ASSIMILATION CAPACITY OF A STRETCH OF PERIYAR RIVER – A CASE STUDY

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ABSTRACT

Water is an essential element on earth; no activity is possible without the presence of water for human civilization, industry and agriculture. In time, the development of society, through population growth and development of agriculture and various industries have increased water uses. After use, the water returned as either untreated or treated, but has not the same quality as that taken prior to use. Quality and quantity of the water has become a real problem worldwide. Discharge of these used waters to the water bodies deteriorates the quantity and quality of the rivers which causes major imbalances 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. Self-purification is the process in which balance restoration of the aquatic environment takes place through simultaneous participation or in some sequence of the physical and chemical factors, biological, hydraulic and morphological characteristics of the river. Analysis of these factors gives us complex information about water quality and an attempt is made through this paper in developing measures to help remedy its quality or to prevent degradation.

***Keywords**: Assimilation Capacity, Self-Purification, Ecosystems, Surface Water, Dissolved Oxygen, Streeter Philips Equation, Critical Time*

I. INTRODUCTION

1.1 River

A river is defined as a large natural stream of water emptying into an ocean, lake, or other body of water and usually fed along its course by converging tributaries. Rivers and streams drain water that falls in upland areas. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world.

1.2 River Water Quality and Pollution

A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic) are concentrated along the rivers. Industries and cities have historically been located along rivers because the rivers provide transportation and have traditionally been a convenient place to discharge waste. Agricultural activities have tended to be concentrated near rivers, because river floodplains are exceptionally fertile due to the many nutrients that are deposited in the soil when the river overflows.

1.3 Sources of Pollution and Water Quality

Chemical waste products from industrial processes are sometimes accidentally discharged into rivers. Factories use water from rivers to power machinery or to cool down machinery. Dirty water containing chemicals is put back in the river. Water used for cooling is warmer than the river itself. Raising the temperature of the water lowers the level of dissolved oxygen and upsets the balance of life in the water. People are sometimes careless and throw rubbish directly into rivers.

The quality of natural water in rivers, lakes and reservoirs and below the ground surface depends on a number of interrelated factors. In its movement on and through the surface of the heart, water has the ability to react with the minerals that occur in the soil and rocks and to dissolve a wide range of materials, so that its natural state is never pure. It always contains a variety of soluble inorganic, soluble organic and organic compounds. In addition to these, water can carry large amounts of insoluble materials that are held in suspension. Both the amounts and type of impurities found in natural water vary from place to place and by time of year and depends on a number of factors. These factors include geology, climate, topography, biological processes and land use. The impurities determine the characteristics of a water body [1].

II. LIERATURE REVIEW

2.1 Water Quality Monitoring

The purpose of water quality monitoring is to determine the physical and chemical properties of natural waters. 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 processes. These properties can be used to determine the effects of stream water on aquatic ecosystem health and can sometimes be used to identify sources of pollution in water.

Changes in these parameters may be detrimental to the organisms in and around the water source. Many factors can affect the quality of the water in an ecosystem including discharges of industrial or agricultural wastes [2].

2.1.1 Temperature

Water temperature is an important property that determines water suitability for human use, industrial applications and aquatic ecosystem functioning. Water temperature can affect the dissolved oxygen content, an important water characteristic that strongly affects many aquatic organisms. Water is generally warmer in the summer and colder in the winter, ranging from about 30^{o} C to near freezing.

2.1.2 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen in water that is available for chemical reactions and for use by aquatic organisms. Most of the oxygen in water is derived from the atmosphere by mechanical mixing (churning action of water as it flows). Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains little. Changes in the dissolved oxygen levels in water can be caused by aquatic vegetation. Streams can also loose oxygen due to the decomposition of organic matter by bacteria and from chemical reactions that consume oxygen [3].

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).

Important examples of dissolved oxygen ranges for natural waters:

- typical range in natural waters 5.4 to 14.8 mg/L
- Optimal range for aquatic growth activity 5.0 to 6.0 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.

