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Analysis of Dissolved Oxygen Deficit in a Flowing Stream

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Abstract

The wastewater, domestic or industrial, is commonly disposed off in nearby water streams, rivers and sea. The wastewater, which has high biological oxygen demand (BOD) and chemical oxygen demand (COD) due to presence of organic matter, is also very lean in D.O. content. It is important to know the D.O. deficit and D.O. concentration at various distances to know the length of the flowing stream affected by the discharge and to know the measure of threat to the aquatic life. In the current investigation, the variation in dissolved oxygen content of a river stream is analyzed at various downstream distances from the point of discharge of wastewater. It takes almost 11 days and 100 km to regain initial dissolved oxygen. It can be concluded that the control of pollutants and organic matter needs to be taken care of more effectively. Almost 100 km distance downstream of the mixing point is affected due to discharge.

Keywords: *biological oxygen demand, oxygen deficit, critical deficit, critical time, saturation*

1. Introduction

The waste water can be characterized by various physical, chemical and biological characteristics. The oxygen demanding waste contains unsaturated hydrocarbons and waste materials. These materials and compounds consume oxygen present in water and thereby reduce dissolved oxygen (D.O.) of water. The wastewater, domestic or industrial is commonly disposed off in nearby water streams, rivers and sea. This wastewater, which has high biological oxygen demand (BOD) and chemical oxygen demand (COD), due to presence of organic matter, is also very lean in D.O. content. If disposed to the flowing stream like river, it causes drop in D.O. at the point discharge and it takes considerable time and distance for the stream to regain original D.O.. The difference between saturation D.O. and actual D.O. is D.O. deficit. The initial BOD at zero time is called as ultimate BOD. It is original concentration of organic matter in wastewater. The D.O. varies with downstream distance from the point of discharge of effluent into flowing stream. It is important to know the D.O. deficit and D.O. concentration at various distances to know the length of the flowing stream affected by the discharge. It is also envisaged to know the measure of threat to the aquatic life. Many investigations are reported on effect of D.O. variations on marine life. Also effect of various waste materials on D.O. content has also been important area of research. Various investigators have carried out investigations on dissolved oxygen of water and various factors affecting it.

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2. Literature Review

An investigation on dissolved oxygen in coastal region was carried out by Jack et.al.[1]. Representative samples from the surface water and underground water were analyzed by them. They observed that presence of plastic and solid waste affects dissolved oxygen and hence the ecosystem. An investigation on the factors like dissolved oxygen, temperature and evaporation on marine aquarium was carried out by Natraj et. al.[2]. According to this research, canister filter, lighting and pump operations caused 1.3 degree rise in the temperature. According to them, perforated lid can be used to minimize the rise in temperature. Gautam studied effect of pollution on the dissolved oxygen of water for Himalayan water [3]. The study indicated that the water was not suitable for bathing, washing and public supply. A review on models for dissolved oxygen and biochemical oxygen demand was carried out by Haidar et.al.[4]. According to them it is important to know the mechanism properly before finding solution to the problem. An investigation on effect of dissolved oxygen on poisons to rainbow trout was carried out by Lloyd [5]. According to him, there is possibility of close relation between toxicity and dissolved oxygen. He observed that effect of reduction in oxygen concentration was more predominant in ammonia solution. Mathematical model to relate absorbance with dissolved oxygen content was developed by Sharma et. al. [6].

MATLAB tool was used by them for correlating dissolved oxygen with absorbance. The values from model were in close agreement with values obtained by Winkler method. Kaur and Verma carried out investigation on river water of two rivers Ganga and Yamuna during Magh Mela [7]. They observed that the dissolved oxygen content was between 3.1 to 4.5 mg/l. They found that the water was not fit for drinking, washing and irrigation. Relationships of dissolved oxygen with chlorophyll and phytoplankton composition in aqueous system were studied by Kunlasak et.al. [8]. The effect of low DO on predation on estuarine fish larvae was investigated by Breitburg et.al. [9]. They observed that the low D.O. has strong potential to alter the absolute and relative importance of a suite of estuarine predators of fish larvae. Frieder et. al. studied base line concentration of dissolved oxygen [10]. They characterized DO and pH variability in the ecosystem over a year. Their investigation indicated that D.O. and pH were strongly correlated up to 7 m depth. In this region, the DO level was as high as 220 μmol kg^{-1}.

