The Effect of Diyala Tributary on Ecological Factors of Tigris River

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Abstract
This study was conducted to investigate the effects of the Diyala Tributary on the physical – chemical factors of the Tigris River. A water sample was collected monthly from five sites. Site 1 was located on the Tigris River before joining the Diyala with Tigris River, site 2 was located on Diyala River, site 3 was located on the Tigris River after 500m from joining area of Tigris with Diyala River, Finally site 4&5 was located 3, 5 Km of site 3 respectively downstream Tigris River. The results of this study illustrated that the variations in the values of turbidity and the total suspended solids in the Tigris River and Diyala Tributary were not sharp, whereas there was clear effect of Diyala Tributary by raising the values of the electrical conductivity, salinity, TDS, BOD₅, total hardness, bicarbonate, sulphate of the Tigris River. Also there was an increase in the phosphate and nitrate concentrations with depletion of dissolved oxygen at site 2 which located on Diyala Tributary that affected on Tigris River significantly.

Keywords: Tigris River; Diyala Tributary; physical and chemical characteristics.

1. Introduction
Water covers a large area of the Earth's surface, accounting for about 71% of it, but the freshwater volume does not exceed 0.03% of this amount [1]. The internal freshwater of Iraq covers an area of 24000 Km² out of about 444,000 Km² Iraq's total area. Thus, Iraq is a country with rich in inland waters compared to neighboring countries [2]. However this surface water is most vulnerable to pollution since the wastewater is easily disposed in it [3]. Approximately 90 per cent of municipal wastewater is discharged into rivers and streams in most developed countries with partial ecological control that is not even acceptable for industrial activities causing poor water quality [4]. Among these water bodies most vulnerable to pollution by municipal wastewater is Diyala Tributary
Many of local studies dealing with physical and chemical characteristics of Tigris, Euphrates Rivers and their tributaries during their ecological study such as [5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16 and 17]. Diyala Tributary, is a major hydro-chemical tributary which affects in the water quality of the Tigris River system. So it is necessary to study the physical and chemical properties of the Tigris Rivers and Diyala Tributary to investigate the impact of Diyala on the Tigris River, especially after the war of 2003 due the current study is the first study after the war of 2003.

2. Material and Methods

2.1 Study area

Diyala Tributary is the most important eastern tributary of the Tigris River, the water source of Diyala Tributary comes from the the Zagros Mountains of western Iran [18]. The river is about 386 Km from its source, until it meets the Tigris River south of Baghdad, Al-Tuthah area [19]. It has an average slope of about 1-85 m/Km [18].

2.2 Sample collection

Monthly sampling was collected from January to December 2014 from five sites from a depth of 0.5 - 1 meter below the water surface, four of which sites was chosen o Tigris River to know the effect of the Diyala Tributary in physical and chemical properties of the Tigris River (Fig. 1), as follows: -

Site (1) located on the Tigris River before joining the Diyala Tributary (which represents the control site) in the Zaafaraniya City near the Animal and Fish Resources Center/ Directorate of Agricultural and Biological Research / Ministry of Science and Technology, before 2 Km from the joining point.

Site (2) located on the Diyala Tributary after sewage treatment plant, waste Rusafa (Rustumia) before 3 Km from its joining with the Tigris (near the old Diyala Bridge).

Site (3) located on the Tigris River, after its joining with Diyala, just 500 meters from the joining of two rivers which represents the mixing between the two rivers.

Finally, the two sites (4 and 5) are located down of the Tigris River, about 3 and 5 Km from the site (3), respectively.
2.3 Procedures

Water samples were collected for Physio-chemical analysis by using polyethylene bottle 5L capacity, which was washed by water sample twice before filling. The sample were collected under the surface water about 20-40 cm, then kept at 15°C in refrigerator. Physical and chemical parameters included:- Air and water temperature were measured by using a precise mercury thermometer. Dissolved oxygen and Biological oxygen demand were measured by using the modified Winkler method [20]. The percentage of saturation oxygen was calculated as reported in [21], electrical conductivity, salinity, pH, and Total Dissolved Solid in water by HANA (HI9811). The Total Suspended Solids were measured according to the method mentioned in APHA [22]. The turbidity was measured by the
turbidity meter Jenwaw company Model-6035. Total hardness, calcium and magnesium were measured according to Lind [23]. Sulphate used the method described by Brand and Tripke [24], the nutrients (Nitrate) and effective phosphate was measured according to the method measured as in APHA [20]. Finally, the Degremont method [25] was used to measure the bicarbonate in the water of the studied sites.