2.2 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 [7].

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 also measures the chemical oxidation of inorganic matter. 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. This means less oxygen is available to higher forms of aquatic life. Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff [2].

2.3 Assimilative Capacity Of Streams

The capacity of natural waters to assimilate organic wastes is called the stream assimilative or purification capacity. Various studies revealed the assimilation capacity that does not lower the oxygen content of the stream below a predetermined value is the significant capacity and should be the maximum capacity made available for intentional waste assimilation. Discharge of any wastes in excess of this maximum capacity must involve a probabilistic analysis. The maximum assimilative capacity is set by the minimum re-aeration capacity because; re-aeration is the only continuous source of oxygen supply. The minimum re-aeration capacity thus is the maximum usable assimilative capacity for uniformly applied and distributed wastes [5].

In waste treatment aeration the effectiveness of external energy input is constrained by the biological reaction. In other words oxygen cannot be transferred faster than it is used. Natural re-aeration of streams is exactly the opposite. In this case oxygen cannot be used unless it is transferred into the water by natural phenomena or unless stream aeration is practiced.

In general, we know that the assimilation capacity of streams depends on:

1. Determination of waste loadings
2. Definitions of hydrologic and climatic factors
3. Adoption and verification of self purification factors
4. Forecasts of expected stream conditions
5. Evaluation of the impact of river developments

The assimilative or purification capacity of a body of water is determined by the product of the minimum surface (mass) transfer coefficient, the maximum dissolved oxygen (DO) deficit, and the surface area being considered.

2.4 Factors Affecting Self Purification Of Stream

Stream self purification is the ability of streams to gradually clean themselves, improving the quality of water over time, if no pollution is introduced. Streams and rivers are capable of absorbing some pollution caused by humans because they possess the ability to purify themselves through the action of living organisms that consumes organic matter and the sedimentation process that contribute to river bottom.

Active biological decomposition of organic matter begins immediately after the waste discharge, which utilizes oxygen. Atmospheric re-aeration is proportional to the DO deficit. Finally, a point is reached at which the rate of oxygen utilized for waste decomposition equals the rate of re-aeration (Xc). Downstream from this point, the rate of re-aeration is greater than the rate of utilization and DO begins to increase. Eventually, the stream will show no effects due to waste discharge. This is the phenomenon of natural stream purification. The main factors influencing are:

1. Biological Factors: stream Eco-systems have a capacity of biological digestion of pollutants. Micro-organisms and larger organisms such as plants and animals absorb small portions of contaminants dissolved in water

2. Chemical Elements: Chemical composition of water also plays an important role in self purification. Concentration of DO is a critical factor in self purification as micro-organisms use DO for the decomposition of organic matter. For eg: water flowing through copper-rich areas may have high concentration of dissolved copper which can gradually remove other suspended metal contaminants as they bound to the copper and fall out as sediments.
3. Physical Factors: physical surrounding of a water body also has an important role. Sands and grasses can act as natural filters for water, removing large impurities. Large topographical features which agitate the water can contribute to the amount of DO in water.
4. Temperature: Rate of Re-aeration is inversely proportional to temperature. As temperature increases, concentration of DO decreases. Water temperature can determine the rate at which certain elements dissolved in water. Temperature can also determine the kinds of species present in water and the rate at which they reproduce. Several changes in the rate of self purification may also occur, as plant species that absorb contaminants grow less during winter. Also, self purification becomes faster as slope, velocity, discharges etc increases [5].

III. METHODOLOGY

The Study concentrated in the selected portion of the river during lean flow period. That is from the month of November to the successive months up to May month. This period was selected not only to obtain a lean and steady flow, considering the uniform cross sections of the selected stretches. If the flow and cross sections are steady, and uniform, the velocity will also be steady. Moreover that, the period selected is the most affected and better for the study.

