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CRITICAL OXYGEN DEFICIENCY- A MEASURE OF RIVER WATER QUALITY

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ABSTRACT

Release of utilized waters to the water bodies falls apart the amount and nature of the streams which causes significant irregular characteristics in the ecosystems. Although river has the ability to self-purification, in some cases contamination is done quickly and to a much higher degree that exceeds the capacity of river to recover. Through this paper it is intended to study how the critical oxygen demand is related with the initial organic load at the time of discharge. The study was done in Periyar River for the period from 2011 to 2013. Monthly samplings were taken and analysis was completed for the parameters like temperature, Dissolved Oxygen and Biochemical Oxygen Demand. Optional information for these parameters were acquired through approved Organisations for the period from 2004 to 2010. The river condition in general can be ascertained through the critical oxygen demand evaluated. The Classic Streeter Phelps Equation is the best effortlessly accessible system for stream examination in the wake of considering its suppositions and confinements. The study reveals the initial discharges and its possible locations. It confers the level of critical deficiency of oxygen and the possible critical distance of the stream. The study discloses the relationship between critical oxygen deficiency and the initial organic load disposed into the stream.

***Keywords*: Surface Water, Dissolved Oxygen, Critical Dissolved Oxygen, Critical Oxygen Deficiency, Streeter Philips Equation**

I. INTRODUCTION

1.1 River as Surface Source for Drinking Water Supply Schemes

A river is a natural flowing water course, usually freshwater, flowing towards an ocean, sea, lake or another river. A river begins at a source and ends at a mouth, following a path called a course. Rivers have been used as a source of water, as a defensive measure, and as a means of disposing of waste along with other purposes. Rivers are the surface water sources along with lakes, streams and ponds. They are open to the environment, may be contaminated by natural or anthropogenic activities and the quality of the water may change significantly with the weather [1]. Surface water as such is not safe to use as drinking water. It is possible to treat surface water and make it potable, but treatment must deal with changing physical, chemical and biological characteristics. Treatment should be designed by an experienced professional to fit the source.

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1.2 Sources of Contamination and Water Quality

The quality of surface water is unpredictable, because the water continually moves and pollutants can be entered at any time. In other words, an area of lake or stream that is fine one day may be contaminated the next day. Biological contaminants can come from sewers and failed septic systems, boat toilets, animals, and other sources. Chemical contaminants, like gasoline, oil, pesticides, and heavy metals, can come from discharge pipes, chemical storage areas, gasoline tanks, oil drums, or anywhere chemicals have been used close to open water [2]. The organic load discharges and the dissolved oxygen in the river are important parameters to measure river quality [3]. So, it is intended to study how the critical oxygen demand is related with the initial organic load at the time of discharge. In view of the available quality of surface water and the intended required quality, it is always advisable to go for a better source area for raw water. This paper is an attempt for a stepping stone to assess better source points in the river under study.

II. LIERATURE REVIEW

2.1 Water Quality Assessment

The purpose of water quality monitoring is to determine the physical and chemical properties of natural waters [4]. Properties of water such as temperature, pH, dissolved oxygen, and the concentration of nitrates and phosphates are important indicators of water quality. These properties can change as a result of natural and human related activities. The same properties can be used to determine the quality of the stream water and can be used to identify sources of pollution in the water. Changes in these parameters may be detrimental to the organisms in and around the water source [5].

2.1.1 Temperature

The most common physical assessment of water quality is the measurement of temperature. Temperature impacts both the chemical and biological characteristics of surface water. It affects the dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms, and the sensitivity of these organisms to pollution, parasites and disease. The problem of low dissolved oxygen levels is magnified by the fact that the metabolic rates of aquatic plants increase as water temperature rises, thus increasing their biochemical oxygen demand. Low dissolved oxygen levels leave aquatic organisms in a weakened physical state and more susceptible to disease, parasites, and other pollutants [2].

Warm water is less capable of holding dissolved oxygen. For this reason, temperature should be measured at the same place within the stream at which dissolved oxygen is measured [2]. This allows the correlation between the two parameters to be observed.

2.1.2 Dissolved Oxygen

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality [6].

The temperature of water also controls the amount of dissolved oxygen in water. Cold water can absorb more oxygen, producing higher values, while warm water produces lower values (when measured as mg/L). It is disclosed that the dissolved oxygen ranges for natural waters is in the range of 5.4 to 14.8 mg/L.