3. Materials and Method

The water samples were collected from nearby river at the point of discharge of effluent and at various downstream distances. The samples were analyzed for dissolved oxygen by using titration method. The BOD_5 values for the samples were determined by standard BOD test. Processes affecting dissolved oxygen (D.O.) content of water are reaeration, photosynthesis, respiration and oxidation of waste. Solubility of oxygen in fresh water at saturation decreases with an increase in temperature. The transfer rate can be expressed as the mass flux of oxygen across unit area of the surface in unit time, N

$$N= k_L (C_s – C_L) \quad (1)$$

where, k_L is liquid mass transfer coefficient. C_s, is D.O. at saturation, C_L is D.O. of the sample. The oxygen deficit for a flowing stream with ultimate biological oxygen demand Lu and initial D.O. deficit D_0 , forward rate constant(deoxygenation constant)) k_1 and reaeration constant k_2 is given by

$$D=\frac{k1\ Lu}{k2-k1}\,[e^{-k1t}-e^{-k2\ t}]+D_0\, e^{-k2\ t} \quad (2)$$

Critical deficit is given by

$$D_c=\frac{k1}{k2}\, L_u\, e^{-k1\ tc} \quad (3)$$

t_c is time required to reach critical deficit.

For the stream under consideration, Stream flow = 2 m^3/sec, BOD_5 = 5 mg/l.

For discharge effluent, Flow rate = 0.5 m^3/sec, BOD of discharge = 25 mg/l, D.O. of discharge = 4 mg/l

Average flow velocity = 0.1 m/sec

For the conditions in the experimentation, k_1 = 0.16 at 25 °C and k_2 = 0.39 at 25 °C. The D.O. of the mixed flow is calculated as

$$L = \frac{Qw.Lw+Qr\ Lr}{Qw+Qr} \quad (4)$$

Where Q_w and L_w are flow rate and BOD of waste stream, Q_r and L_r are flow rate and BOD of flowing stream(river).The ultimate BOD(L_u) of mixed flow is calculated as

$$L = L_u\,(1- 10^{-k1.t}) \quad (5)$$

4. Results and Discussion

For the flow under consideration, the BOD of mixed flow was calculated to be 8.2 mg/l and the ultimate BOD of mixed flow was calculated to be 9.74 mg/l. D.O. of the mixed flow was also calculated similarly. It was found to be 8 mg/l. The saturation D.O. at 25^0C is taken as 9 mg/l from literature. Time required to travel distance d is given by:

$$t = d/v, \quad (6)$$

v is velocity of flow, d is distance travelled. The distance-time relation is plotted in Fig.1.The variation in D.O. deficit with distance is plotted in Fig.2. The variation in D.O. deficit with time is plotted in fig.3. Calculated and measured D.O. deficit values at various distances are tabulated in Table 1. Calculated and measured D.O. deficit at various times are tabulated in Table 2.Variation of D.O. with distance is shown in Fig.4. Fig. 5 depicts variation of D.O. with time. In Table 3, measured and calculated D.O. values at various distances are tabulated. In table 4 calculated and measured values of D.O. at various times are tabulated.

It can be seen from the observations that D.O. of the river flow follows a typical oxygen deficit curve with characteristics such as critical time, critical deficit and saturation. The theoretical and experimental curves for D.O. deficit were very similar. The actual D.O. at various times was less than the theoretical values because of change in various factors such as surface phenomenon, little change in climate, temperature and may be addition of inland sources and contaminants in water stream. It is not possible to take into account these entire minor factors which are not consistent in their behavior.

Table 1: Calculated and measured D.O. deficit at various distances

Distance, km	Calculated D.O. deficit, mg/l	Measured D.O. deficit, mg/l
0	1	1
10	2.34	3
20	2.16	2.5
30	1.639	2
40	1.15	1.25
50	0.775	1
60	0.5163	0.45
70	0.34	0.28
80	0.2266	0.2
90	0.148	0.12
100	0.097	0.1

Table 2: Calculated and measured D.O. deficit at times

Time, days	Calculated D.O. deficit, mg/l	Measured D.O. deficit, mg/l
0	1	1
1.15	2.34	3
2.3	2.16	2.5
3.45	1.639	2
4.6	1.15	1.25
5.75	0.775	1
6.9	0.5163	0.45
8.05	0.34	0.28
9.2	0.2266	0.2
10.3	0.148	0.12
11.5	0.097	0.1