To find out the self purification of a river, let us utilize the best content of the classic Streeter Philip's Equation. It is agreed that all the assumptions and limitations and the reported constraints for utilizing the equation as such. But, instead of finding the sag curves, we can very well utilize the other portions and assumptions for the rivers after considering the river under study is taken into different stretches to minimize the constraints and also to find out the load and other contributing factors as indicated by Streeter Philips.

3.1 Re-oxygenation in Rivers

The amount of Re-aeration is proportional to the Dissolved Oxygen deficiency

The Rate of Re-aeration r_R 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

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

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

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

3.2 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 (A)

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,

$Dt = [\{(K' L_0)/ (K_2' - K')\} \times (e^{-K't} - e^{-K2't})] + D_0\, e^{-K2't}$ - Equation (B)

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

$D_c = (K'/K2') \times L_0 e^{-K'tc}$ - Equation (C)

Where tc = the time required to reach the critical point. The value of tc can be determined by differentiating Eqn (B) with respect to t setting $dD / dt = 0$

$tc = \{1/(K_2' - K')\} \times \ln[(K_2'/K') \times \{1- D_0(K_2'-K')/K'L_0\}]$

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

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

K' for first order reaction rate constant in d^{-1} and K2' = Re-aeration Constants and

tc = Critical Time, xc= Critical distance, Dc = Critical deficit DO

$D_c = (K'/K2') \times L_0 e^{-K'tc}$

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

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

K2' for Large Streams of Low Velocity = 0.35 - 0.46 (for this river stretch)

[a] For other temperatures use $K_2' = K_2'_{20} X 1.024^{T-20}$

3.3 Method

The study area has been conveniently divided into few 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 [4]. Using the saturation DO table the initial Oxygen Deficiency and using the already defined formula, the initial organic loading has been computed. The critical time (tc), critical distance (Xc), critical deficit DO (Dc) and Critical DO have been computed for these periods for all the stretches for further evaluations.

IV. RESULTS AND DISCUSSIONS

4.1 Details of Study Area

Considering the convenience, the river portion under study was divided into nine sections from Neriyamangalam to the estuaries. From Aluva to further downstream, the river bifurcates into two, one towards Eloor and the other towards Purappallikadav, both estuaries. But, for this paper, only the stations up to Aluva and the branch of Purappallikadavu are considered. Details of the sections are described in Table-I below.

4.2 Description of the Stations Code

NM- AV - Neriyamangalam to Avolichal, AV- VP – Avolichal to Vettampara , VP- KO – Vettampara to Kotanad, KO - VA – Kotnad to Vallam, VL-CW – Vallom to Chowara, CW- AL – Chowara to Aluva, AL-PU – Aluva to Purapillikadavu, AL-PA – Aluva to Pathalam, PA-MJ – Pathalam to Manjummel

The average geometrical details of the sections were obtained for the study. Flow details [4] were obtained for computing the velocity, and related geometrical parameters.

Table -1 Section Details of the Study Area

Station Code	Between	Location	Length in Km	Average Width in mts	Average Depth in mts	Average Velocity in m/s
NM		10°03' 33o94"N 76°46'39o47"E	0.000			
AV	NM - AV	10°4'26.93"N 76°44'58.09"E	3.710	172.84	2	0.142
VP	AV - VP	10°09'05.88"N 76°38'55.20"E	15.000	113.30	2	0.330
KO	VP - KO	10°11'02.60" N 76°30'31" E	18.000	114.11	4	0.170
VA	KO - VA	10°07'52.59" N 76°27'25.70 E	14.760	304.00	3.5	0.480
CW	VA - CW	10°07'26.18" N 76°23'26.65" E	8.480	225.86	4	0.400
AL	CW - AL	10°06'51.17" N 76°21'36.15" E	3.770	206.00	4	0.350
PU	AL - PU	10°08'34.48" N 76°17'03.17" E	11.326	222.36	4	0.330
PA	AL - PA	10°04'35.26" N 76°18'30.27" E	7.833	149.00	2	0.200
MJ	PA - MJ	10°04'52.84" N 76°19'02.97" E	1.250	111.00	2	0.200

4.3 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 [6]. Parameters like temperature, dissolved oxygen content, and bio-chemical oxygen demand were selected for this study.

