Dissolved Oxygen Sag Curve for Diyala River at Baquba City

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Abstract. The water pollution is one of the major environmental problems that which suffered in rivers at Diyala governorate when the untreated waste or partially treated is disposed to rivers. In this study the effect of five sources of raw waste water distributed along Diyala River on the dissolved oxygen sag curve behavior was investigated for selected reach of river when passing Baquba city in Iraq. Dissolved oxygen sag curve tested by using Streeter and Phelps model during summer season Jun, 2018. The study results showed that there was an accumulative effect by decreasing in dissolved oxygen due to these five sources. The dissolved oxygen in the river being below 4 mg/L after the fifth source and continues for (99.4 Km) distance, this point located before river mouth with Tigris River by about 3.4 Km. Dissolved oxygen declined to its critical value after 45Km from first source with maximum deficit. According to the model calculation, Diyala River decants in Tigris River with low limit of dissolved oxygen by about 4.1 mg/L if there were no another sources downstream the observed sources and before achieving its self purification required distance. Also, biochemical oxygen demand was greater than 4 mg/L before river meeting the sources and increased gradually to be greater than 10 mg/L after the fifth source and the temperature increased by about 4 °C.

Keywords: Diyala River, Dissolved Oxygen D.O, Biochemical Oxygen Demand BOD$_5$, Streeter Phelps model, Dissolved Oxygen Deficit D.

1. Introduction
The rivers consider in the foreword of the important surface water sources and till impended by pollutions through disposing different types of untreated or partially treated wastes such as domestic, municipal, industrial, and agricultural waste with high organic content. These effluent changes the behavior of dissolved oxygen (D.O) and biochemical oxygen demand (BOD$_5$) with its adversely effect on the water life [1]. This change needs large time and distance to permit the river self purification to occur [2]. The high organics effluent represents by untreated wastes which discharges to rivers can cause apparent increase in the biochemical oxygen demand (BOD$_5$) levels. The exerted BOD$_5$ results in change of physical and chemical attribute which in the end affect the biological characteristics of water body [3]. Diyala River is the alone and simplest source of fresh water for multi life uses for all Diyala cities and the pollution of this source make large problems by causing deprivations for many uses of its water. Also, the high degree of pollution causes large deficit in D.O concentration which lead to minimizing fish wealth and many environmental problems. An assessment of pollution and investigation of chemical and physical characteristics of Diyala River water before Tigris River confluence were conducted. The results showed there were multi points of raw waste water disposed through bypass and outfalls of AL Rustimiyah waste water treatment plant and heavily pollution occurred at this reach of Diyala River [4].
Physical and chemical properties of Diyala River water were assessed at downstream of AL Rustimiyah waste water treatment plant by examination of multi Physical and chemical parameters. The study outcomes obvious there were exceeding of Iraqi conservation limits for rivers [5]. In this study the Streeter and Phelps model as reaction equations of D.O and BOD5 will use to give apparent effect of mixing effluent organics waste with Diyala River water at Baquba City in Iraq.

2. Methodology

2.1. Study Area
Diyala River is one of the major and important tributaries of Tigris River in Iraq and consider alone source of fresh water for different demands of domestic, municipal, industrial and agricultural for Diyala cities [6]. The river located between (44° 13’ 00” N- 44° 50’ 00” N) Latitude and (44° 30’ 00” E- 44° 5’ 00” E) Longitude. River path passing through many towns and cities [7]. The river length was about 445 Km and covers 32600 Km² area. There were two dams along the river to control floods and water storage and one regulator to divert and distribute the water for different canals according to irrigation and agricultural plans. Its discharges above 20 m³/s at winter months and (10-15) m³/s at summer months. The end of Diyala River confluence with Tigris River south of Baghdad [8]. The study reach of Diyala River was selected after the river entering Baquba city border by 5 Km when high population and city activities located.