Table 3: Calculated and measured D.O. at various distances

Distance, km	Calculated D.O. mg/l	Measured D.O. mg/l
0	8	8
10	6.66	6
20	6.84	6.5
30	7.361	7
40	7.85	7.75
50	8.225	8
60	8.4837	8.55
70	8.66	8.72
80	8.7734	8.8
90	8.852	8.88
100	8.903	8.9

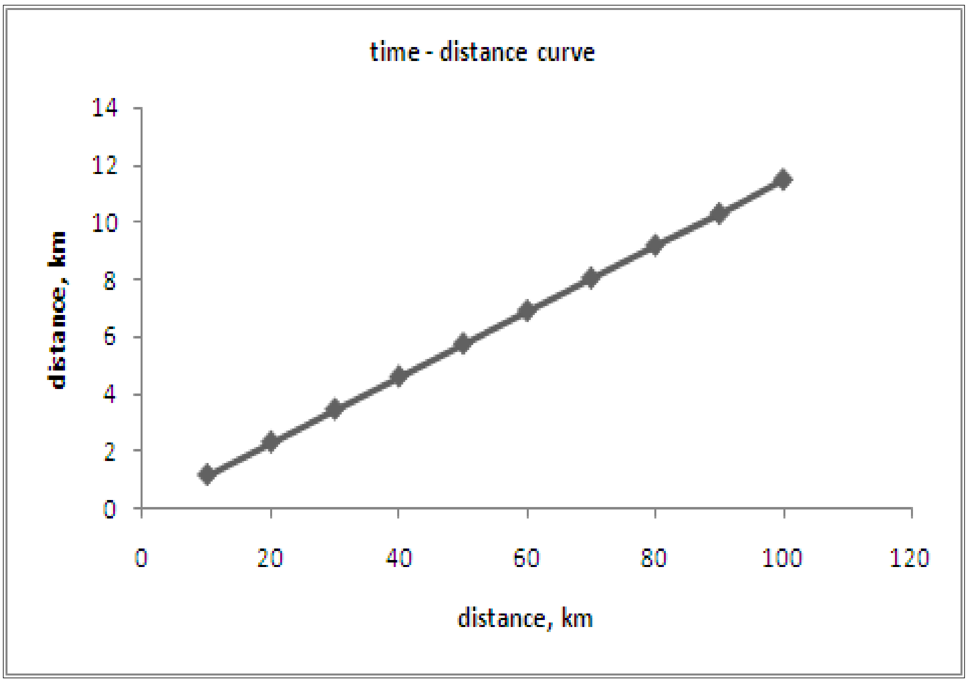

Fig. 1: Time-distance relation

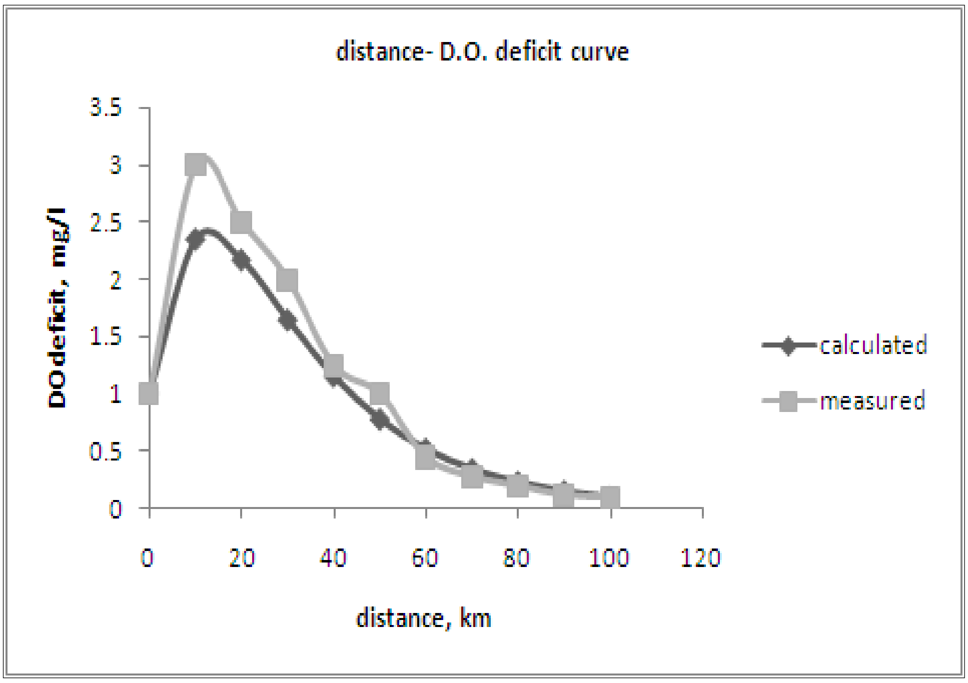

Fig. 2: Distance-D.O. deficit curve

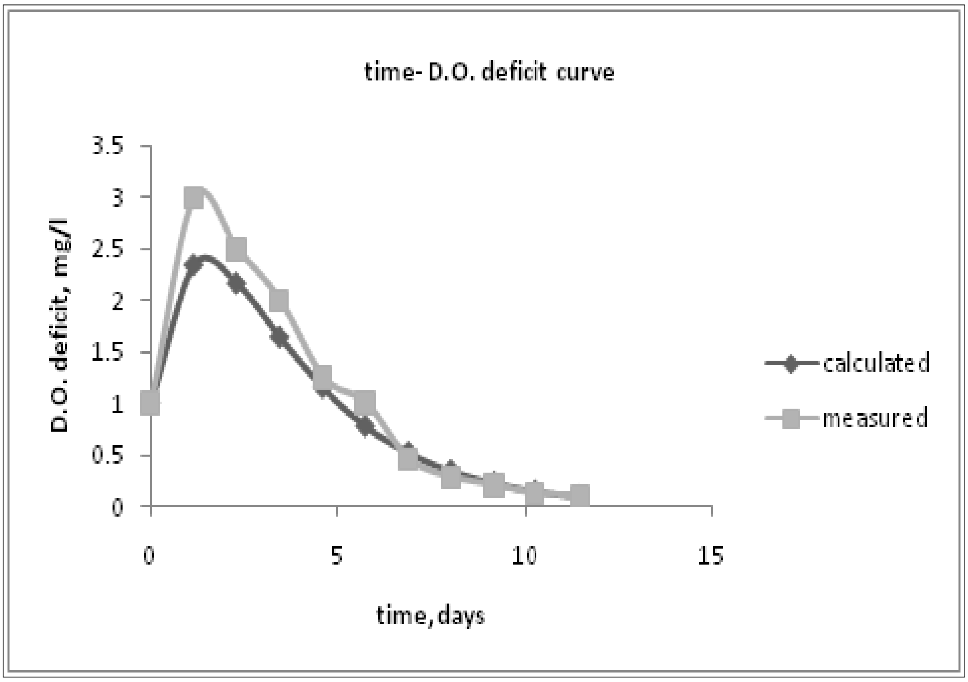

Fig. 3: Time-D.O. deficit curve

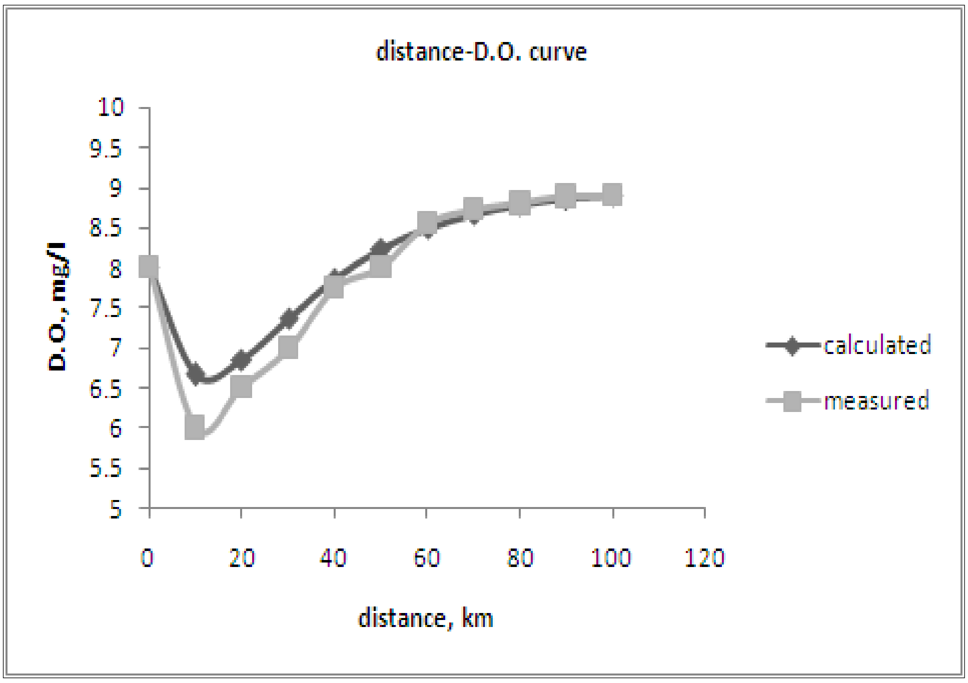