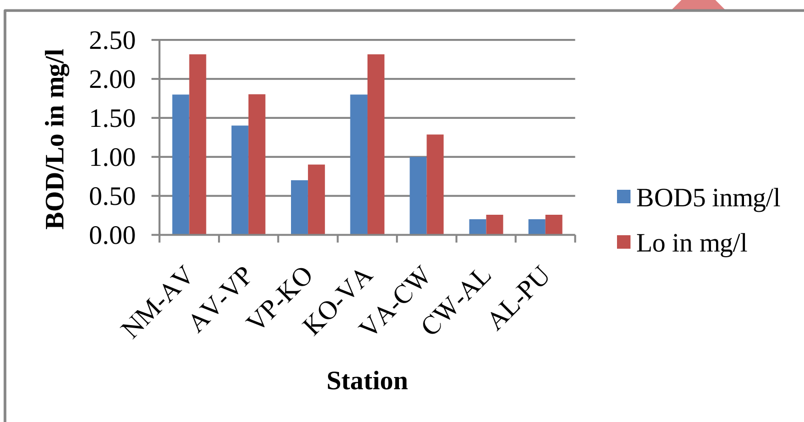
Re-aeration and De-oxygenation constants at 20^0C of the river under study for various stretches have been obtained. The Re-aeration and De-oxygenation constants K_2' and K' or the temperatures obtained for the samples were computed using the formulae described in the previous chapter. The corresponding saturation DO has been noted and tabulated for the temperatures of the samples. Initial organic loading has been computed using the BOD values obtained for the samples. 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.

Velocity Considered for the Section during Lean Period=30.240km/d =1.26 km.hr

River Section - Chowara - Aluva (CW- AL)

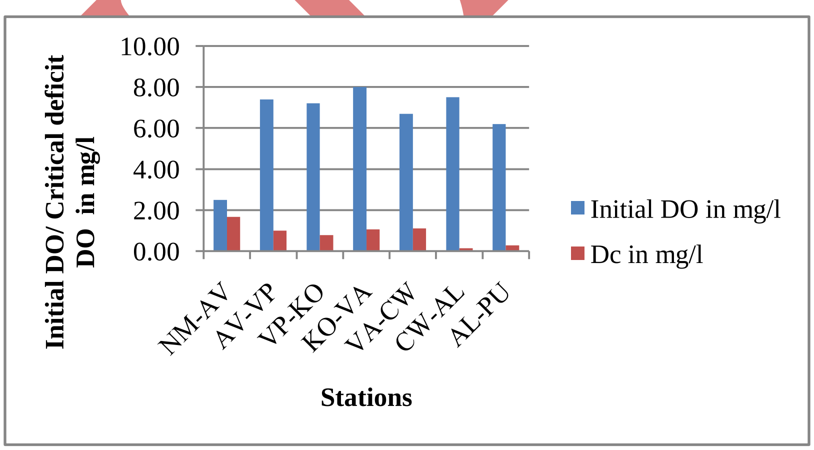
2012-2013 /Month	Temp in ^{0} C	Initial DO in mg/l	Satn DO in mg/l	D_o	BOD_5	Lo	K'	K2'	tc (d)	xc (km)	Dc	Critical DO
November	33.0	7.40	6.49	0	0.60	0.77	1.0375	0.4764	1.387	41.95	0.399	6.091
December	32.0	7.20	6.85	0	1.20	1.54	0.9141	0.4652	1.505	45.50	0.767	6.083
January	35.0	7.50	5.71	0	0.20	0.26	1.3365	0.4995	1.176	35.56	0.143	5.567
February	34.0	5.40	6.10	0	0.20	0.26	1.1775	0.4878	1.278	38.64	0.138	5.962
March	35.0	7.60	5.71	0	1.00	1.29	1.3365	0.4995	1.176	35.56	0.715	4.995
April	35.0	7.20	5.71	0	3.10	3.99	1.3365	0.4995	1.176	35.56	2.218	3.492
May	35.5	6.70	5.52	0	0.30	0.39	1.4239	0.5055	1.128	34.10	0.218	5.302