Low oxygen can result pollution from discharge of industries, urban runoff, wastewater and sewage treatment plants which often contain organic materials that are decomposed by microorganisms using oxygen in the process. Other sources of oxygen-consuming wastewater include animal feedlots and failing septic systems.

Dissolved oxygen enters water through the air or as a plant byproduct. From the air, oxygen can slowly diffuse across the water's surface from the surrounding atmosphere, or be mixed in quickly through aeration, whether natural or man-made [8]. The aeration of water can be caused by wind (creating waves), rapids, waterfalls, ground water discharge or other forms of running water.

2.1.3 Dissolved Oxygen and Biochemical Oxygen Demand

The stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen.

Wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand or BOD. Oxygen is measured in its dissolved form as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die [8].

DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes.

Biochemical oxygen demand, or BOD, measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream [5].

III. METHODOLOGY

The study was done in Periyar River from Neriyamangalam to the Estuaries through the selected stations in the stream for the period from 2011 to 2013. Month to month samplings were taken and analysis was completed for the parameters like temperature, Dissolved Oxygen and Biochemical Oxygen Demand. Optional information for these parameters was acquired through approved Organisations; such as Kerala Water Authority, Central Water Commission and Kerala State Pollution Control Board for the period from 2004 to 2010.

Dissolved oxygen level refers the condition of the water. The river condition in general can be ascertained through the critical oxygen demand evaluated.

The Classic Streeter Phelps Equation is the best effortlessly accessible system for stream examination in the wake of considering its suppositions and confinements [2]. Here, for the river under study is considered in different stretches to minimise the constraints and also to find out the load and other contributing factors as indicated by Streeter Phelps.

.To achieve the target, the concepts of Re-oxygenation and De-oxygenation are to be taken into account.

(1) Re-oxygenation in Rivers: The amount of Re-aeration is proportional to the Dissolved Oxygen deficiency.

The Rate of Re-aeration is defined as

$r_R = K_2'(C_s - C);$

Where, K_2'= re-aeration constant, d^{-1} (base e)

C_s=dissolved Oxygen saturation concentration, mg/l, C=dissolved Oxygen concentration, mg/l

In this, the generalized formula proposed by O'Conner and Dobbins for natural streams is,

$K_2' = [294(D_L U)^{1/2}]/H^{3/2}$

Where, D_L= Molecular diffusion coefficient for oxygen, m^2/d, U= mean stream velocity, m/sec

H= average depth of flow

The Variation of the coefficient of molecular diffusion with temperature can be approximated with the following expression

D_{LT}= 1.760 X 10^{-4} m^2/d X 1.037^{T-20}

Where, D_{LT}= Molecular diffusion coefficient for oxygen at Temperature T, m^2/day

1.760 X 10^{-4}= Molecular diffusion coefficient for oxygen at 20°C, m^2/day, T= Temperature, °C

(2) De-oxygenation in Rivers: The amount of oxygen required to stabilize a waste is normally measured by the BOD_5 test; BOD_5 is therefore the primary source of oxygen depletion or utilization in a waterway. The rate of de-oxygenation r_D is

$r_D = -K'L$ - Equation (1)

Here, let us consider the classic Streeter- Philips Oxygen-Sag equation, which is commonly used in river analysis.

Oxygen deficit at time t, in mg/l,

$Dt = [\{K'L_0 \mid (K_2' - K')\} X (e^{-K't} - e^{-K_2't})] + D_0 e^{-K_2't}$ - Equation (2)

It is given a caution in applying the equation as such since it is best suitable for channels of uniform cross section where effects of algae and sludge deposits are negligible. Considering all these limitations, it is decided to utilize the best theory parts for Periyar River analysis. For obtaining uniform cross sections, the river is divided into various stretches accordingly. As the effect of tidal variations and considering the flow and nature of river, effect of algal growth and sludge deposits are not considered for the ultimate aim of this study.

The critical deficit can be determined by setting dD/dt is Zero in the original equation, we get

$D_c = \left(\frac{K'}{K_2'}\right) X L_0 e^{K't_c}$ - Equation (3)

Where t_c = the time required to reach the critical point.