3. Results and Discussion

The seasonal variation of physical and chemical parameter (Table 1) shows that the water temperature demonstrated a slight change between the sites and it was closely correlated with air temperature (Fig. 2,3). Other researchers have reached the same conclusion [12;14 and16]

Table 1. Minimum and maximum (First Line), mean and standard deviation (Second Line), for physical and chemical characteristics at study sites.

| Parameter       | 1                | 2                | 3                | 4                | 5                |
|-----------------|------------------|------------------|------------------|------------------|------------------|
| Air Temp. °C    | 15.3-41.2        | 15.3-45.4        | 15.3-4.45        | 15.3-45.5        | 15.3-45.5        |
|                 | ±9.78            | ±0.43            | ±10.44           | ±10.44           | ±10.14           |
| Water Temp. °C  | 14.6-30.6        | 16-30.5          | 14.8-30.8        | 14.8-30.7        | 14.8-30.8        |
|                 | ±3.37            | ±0.58            | ±0.56            | ±0.56            | ±0.56            |
| Turbidity NTU   | 14.49-250        | 2.89             | 13.45-227        | 14.19-80         | 5.53 -232        |
|                 | ±13.24           | ±59.48           | ±56.51           | ±56.51           | ±56.51           |
| EC µS/cm        | 680- 1270        | 1800-            | 12-124           | 61.98            | 61.98            |
|                 | ±39.9            | ±11.13           | ±11.13           | ±11.13           | ±11.13           |
| Salinity ‰      | 0.43-0.81        | ±0.81            | 0.5-0.8          | 0.49-0.87        | 0.47-0.851       |
|                 | ±0.64            | ±0.23            | ±0.72 ±0.12      | ±0.71 ±0.12      | ±0.7 ±0.11       |
| pH              | 7-8.3            | 7-8.5            | 7.7-8.3          | 7.8-8.5          | 7.8-8.5          |
|                 | 7.75 ± 0.43      | 7.33 ± 0.49      | 7.71 ±0.53       | 7.66 ± 0.47      | 7.66 ± 0.47      |
| DO mg/ L        | 5.3-11           | 0.48             | 4.2-9.2          | 3.6-7.9          | 4.3-7.5          |
|                 | 7.56 ± 1.75      | 1.23             | 5.9 ± 1.54       | 5.39 ± 1.3       | 5.6 ± 1.13       |
|                 | ±0.42            | ±0.42            | ±0.42            | ±0.42            | ±0.42            |
| BOD₅ mg/ L      | 0.8-4.6          | 2.86 ± 1.2       | 1.3-7.6          | 0.9-6.4          | 0.3-6.6          |
|                 | 12-124           | 42.02 ±          | 4.26 ±39.9       | 3.47 ± 1.75      | 3.69 ± 2.01      |
| The percentage of oxygen | 71.14-75.55 | 46.25-93.3 | 44.4-8012 | 54.84-76.11 |
|                 | 109.23 85.98     | 67.37 ±          | 61.98 ±          | 63.88 ± 7.38     |
|                 | ± 11.68          | ±11.68           | ±11.68           | ±11.68           | ±11.68           |