2.2. Sampling Points
There were five sources observed scattered along the river stream for about 5.35 Km named (S1, S2, S3, S4 and S5) with apart by (890, 3235, 529 and 694) m respectively and distance from S5 to confluence point with Tigris River was 97.4 Km as shown in Figure 1. For the five sources, the samples were taken for the river and source before mixing. The discharge, biochemical oxygen demand and temperature were fixed at the site and BOD5 analyzed in the laboratory.

![Diyala River at Baquba City with five waste water sources.](image)

Figure 1. Diyala River at Baquba City with five waste water sources.

3. Results and Discussion
This study were conducted to investigate the effect of multi different waste sources on Diyala River D.O and BOD5 behaviors for selected reach inside Baquba city during Jun, 2018. The discharge of river was 10 m³/s with flow velocity 0.23 m/s, the values of D.O saturation level, K1 and K2 fixed as 9 mg/L, 0.1 d⁻¹ and 0.31 d⁻¹ respectively [9]. The results were two parts, the first tested and second calculated
by using Streeter and Phelps equations depending upon tests of river and source before mixing at each point as presented in Table 1.

### Table 1. Tested and calculated parameters of D.O sag curve

| Source | Point | Q (m³/s) | BOD₅ (mg/L) | D.O (mg/L) | T (°C) | Tₘ₅₉ (°C) | BOD₅₉₉₉ (mg/L) | D.O₉₉₉₉ (mg/L) | D.O₉₉₉₉ (mg/L) | BOD₅₉₉₉ (mg/L) | K₁ d¹ | K₂ d² | L₀ (mg/L) | D₀ (mg/L) | tₙ day | Dₙ (mg/L) | D.O₉₉₉₉ (mg/L) | Xₙ/km |
|--------|-------|----------|-------------|------------|--------|------------|----------------|----------------|----------------|----------------|--------|-------|---------|-----------|--------|----------|----------------|------|
| 1      | R 10  | 5.1      | 7.2         | 20         | 20.2   | 7.09       | 6.26           | 0.1            | 0.3            | 15.9           | 1.91   | 4      | 3.43    | 5.57      | 79.5   |
| S 0.238|       | 55       | 2.8         | 27.2       | 21     | 6.68       | 6.8            | 0.1            | 0.3            | 17.28          | 2.32   | 3.7    | 3.73    | 5.27      | 73.3   |
| 2      | R 10  | 6.6      | 6.7         | 21         | 21     | 6.68       | 6.8            | 0.1            | 0.3            | 17.28          | 2.32   | 3.7    | 3.73    | 5.27      | 73.3   |
| S 0.042|       | 59       | 2.66        | 27.7       | 22.3   | 6.06       | 7.42           | 0.1            | 0.4            | 17.53          | 2.94   | 2.9    | 3.99    | 5.01      | 58     |
| 3      | R 10  | 6.9      | 6.1         | 22.3       | 23.5   | 5.18       | 8.22           | 0.1            | 0.4            | 18.22          | 3.82   | 2.3    | 4.6     | 4.4       | 45.9   |
| S 0.11 |       | 55       | 2.5         | 27.5       | 23.5   | 5.18       | 8.22           | 0.1            | 0.4            | 18.22          | 3.82   | 2.3    | 4.6     | 4.4       | 45.9   |
| 4      | R 10  | 7.8      | 2.5         | 27.5       | 23.5   | 5.18       | 8.22           | 0.1            | 0.4            | 18.22          | 3.82   | 2.3    | 4.6     | 4.4       | 45.9   |
| S 0.069|       | 70       | 2.98        | 27         | 23.5   | 5.18       | 8.22           | 0.1            | 0.4            | 18.22          | 3.82   | 2.3    | 4.6     | 4.4       | 45.9   |
| 5      | R 10  | 10       | 3.74        | 24         | 24.1   | 3.68       | 10.84          | 0.1            | 0.4            | 24.03          | 5.32   | 2      | 6.108   | 2.892     | 40.3   |
| S 0.321|       | 37       | 1.77        | 26.5       | 24.1   | 3.68       | 10.84          | 0.1            | 0.4            | 24.03          | 5.32   | 2      | 6.108   | 2.892     | 40.3   |

