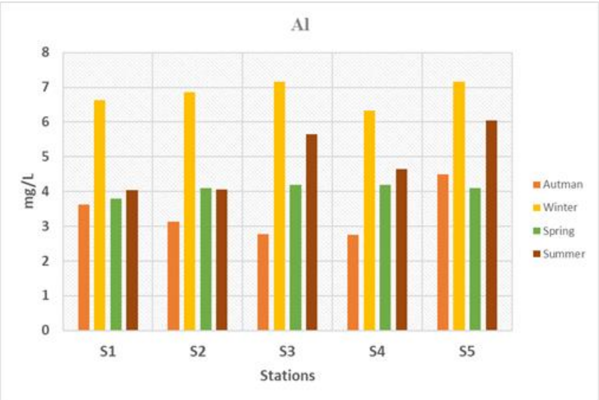
The results showed that the highest value of TSS was found at station one in the spring and at station two in the summer with a value of 1000 mg/L, while the lowest concentration of TSS was found at three stations (1, 3, and 5) with a value of 200 mg/L in different seasons, as shown in **Figure (2-m)** and **Table (1)**. According to the findings of this study, the TSS values exceed the permission limits of both the WHO Guideline and the Iraqi Standard for water quality in all seasons. Although the study of [37] got results over the standard limits, the current study had much higher results than the previous studies. USEPA in 2002 [38] classified water into three categories based on TSS, with readings below 20 mg/L being considered clean, between 20 and 80 mg/L being considered low turbidity water, and beyond 150 mg/L being considered turbid. As a result of the TSS levels measured, the water in the Tigris River is turbid, as will be shown in the turbidity results.

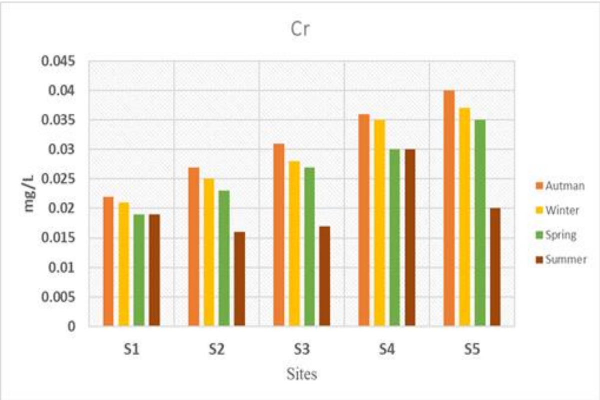
The results showed that the highest value of turbidity was in spring 2022 at station 3, which was 96.2 NTU, and the lowest was in summer 2022, when it was 6.35 NTU at the same station (**Figure 2-n, Table 1**). The results show that all turbidity values are higher than the limitations of the WHO (2011) [21] and the Iraqi standard (2009) [20] at all seasons and at all sampling stations. The highest values were found in the spring; this could be because of pollution from organic matter, other effluents, runoff with a lot of suspended matter, and heavy rain. The lower values that were measured in the summer can be explained by the fact that all the tributaries had dried up at that time. This meant that less suspended matter was coming into the river [39]. It can be noted that the high concentration of turbidity during the increase in water level [23] and rapid flow during the rainy period causes an increase in water suspended materials and mixing of water [40]. In addition, the continuous mixing of a river's water by wind action tends to stir up the bottom sediment and cause higher turbidity [41]. According to Welch (1952) [42], many organisms smother in prolonged conditions of very high turbidity by clogging the respiratory mechanisms.

The highest value of chloride indicated at station five was 540 mg/L in the autumn, and the lowest recorded value was 177 mg/L in the spring and summer at station one (**Figure 2-o, Table 1**). The results show that the chlorine concentration level exceeds the maximum permitted limits for both the WHO recommendation and the Iraqi standard for water quality (250 mg/L) in all seasons and increases from upstream to downstream, as agreed with the study of Chabuk et al. (2020) [43]. The source of the chloride might be either natural or anthropogenic. Anthropogenic sources of sodium and chloride include effluent from septic systems, agricultural chemicals, and municipal landfills. Natural sources include atmospheric deposition, interactions between soil or rock and water, and saltwater incursion. The concentration of sodium rises with an increase in salinity. High quantities of sodium are frequently seen in highly mineralized waterways. The amount of sodium and the EC are linked to the chloride concentration. Excessive levels of chloride may be poisonous to plants and damaging to pipelines [44].