The percentage of oxygen
| Parameter   | Site 1          | Site 2          | Site 3          | Site 4          | Site 5          |
|-------------|----------------|----------------|----------------|----------------|----------------|
| T.H mg/ L   | 150-520        | 210-844        | 200-580        | 120-576        | 195-748        |
|             | 297.83 ±       | 433.6          | 314.2 ±        | 288.4 ±        | 322.2 ±        |
| Ca\textsuperscript{2+} mg/ L | 80 – 200       | 112-245        | 60.12-170      | 52.104-        | 80.16-165      |
|             | ±34.72         | ±37.26         | ±30.5          | ±115 + ±32.05  | ±26.02         |
| Mg\textsuperscript{2+} mg/ L | 16.85-126      | 57- 100.7      | 38.87- 120     | 23.74- 115     | 21.27-130      |
|             | 69.83 ±38.6    | 78.86 ±        | 73.27          | 68.47          | 70.12          |
| SO\textsuperscript{4-} mg/ L | 70-260          | 80-400         | 120-400        | 90 – 300       | 60 – 200       |
|             | 118.33         | 164.16         | 186.66         | 135 ±56.8      | 127.5          |
|             | ±49.87         | ±89.69         | ±82.71         | ±115 + ±32.05  | ±35.19         |
| HCO\textsubscript{3}- mg/L | 110-166         | 200 – 290      | 130-170        | 120-170        | 120-168        |
|             | 141 ± 18.39    | 265.83 ±       | 147.58 ±       | 141.16 ±       | 142.25 ±       |
|             | 32.79          | 12.1           | 16.27          | 15.83          |                |
| TDS g/L     | 0.33-0.63      | 0.5-1.39       | 0.39-0.68      | 0.38 - 0.68    | 0.37 -0.66     |
|             | 0.5 ± 0.09     | 1.09           | 0.56 ±0.09     | 0.55 ±0.09     | 0.55 ±0.09     |
|             | ±0.25          |                |                |                |                |
| NO\textsubscript{3}- mg/L | 0.27-2.05      | 0.0049-        | 0.175-3.23     | 0.369-2.27     | 0.24 - 2.46    |
|             | 0.915 ±        | 5.25 1.68      | 1.22 ±0.79     | 1.066          | 1.088 ±0.63    |
|             | 0.516          | ± 1.77         | ±0.58          |                |                |
| PO\textsubscript{4}-mg/L | 0.008-0.283    | 0.311-         | 0.033-         | 0.041 -0.182   | 0.035 - 0.46   |
|             | 0.043 ± 0.07   | 0.982          | 0.261          | 0.07 ±0.03     | 0.12 ± 0.13    |
| TSS mg/L    | 0.0014–        | 0.0005 -       | 0.003-         | 0.0008-        | 0.0015-0.24    |
|             | 0.214 0.03 ±   | 0.048          | 0.197          | 0.051          | 0.041 ±0.06    |
|             | 0.05           | 0.021          | 0.018 ±        | 0.0186 ±       |                |
|             | ±0 014         | 0 016          | 0 016          |                |                |
The variations in the values of turbidity and the total suspended solid (TSS) in the Diyala Tributary were not sharp (Fig. 4,5), with a significant increase during December. Either in Tigris River, the variations were more severe, so were recorded the highest values 250, 227, 232 NTU and 0.214, 0.197, 0.24 mg/L during the beginning of the spring, especially on March at sites 1, 3 and 5 respectively. Current study agrees with previous studies that indicate the arises of turbidity in the Tigris River caused from the total suspended solid such as mud and silt that increase during high water discharge and rain periods, so higher values of turbidity were recorded in the Tigris River during these periods [26 and 27]. The turbidity values recorded in the Tigris River during the present study are more than that of the Diyala River; this may be due to the effect of the Tigris River by the turbid Al-Adeam Tributary [28].

USEPA[29] divided the water into three kinds based on the TSS, since the concentration below 20 mg / L was pure, the water with a TSS of 20-80 mg / L is low turbidity water, and the values above 150 mg / L are turbid, so the Tigris and Diyala Tributary water is pure according to reported TSS values.
Electrical conductivity, salinity and total dissolved solids (TDS) showed a positive relationship between them (Fig. 6,7,8). The highest rates of electrical conductivity, salinity and TDS were recorded on the Diyala River, while the lowest was in the Tigris River. The electrical conductivity, salinity and TDS of the Tigris River before joint Diyala Tributary with Tigris River was less than that at site 3 after the joint of the Diyala Tributary with Tigris River. It was noted that the seasonal variations of electrical conductivity, salinity and TDS in the Tigris and Diyala Rivers did not follow a same pattern during the study period. According to the EPA [30], the water of the Diyala Tributary was considered as brackish water, whereas on the Tigris River before joint of the Diyala Tributary with Tigris River was considered freshwater, furthermore the water of the Tigris River after joint it with Diyala Tributary was considered as brackish water. It was found that clear effect on the Diyala Tributary by raising the values of the electrical conductivity, salinity and TDS of the Tigris River.
The total dissolved solids values for both of Tigris River and Diyala Tributary were within the allowed limits of 1.5 g/L [31].

Figure 6. Variation of conductivity.

Figure 7. Variation of salinity.
The present study agreed with previous studies on week alkaline of Iraq water body (Fig. 9) due to the abundance of bicarbonate and carbonate ion [5; 6; … and 18]. The relatively high pH values during the autumn season may be due to the phytoplankton density during this season, thus increasing the efficiency of photosynthesis, which leads to the consumption of carbon dioxide and increased pH [32]. The recording of light pH values at the Diyala Tributary may be due to the degradation of the organic matter which observed at this site [33].