Fig.4: distance-D.O. curve

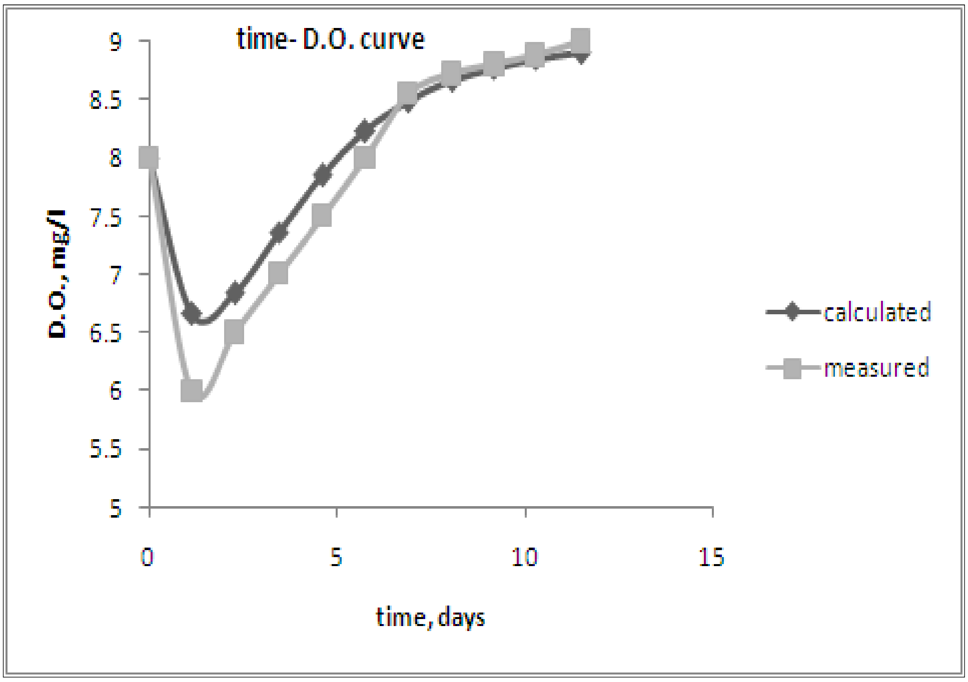

Fig. 5: time-D.O. curve

Table 4: Calculated and measured D.O. at various times

Time, days	Calculated D.O. mg/l	Measured D.O. mg/l
0	8	8
1.15	6.66	6
2.3	6.84	6.5
3.45	7.361	7
4.6	7.85	7.5
5.75	8.225	8
6.9	8.4837	8.55
8.05	8.66	8.72
9.2	8.77	8.8
10.3	8.85	8.88
11.5	8.9	9

5. Conclusion

It can be observed that the dissolved oxygen concentration in the river water drops drastically on addition of wastewater stream. Simple material balance equations can be used to estimated deficit and D.O. at the mixing points. It takes almost 11 days and 100 kms to regain initial dissolved oxygen of oxygen. It can be concluded that the control of pollutants and organic matter needs to be taken care of more effectively. Almost 100 km distance downstream of the mixing point is affected due to discharge. First 5 to 6 km distance has become unsuitable for aquatic life as D.O. has dropped to 5.5 mg/l.

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