The value of t_c can be determined by differentiating Equation (2),

with respect to t setting, dD / dt = 0

$t_c = \left\{\frac{1}{K_2' - K'}\right\} X \ln \left[\left(\frac{K_2'}{K'}\right) X \left\{1 - \frac{D_0 (K_2' - K')}{K' L_0}\right\}\right]$

The distance x_c equal to, $x_c = t_c$ v; where v is the velocity of flow in river,

D_o = Initial Oxy. Deficit in mg/l

L_o = Ultimate BOD at point of discharge, mg/L

K' for first order reaction rate constant in d^{-1} and K_2' = Re-aeration Constants and

t_c = Critical Time, x_c= Critical distance, D_c = Critical deficit DO

$$D_c = \left(\frac{K'}{K_2'}\right) X\, L_0 e^{K' t_c}$$

K' for Large Streams of Low Velocity = 0.15 - 0.25 (for this river stretch)

[a] For other temperatures use $K' = K'_{20}$ X 1.135^{T-20}

3.1 Method

The study area has been conveniently divided into eight stretches so as to enable to get uniform cross section in various portions of the individual stretch. As the flow and cross sections are steady and uniform, the velocity will also be steady.

Temperature, Dissolved Oxygen and BOD has been ascertained from the tests and analysis results of the samples collected as per standard methods. The related K' and K_2' values for each stretch for varying related parameters have been computed for easiness of the work. Flow details of each stretches including the velocity and other geometrical parameters required for the study has been obtained [5]. Using the saturation DO table the initial Oxygen Deficiency and using the already defined formula, the initial organic loading has been computed. Critical deficit DO (Dc) and Critical Oxygen Demand have been computed for these periods for all the stretches for further evaluations.

An attempt has been made to formulate a relationship between the initial organic loading and the critical oxygen demand for all the selected stretches for all the twelve months. The formulated relationships were tested for the previous year as well as for other successive year also and found that the relationships are useful for achieving the targets of the study as well as for guidance to the authorities concerned for urgent appropriate measures.

IV. RESULTS AND DISCUSSIONS

4.1 Details of Study Area

Considering the convenience, the river portion under study was divided into eight sections from Neriyamangalam to Purappallikadavu. The sections details are coded and tabled as given below.

Table-1 Description of section code and stretch details

Sl.No	Station Code	River Stretch	Sl.No	Station Code	Stretch
1	NM- AV	Neriyamangalam to Avolichal	5	VL-CW	Vallom to Chowara
2	AV- VP	Avolichal to Vettampara	6	CW- AL	Chowara to Aluva
3	VP- KO	Vettampara to Kotanad	7	AL-PU	Aluva to Purapillikadavu
4	KO - VA	Kotanad to Vallam	-	-	-

4.2 Sampling and Analysis

Samples for the above stations were collected as per standards; and tests and analysis were conducted as per standard methods for interpretations [7]. Parameters like temperature, dissolved oxygen, and bio-chemical oxygen demand were selected for this study.

Re-aeration and De-oxygenation constants at 20°C of the river under study for various stretches have been obtained. The Re-aeration and De-oxygenation constants K_2' and K' for the temperatures obtained for the samples were computed using the formulae described in the methodology. The corresponding saturation DO has been worked out and tabulated for the temperatures of the samples. Initial organic loading has been computed using the BOD values obtained for the samples in month wise for the period 2005 to 2012 for all the selected sections. The initial oxygen deficiency, critical oxygen deficit, critical oxygen demand, critical distance and critical time were computed from the values of the parameters determined on sample analysis for the periods and sections mentioned above.

Table 2 Analysis Details at Aluva during 2012

Mon	Temp °C	Initial DO in mg/l	Satn DO in mg/l	D_o	BOD_5	L_o	t_c (d)	xc (km)	D_c	Critical DO
Jan	29	6.60	7.58	0.98	0.70	0.90	0.413	5.07	1.00	6.57
Feb	29	6.40	7.35	0.95	0.80	1.03	0.614	7.53	1.01	6.34
Mar	31	6.30	6.99	0.69	2.10	2.70	1.329	16.31	1.64	5.35
Apr	33	6.40	6.82	0.42	0.80	1.03	1.030	12.63	0.77	6.05
May	32	6.50	7.08	0.58	0.30	0.39	0.273	3.35	0.59	6.49
Jun	28	6.60	7.67	1.07	1.40	1.80	1.059	13.00	1.31	6.36
Jul	28	7.10	7.13	0.03	2.40	3.09	2.049	25.13	1.30	5.83
Aug	25	6.30	7.74	1.44	1.20	1.54	0.067	0.82	1.44	6.30
Sep	31	6.90	7.66	0.76	0.80	1.03	0.838	10.28	0.93	6.73
Oct	29	5.60	7.69	2.09	1.20	1.54	0.099	1.21	2.10	5.60
Nov	30	6.30	7.07	0.77	0.60	0.77	0.571	7.01	0.82	6.25
Dec	30	6.20	6.96	0.76	0.40	0.51	0.113	1.38	0.76	6.20