The dissolved oxygen and percentage of dissolved oxygen values in the Tigris were relatively high (Fig. 10, 11), they were not less than 5.3 mg/L in the waters of the Tigris River before the joint with Diyala Tributary, while the effect of the Diyala Tributary was clear in reducing the oxygen values in the Tigris River at sites which located after jointing it with Diyala Tributary reached to 3.6 mg/L in June at the site 4. On the other hand there was recorded a depletion of dissolved oxygen values of the Diyala River. The dissolved oxygen ranged from 0.7-2 mg/L with an average of 1.29 mg/L, this may be due to the oxidation and fermentation of the resulting materials from the decomposition of the
organic matter from the Rustmiya Water Treatment Plant [34]. As well as low pH values which was recorded at that time [35]. The concentration of dissolved oxygen in Diyala and Tigris Rivers was high in winter season. This may be related to increase in aeration because of rainfall, also decreased temperature during the winter causing an increase of the oxygen solubility [36].

The results of the biological oxygen Demand BOD \textsubscript{5} of the Diyala Tributary showed high values in the summer and autumn (Fig. 12), which caused the increase of the values of this factor in the sites of the Tigris River downstream after jointed with Diyala River. The real reason for the high values of the BOD \textsubscript{5} is the presence and degradation of organic matter as well as presence of large amounts of pollutants, which can lead to the lack of
dissolved oxygen, also the decay conditions which observed in the Diyala Tributary can cause low concentrations of oxygen compared to with the rest of the sites, when there was enough oxygen for organic decomposition, the carbon turns to carbon dioxide, phosphorus to phosphates and nitrogen to ammonia and nitrate, But when no enough oxygen, the carbon turn to methane, nitrogen compounds to amines (stench) [36]. Generally, results indicate that increasing levels of BOD5, especially at site 3 during the study period; this may be due to decomposition of organic matters that run directly to the river with domestic sewage to Diyala Tributary which flows into the Tigris River. Such finding was found by Nashaat. [37]; Marhoon et al. [38] and Abed and Nashaat [14].

Odum [39] divided the water into two types depending on BOD5 as BOD5 = 2 Clean, BOD5 = 5 or more are doubtful in its cleanliness, Thus, it can be noted that Tigris and Diyala River was doubtful in its cleanliness especially after joint Diyala with Tigris River .

![Figure 12. Variation of BOD5.](image)

The high values of the total hardness were recorded in the Diyala Tributary (210-792 mg/L) compared to the site upstream before the jointed with Diyala Tributary (150-120 mg / L) whereas at site 3 on Tigris River after jointed it with Diyala Tributary (Fig. 13), the total hardness was observed an increasing in value, with the rate reached to 273.5 mg/L, so according to the Kevin [40] calcification of water hardness the water of the Tigris River and Diyala Tributary was very hardness and the effect of Diyala hardness on the Tigris was similar to salinity as the values were high after jointed it with Diyala Tributary.
Figure 13. Variation of total hardness.

Our result denoted a clear increase in positive ions values in the Diyala Tributary compared with Tigris River (Fig. 14,15). In addition, it was found a clear impact on the Diyala Tributary at site 3 by increased a positive ion concentration, furthermore the current study found presence of calcium with higher concentrations than magnesium ion concentrations.

The results of this study show that the Tigris River and Diyala Tributary falls within the permissible limit of 150 mg / L for magnesium , while as only Tigris River falls within the permissible limit of 200 mg / L natural water for calcium [41].

Figure 14. Variation of calcium.
Bicarbonate ions were present at high concentrations in the Diyala Tributary compared to the Tigris River as well as with Sulphate ions (Fig. 16,17). Similar results were reported in other Iraqi studies [11 and 37]. As for Sulphate ion may come from the decomposition of the organic matter which effluent from sewage treatment plants or from the effects of farm waste or fertilizer that added to farms [42] The increase in sulphate value in winter season and decrease in summer season may be generally related with discharge of the domestic sewage and agricultural runoff, these ions can be produced by decompositions of organic matters or using chemical fertilizers [22].
It was found all nutrient shapes were with semi concentrations at site 1 during the study period, whereas showed a clear increase in these nutrients in the Diyala Tributary compared to the Tigris River with a clear effect of Diyala nutrients at site 3 (Fig. 18, 19). The presence of nitrates at high concentrations, especially in the summer may be due to increased organic oxidation and metabolic activities of organisms that release nutrients to the aquatic environment [43], while the increase in phosphate values in the Diyala Tributary may be due to the discharge of the wastewater from Al-Rustamiyah sewage treatment plant.

By reviewing the nitrate results, we find that it was below the usual permissible limits (15 mg/L) for Iraqi water standards [44].
4. **Conclusions:**

The results of this study concluded that there was clear effect of Diyala Tributary by raising the values of the all Tigris River water characteristics except turbidity and TSS characteristics. Also there was an increase in the phosphate and nitrate concentration with depletion of dissolved oxygen on water of Diyala Tributary that a significant effected on Tigris River.

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