Where: S=source, R=River, Q=discharge, BOD₅=5 days Biochemical oxygen demand, D.O=dissolved oxygen, T=Temperature, Tₘ₅₉=mixture temperature, D.O₉₉₉₉=dissolved oxygen concentration, BOD₅₉₉₉=mixture 5 days Biochemical oxygen demand, K₁=de-oxygenation coefficient, K₂=re-oxygenation coefficient, L₀=initial Biochemical oxygen demand, D₀=initial D.O deficit, tₙ=critical time, Dₙ=critical deficit, D.O₉₉₉₉=minimum D.O concentration, Xₙ=critical distance [9].

#### 3.1. Dissolved Oxygen

When D.O sag curve for each source analyzed separately, the D.O behavior for S₁, S₂, S₃, S₄ and S₅ being as presented in Figure 2. It is clearly shown that the initial deficit in D.O increased with sequence increasing of sources with minimizing initial D.O. Minimum D.O (critical deficit) occurred after S₅ with values less than 4 mg/L for about 4.9 days which confirms with the explanation of D.O curve development for [1] and [10]. Larger self purification time and distance occurred for S₅.

![Figure 2. D.O sag curves for five sources separately.](image_url)
Actually the effect of waste sources were accumulative, each source affected by the previous. Therefore, the total D.O sag curve along the river reach can be presented in Figure 3. It obvious that the initial deficit of D.O was the same of S1 curve in Figure 2. The declining in D.O concentrations at first four sources was agile because of the short time and distance between them (the effect of follow source come before the curve reach to minimum D.O). Large declining occurred in D.O values after S4 which was below 4 mg/L and continuous for 5days (99.4 Km) from S1. These low values of D.O continuous before Tigris River meeting by 3.4 Km. Minimum D.O after S5 was 2.89 mg/L at 2.3 day (45 Km) from S1. Diyala River water with 4.1 mg/L of D.O confluence Tigris River if hypothesizing there were no another pollution sources. The river self purification need more time and distance to achieved before Tigris meeting.

![Figure 3. Total D.O sag curve.](image)

3.2. Biochemical Oxygen Demand
Depending upon the tested and calculated values, BOD5 variation for river and the five sources after mixing presented in Figure 4. It is shown that the BOD5 for river was above 4 mg/L before S1 which exceed river limitations. BOD5 increased gradually to be greater than 10 mg/L after S5 which give apparent accumulative effect of organics from sources which give good agreement with [10].

![Figure 4. BOD5 variation for river and sources.](image)
3.3. Temperature
From tested and calculated values, temperature variation can be presented in Figure 5. The Figure clearly had shown the gradually increasing to reach above 24°C after S₅ due to biological activities which give impression of the waste effect on the river body and conforms to conclusions of [11] and [12].

![Figure 5. Temperature variation for river and sources.](image_url)

4. Conclusions and Recommendations
The results of this study analysis illustrated that there were previous pollution in Diyala River water caused decreasing in D.O concentration from the wonted level in most rivers and increasing in BOD₅ above 4 mg/L. there were initial deficit caused by S₁ to decrease D.O below the value before it. Large declining in D.O occurred through the first forth sources for about 4.7 Km. D.O continuous to declining below 4 mg/L after S₅ till reaching minimum D.O (maximum D) for about 45 Km, the river D.O concentration was below 4 mg/L for about 99.4 Km from S₁ (i.e before Tigris River confluence by 3.35 Km), river water D.O was 4.1 mg/L just before meeting point with Tigris River. The self purification after these sources was not achieved before confluence because of low discharges during study month with low velocity.

There were gradually increasing in BOD₅ for the first forth sources with high increasing at S₅ due to high BOD₅ of source. Also, gradually increasing occurred in river temperature due to the five sources to end by about 4°C.

Abbreviated recommendations can be presented to prevent or alter the above water pollution problems as treating or partially treating the waste water that’s effluent from these sources or others. Water haying to allowing a good stream flow. Another studies for river at downstream the passing cities and laying limitation to use this water for different demands.

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