The data analysis details for Aluva station during 2012 is given vide Table 2 for ready reference. The table provides the stream temperature, Initial Dissolved Oxygen and the corresponding saturation Dissolved Oxygen and the Biochemical oxygen demand (BOD_5). The saturation DO was worked out using the standard Saturation DO Table. The initial Organic Load (L_0) in mg/l, Critical Time (t_c) in day and the Critical Distance X_c in km were computed using the Streeter Phelps equation. Similarly, the critical DO deficiency and the Critical DO were worked out and tabulated for the station Aluva during 2012 for further discussions.

There is apparently no relation between the successive months in a year for polluting the river by disposing organic matters in the river. Even if we consider the disposal quantity is same, the pollution concentration level will vary with the flow of river. The flow of river will not be same throughout the year. It may vary from month to month due to various reasons, but can similar in a month of successive years. But it is interesting to see how the Initial Oxygen Deficiency is changing with respect to the change in BOD.

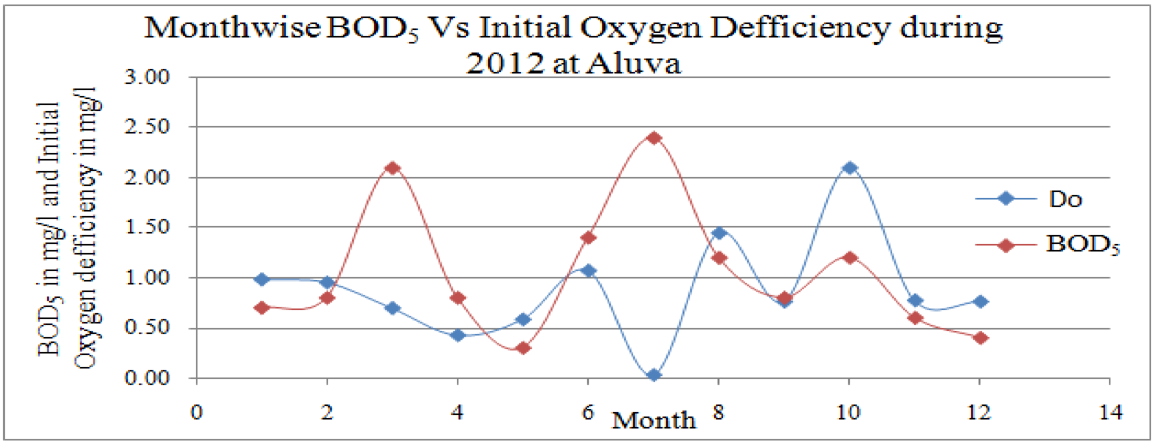

Fig. 1 Initial Oxygen Deficiency Vs BOD_5 at Aluva for the Year 2012

Fig. 1 is Initial Oxygen Deficiency Vs Biochemical Oxygen Demand for Chowara-Aluva area for the year 2012. The figure shows that the Initial Dissolved Oxygen Deficiency level amid the period is inversely proportional to the Biochemical Oxygen Demand in the waterway.