3.2. Heavy Metals

The results showed that the highest value of Cr was found in the autumn of 2021 at station five with a value of 0.04 mg/L, while the lowest concentration of Cr was found in the summer of 2022 at station two with a value of 0.016 mg/L (**Figure 3-A, Table 1**). The current investigation demonstrated that in all seasons, the value of Cr is below the highest permissible limits set by both the WHO (2011) and the Iraqi Standard (2009) [20, 21].





a b

Figure 3. Seasonal Variation of Heavy Metals Parameters in Tigris River during Nov.2021-Sep.2022.

The highest concentration of Al was found at station three in the winter of 2021, with a value of 7.17 mg/L, while the lowest concentration of Al was found at station four in the autumn of 2021, with a value of 2.75 mg/L. (**Figure 3-b, Table 1**). The findings demonstrate that the Al concentration level consistently exceeds the highest permissible limits for both the WHO guideline and the Iraqi water quality standard (0.2 mg/L). Due to the fact that Aluminum (Al) is the third most abundant element, and the most abundant metal, in the Earth's crust, accounting for 8.8% of the crust's rocks, it is found in nature mixed with a wide range of other elements to generate a wide range of combinations [45]. It can be categorized into two groups based on where it comes from: naturally occurring sources and man-made sources. Natural sources of acid rain include minerals, the earth, the atmosphere, the water, and even some types of vegetation.

(e.g., tea) [46, 47]. Because of decreasing the river water discharge, the concentration of Al has increased more than usual amount, which has harmful impacts on the human and aquatic system health.

3.3. Biological Measurements

The tables below illustrate the distribution of seasonal variety for the total bacteria identified in the Tigris River's water in the research region, which was total plate count (T.P.C.), total coliform (T.C.), thermotolerant faecal coliform (F.C.), *Escherichia coli* (*E. coli*), and Faecal streptococcus (F.S.).The analysis results show that the first two stations (Balad and Al-Ghrai'at) have no biological pollution indicated at all four seasons and by using both Nutrient and MacConkey Agar cultural media. On the other hand, at the Al-Shuhada'a Bridge, Al-Za'afarania, and Jisr Diyala sampling stations, it has been revealed that bacteria have been found in the water at all seasons when the MacConkey Agar cultural medium has been used in the investigation, which is a significant indicator of the level of fecal pollution, primarily brought on by effluents from domestic and industrial wastewater treatment plants and medical waste from Medical City Hospital that discharge processed and untreated sewage into the river [48, 49] (**Tables 2, 3, 4, and 5**).

Table 2. The distribution of total bacteria identified in the Tigris River's water in autumn.

Agar	Biological N. Agar					Biological MacConkey Agar				
Bacteria types	T.P.C	T.C	F.C	E. coli	F.S.	T.P.C	T.C	F.C	E. coli	F.S.
S1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S3	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S4	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S5	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.

Table 3. The distribution of total bacteria identified in the Tigris River's water in winter.

Agar	Biological N. Agar					Biological MacConkey Agar				
Bacteria types	T.P.C	T.C	F.C	E. coli	F.S.	T.P.C	T.C	F.C	E. coli	F.S.
S1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S3	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S4	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S5	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.

Table 4. The distribution of total bacteria identified in the Tigris River's water in Spring.

Agar	Biological N. Agar					Biological MacConkey Agar				
Bacteria types	T.P.C	T.C	F.C	E. coli	F.S.	T.P.C	T.C	F.C	E. coli	F.S.
S1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S3	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S4	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.
S5	Neg.	Neg.	Neg.	Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.

Table 5. The distribution of total bacteria identified in the Tigris River's water in Spring.

Agar	Biological N. Agar					Biological MacConkey Agar				
Bacteria types	T.P.C	T.C	F.C	E. coli	F.S.	T.P.C	T.C	F.C	E. coli	F.S.
S1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
S3	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.
S4	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.
S5	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.

Furthermore, the three stations have indicated biological pollution in the summer when nutrient agar is used in the bacteria investigation. Due to the positive correlation between temperature and bacterial levels (**Table 5**), it is possible that heat-induced growth is a component of the elevated seasonal bacterial levels [50]. While, in the autumn, only Jisr Diyala station indicated biological pollution when the nutrient Agar cultural media was used in the diagnosis of the bacteria (**Table 3**).

4. Conclusion

The results revealed that the most examined water parameters were relatively higher than Iraqi and WHO standards for the water river. The result presented was that the water quality of the Tigris River dropped gradually when the river water flowed from the north to the south. The biological pollution was noticeable at the three southern stations in all seasons due to the discharge of domestic and industrial wastewater into the river.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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Ethical Clearance

Ethics of scientific research were carried out in accordance with the international conditions followed in dealing with laboratory animals and included animal health, husbandry and care for it, and providing appropriate conditions for it in terms of food, and appropriate methods were adopted in dealing with it when experimenting, and this is consistent with the instructions of the Iraqi Ministry of Health and Environment.

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