Fig-1 Station wise BOD and Initial Discharge during January 2013



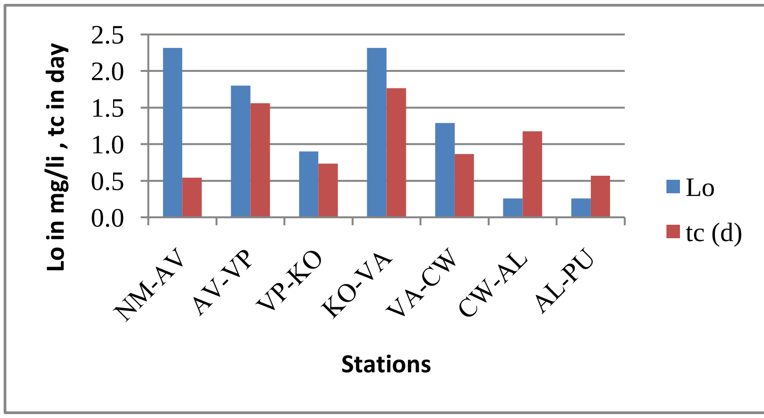
(Fig-I) describes about the Initial discharge Lo variation in station wise with respect to the temperature. During 2013 January the initial discharge was high at Neriyamangalam- Avolichal and Kotanad – Vallom sections. This indicates that the organic loading is higher in these stretches and lower in the last stretches Viz; Chowara Aluva and Aluva – Purappallikkadavu stretches. It is also noticed that the discharge at Vettampara – Kotanad stretch is little better than its adjacent stretches.

Fig-2 Station wise Initial DO and Critical deficit DO during January 2013



(Fig-2) describes about the Initial DO and Critical deficit DO variation in station wise with respect to the temperature. During 2013 January the initial DO and the critical deficit DO was less at Neriyamangalam- Avolichal, At Chowara- Aluva Stretches the initial DO was moderately good and hence the critical deficit was also less. This gives an indication that the downstream of the river get re-aerated.

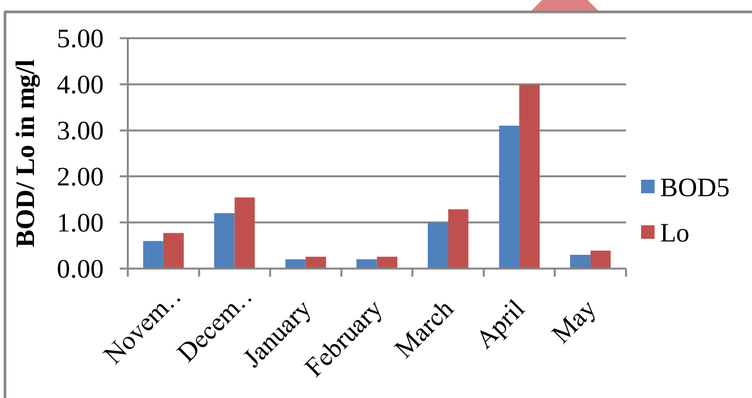
Fig-3 Station wise Initial Discharge and Critical time during January 2013



(Fig-3) describes about the Initial organic load and Critical time variation in station wise with respect to the temperature. During 2013 January the initial load was high at Neriyamangalam- Avolichal and Kotanad – Vallom Stretches; and the critical time also found more. At Chowara- Aluva Stretches, even though the initial load was less, it's critical time was more compared with the load. This gives an indication that the re-oxygenation in this stretch was slow.