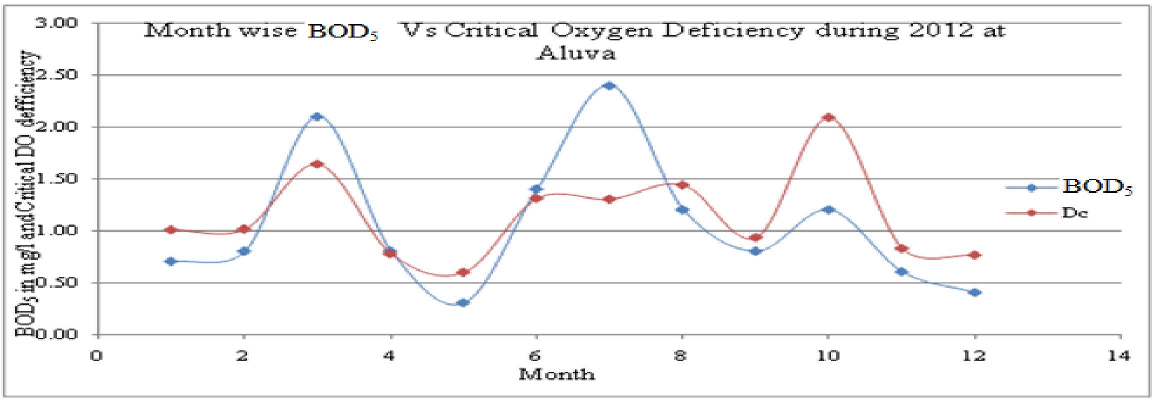

Fig .2 BOD_5 Vs Critical Oxygen Deficiency at Aluva for the Year 2012

Fig .2 gives the Biological Oxygen Demand (BOD_5) and the Critical Oxygen Deficiency (Dc) for Aluva segment amid 2012. The figure obviously uncovers the relationship between the BOD_5 and the Critical Oxygen Deficiency of Periyar Stream at Aluva segment. It could be understood that the Critical Oxygen Deficiency is proportional to the BOD present in the water body.

Fig.3 made accessible the Biological Oxygen Demand (BOD_5) and the Critical Dissolved Oxygen level for Aluva area amid 2012. The figure demonstrates the relationship between the BOD_5 and the Critical Dissolved Oxygen level of Periyar waterway at Aluva area amid the period. It could be understood that the Critical Dissolved Oxygen level is inversely proportional to the BOD present in the water body.

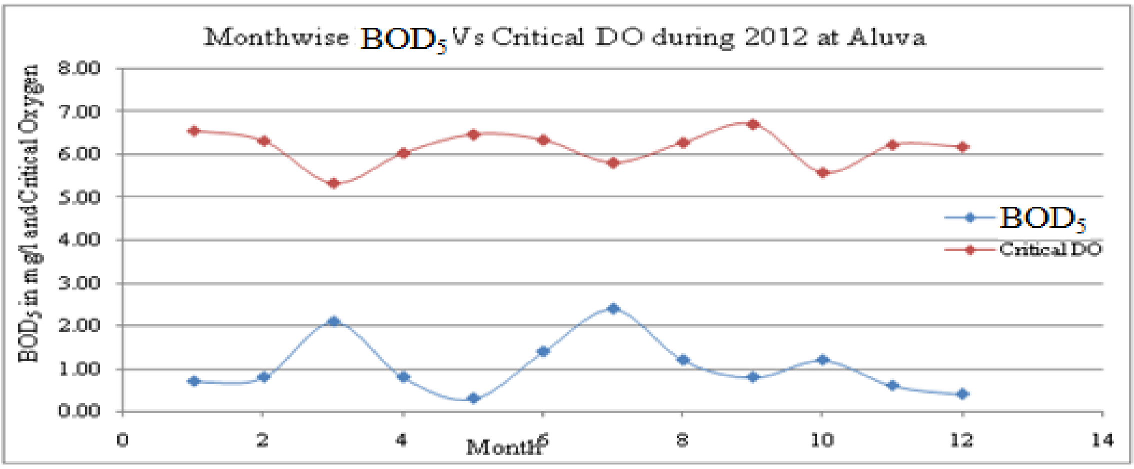

Fig. 3 BOD_5 Vs Critical Dissolved Oxygen at Aluva for the Year 2012

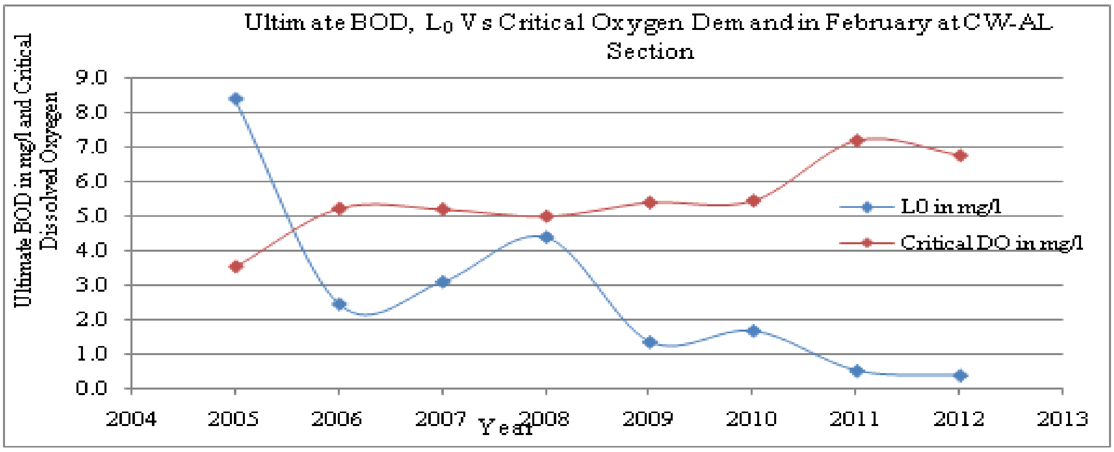

Fig .4- Initial Organic Loading and Critical Dissolved Oxygen in the month of February at Chowara

The fig. 4 reveals the relationship between Initial Organic Loading and Critical Dissolved Oxygen in the month of February at Chowara-Aluva Segment. All in all, it could be comprehended that the critical dissolved oxygen level is inversely proportional to the initial organic load. In this area during February the initial organic load is seen impressively lessened following 2005 to 2012 with the exception of the year 2008. In 2005 the initial organic load measured as around 8.5 mg/l, though the same recorded in 2012 was about 0.50mg/l. The reduction in initial organic load from 2005 to 2012 in the section is giving much hope in the river maintenance and pollution control.

Table 3 Initial Organic Load and Critical Dissolved Oxygen level at Aluva from 2005 to 2008

Mon	2005		2006		2007		2008	
	Lo	Critical DO	Lo	Critical DO	Lo	Critical DO	Lo	Critical DO
Jan	2.06	6.37	2.70	5.33	2.57	5.87	1.29	6.63
Feb	8.37	3.52	2.45	5.20	3.09	5.18	4.38	4.97
Mar	4.25	5.04	3.35	4.57	3.09	5.37	2.83	5.70
Apr	3.99	4.90	3.60	4.34	3.35	4.78	3.80	5.05
May	3.60	4.99	3.35	3.98	3.09	4.98	2.06	5.53
Jun	2.19	6.52	3.73	6.03	3.09	6.28	1.29	7.01
Jul	5.54	4.97	8.37	4.84	5.92	5.45	4.25	5.27
Aug	3.99	5.74	2.06	6.26	1.93	6.72	3.02	6.11
Sep	3.09	4.90	4.12	6.04	3.48	5.98	2.06	5.69
Oct	2.83	5.39	6.18	5.18	4.89	5.40	2.38	5.54
Nov	1.80	6.37	4.76	4.95	3.73	5.35	1.16	6.84
Dec	2.19	6.10	4.51	4.71	3.86	4.97	1.48	6.07

Tables 3and 4 provides the initial organic loading (L_0) and critical dissolved oxygen for Aluva section from 2005 to 2012. This was worked out along with other stations from 2005 to 2012 using the Streeter Phelps equation.

Table 4 Initial Organic Load and Critical Oxygen level at Aluva from 2009 to 2012

Mon	2009		2010		2011		2012	
	Lo	Critical DO	Lo	Critical DO	Lo	Critical DO	Lo	Critical DO
Jan	1.48	6.35	1.42	6.04	0.77	5.97	0.51	5.75
Feb	1.35	5.37	1.67	5.42	0.51	7.16	0.39	6.73
Mar	2.32	5.50	2.19	5.87	1.29	5.86	1.42	6.02
Apr	3.80	4.47	3.67	4.64	3.35	4.94	3.60	5.10
May	1.87	5.44	1.74	5.45	0.77	6.20	0.51	6.12
Jun	2.00	6.17	1.67	6.25	0.51	7.40	0.39	7.41
Jul	8.37	4.90	7.14	5.06	2.83	5.58	2.96	5.24
Aug	1.09	6.74	1.03	6.72	2.45	6.35	2.06	6.47
Sep	2.32	6.42	2.00	6.82	1.42	5.70	1.03	6.46
Oct	4.44	5.73	3.80	5.77	2.19	5.63	1.93	5.81
Nov	3.48	5.53	2.96	5.64	2.70	5.90	0.77	5.58
Dec	2.83	5.58	2.51	5.72	0.90	6.60	0.77	6.10