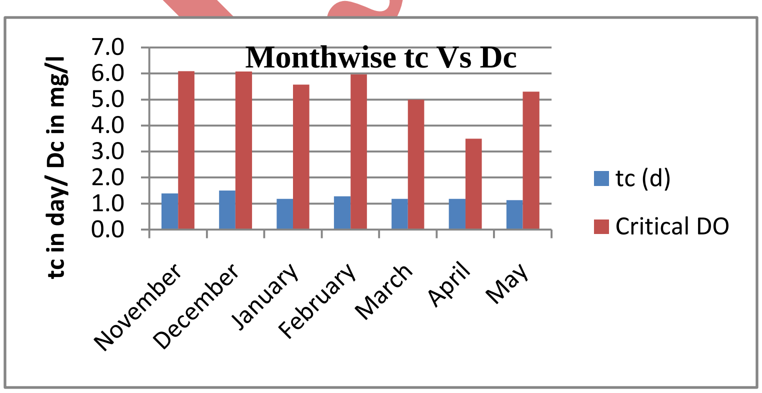
Let us consider the stretch of Chowara- Aluva during 2012-2013 for further discussions.

Fig-4 Month wise BOD and Initial Discharge



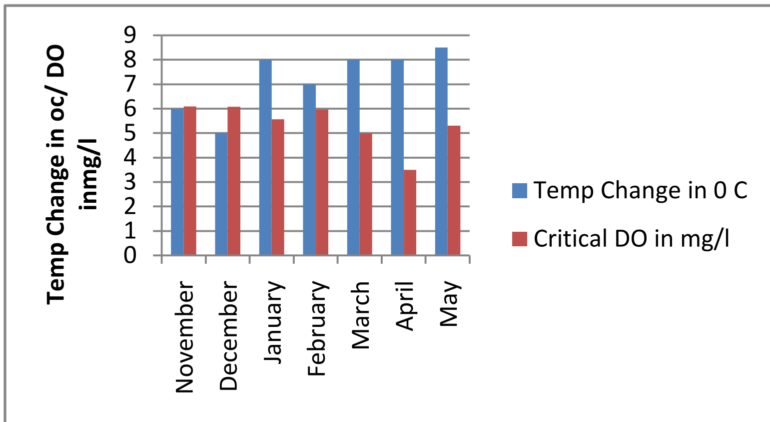
(Fig-4) describes about the BOD_5 Initial organic load variation at Chowara - Aluva stretch during 2012-2013. The figure indicates that the organic load disposal in this stretch is more during April or the concentration is high due to low flow. Whereas the same is low during January – February months. This gives an indication that the aeration requirement during the period is reduced and the abuse of river during these months is less compared to other lean periods.

Fig-5 Month wise Critical time and Critical Oxygen Deficiency



(Fig-5) describes about the critical time and critical Oxygen deficiency variation at Chowara - Aluva stretch during 2012-2013. The figure indicates that the highest critical oxygen deficiency is during November and December months. This indicates that the degradation is less during the period and more attention is to be given during the period to protect the river.

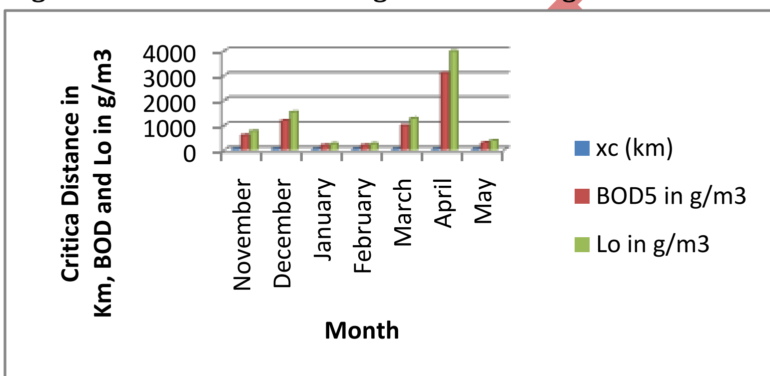
Fig-6 Month wise Temperature Change and Critical DO