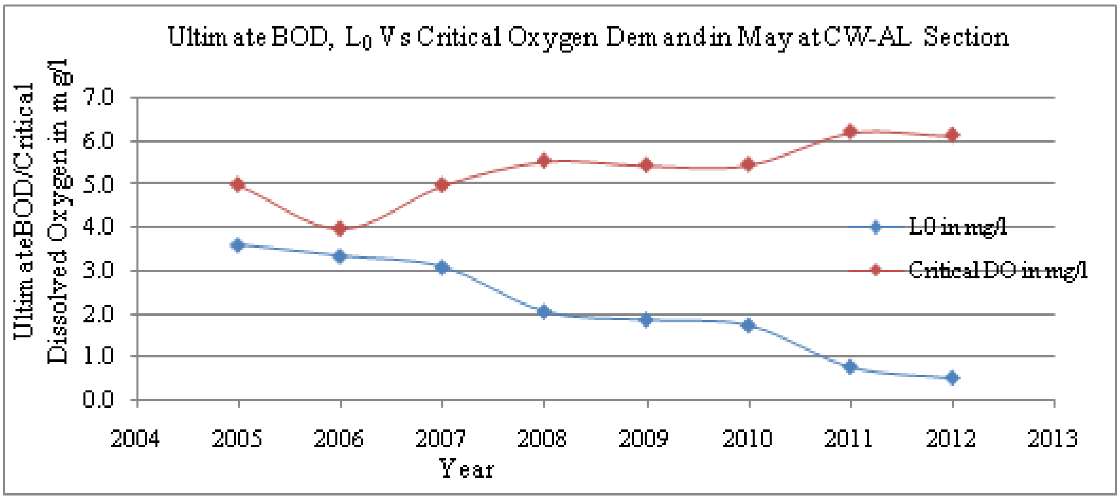

Fig .5- Initial Organic Loading and Critical Dissolved in the month of May at Chowara

Fig .5 indicates the relationship between Initial Organic Loading and Critical Dissolved Oxygen in May at Chowara-Aluva Area. On account of this, it is seen that the critical dissolved oxygen level is inversely proportional to the initial organic load. About this area amid May month, the initial organic load is seen decreased following 2005 to 2012. In 2005 the initial organic load measured as around 3.70 mg/l, while the same recorded in 2012 was about 0.50 mg/l. The reduction in initial organic load from 2005 to 2012 in the section is benevolent much hope in the river maintenance and pollution control.

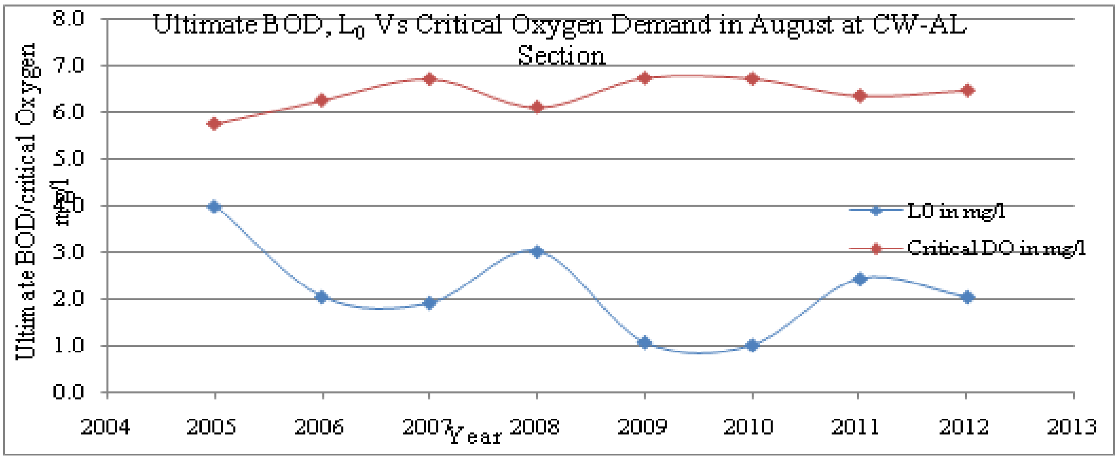

Fig .6- Initial Organic Loading and Critical Dissolved Oxygen in the month of August at Chowara

Fig .6, portrays the relationship between Initial Organic Loading and Critical Dissolved Oxygen in the month of August at Chowara-Aluva Area. It is observed that the critical dissolved oxygen level is inversely proportional to the initial organic load during the months of August. In relation to the section during August month, the initial organic load is seen reduced since 2005 to 2012 except for the year 2008. In 2005 the initial organic load was measured as 4.00 mg/l, whereas the same recorded in 2012 was about 2.00 mg/l. During 2009, the Initial organic load was seen reduced to 0.80 mg/l. The reduction in initial organic load from 2005 to 2012 in the section is benevolent much hope in the river maintenance and pollution control.

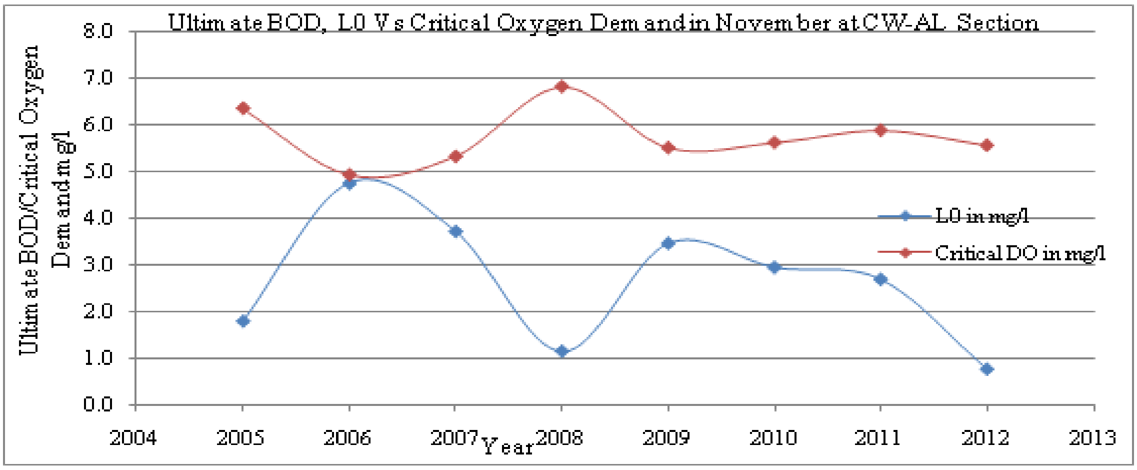

Fig .7- Initial Organic Loading and Critical Dissolved Oxygen in the month of November at Chowara

Fig.7 describes the relationship between Initial Organic Loading and Critical Dissolved Oxygen in the month of November at Chowara- Aluva Section. It was seen that the critical dissolved oxygen level is inversely proportional to the initial organic load during the months of November. During November, the initial organic load is seen reduced since 2005 to 2012 for the section. The initial organic load was seen increased during 2006, 2007, 2009, 2010 and 2011. The critical dissolved oxygen was also changed in proportion to the input values. The initial organic load measured during 2005 was 1.80 mg/l, whereas the same recorded in 2012 was 0.80 mg/l. The reduction in initial organic load from 2005 to 2012 in the section is compassionate much hope in the river maintenance and pollution control.

Fig .4, Fig .5, Fig .6 and Fig .7 have depicted the relationship between the Critical Dissolved Oxygen against the Initial Organic loading for the months of February, May, August and November for Chowara- Aluva section. The figures clearly indicate that the Critical Dissolved Oxygen is inversely proportional to the initial organic loading. That means the critical oxygen deficiency is directly proportional to the organic loading.

V. CONCLUSION

- The study reveals an idea of initial discharges and its possible locations.
- The study gives an idea of possible critical deficiency of oxygen
- The study reveals the possible critical distance with respect to the stretch under consideration
- The study reveals that the critical oxygen deficiency is directly proportional to the initial organic load disposed into the stream.
- The study reveals that the critical dissolved oxygen is inversely proportional to the initial organic load disposed into the stream.

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