(Fig-6) describes about the critical Dissolved Oxygen variation due to change in temperature at Chowara - Aluva stretch during 2012-2013. The figure indicates that the highest critical oxygen deficiency indicates during November and December months when temperature change was low. This indicates that the

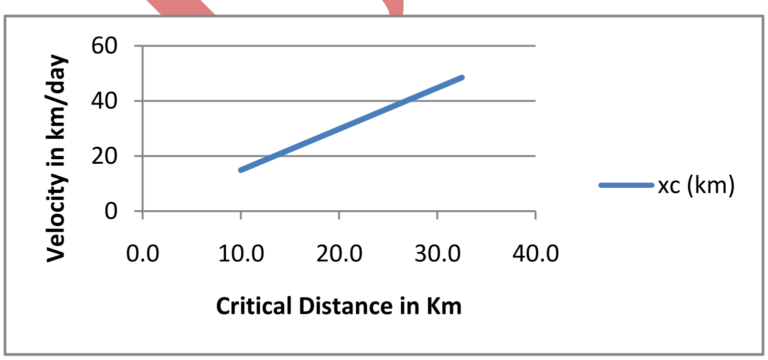
3change in temperature has a critical role in controlling the oxygen deficiency.

Fig-7 Effect of Initial Discharge in controlling Critical Distance



(Fig-7) describes about the critical distance variation due to the effect of initial discharge at Chowara - Aluva stretch during 2012-2013. The figure indicates that the highest critical oxygen deficiency indicates during November and December months when temperature change was low. This indicates that the 3change in temperature has a critical role in controlling the oxygen deficiency.

Fig-8 Effect of Velocity in controlling Critical Distance



(Fig-8) describes about the critical distance variation due to the effect of velocity change at Chowara - Aluva stretch during 2012-2013. The figure indicates that the critical distance is directly proportional to the prevailing velocity possessed by the flow when the river temperature and initial load is same. The r^2 value found for the relationship as 0.999.

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 the change of critical distance on assessing on the successive stretches, which indicates the presence of other loads which are not considered for this study.
- The study gives indication to the authorities concerned about the possibilities of the locations of disposals of untreated or under treated organic wastes.
- The study reveals that the critical distance is directly proportional to the flow if the temperature and other initial parameters kept constant.
- The study gives strong idea to find out the memory time and the assimilation capacity of the river which will be more beneficial to take appropriate actions to protect the river.

REFERENCES

Journal Papers

[1] Monica Achieng Owili, Assesment of Impact of Sewage Effluents on Coastal Water Quality in Hafnarfjordur, Iceland, Kenya, *Marine and Fisheries Research Institute, Kisumu, Kenya.*

[2] Ravindra K., Ameena, Meenakshi, Monika, Rani and Anubha K., Seasonal Variations in Physico–Chemical Characteristics of River Yamuna in Haryana and its Ecological Best-Designated Use, *Journal for Environmental Monitoring*, 2003, Vol. 5, PP 419-426.

[3] N.N.Menon, A.N.Balchand and N.R.Menon, Hydrobiology of the Cochin Backwater System – a Review, *Hydrobiologia*, 2000, Vol. 430, PP 149–183.

[4] M.M.Prabhakaran and G Resmi, Significance of Estuary Discharges in Controlling Salinity – A Case Study on Kochi Water Supply Scheme, *International Journal of Advance Research in Science and Engineering, IJARSE, Vol. No.2, Issue No.9, September 2013*, PP15-25

Books

[5] Metcalf and Eddy, *Wastewater Engineering – Treatment, Disposal, Reuse*, Tata McGraw-Hill, Second Edition, 1979.

[6] American Public Health Association (APHA), 1985, *Standard Methods for the Examination of Water and Wastewater*, Washington, 20th edition.

Proceedings paper

[7] J.A.Adakole, D.S.Abulode and M.L.Balarabe, Assessment of Water Quality of a Man-made Lake in Zaria, Nigeria, *Proceedings of Taal 2007: The 12th World Lake Conference*: 1373-1382.