# Water Quality Modelling for Oxygen Depletion in Thenkarai Pond

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**Abstract -** *Mathematical Model used to stimulate the water quality and the processes of self-purification of water bodies are important tools to support the water resources management. A framework of Dissolved oxygen (DO) modelling of the Thenkarai pond has been developed based on a combination of laboratory measurement and field and monitoring data. The model is based on the basic principles of the Streeter Phelps model equation. The main objective of the present study was to develop and demonstrate the use of a rather simple water quality model as a tool for the evaluation of alternative water management scenarios for the pond. The model is an extension of the Streeter-Phelps model and takes into account the physic-chemical and biological processes most relevant to modelling the quality receiving water bodies. To calibrated the results in various time interval with oxygen deficit based on the Oxygen sag curve. The analysis of the oxygen sag curve can be easily done by the superimposing the rates of deoxygenation and reoxygenation as suggested by the Streeter-Phelps analysis. Based on the results, a definite trend of dissolved oxygen concentrations was observed in the pond*

*Key Words*:  **Streeter's Phelps model, Oxygen sag curve, Dissolved oxygen etc.,**

## 1. INTRODUCTION

Water quality models are important tools to test the effectiveness of alternative management plans on the water quality of the respective water bodies. It is well known that steady state water quality models are simpler than dynamic models and require fewer input data. More complex water quality models (1- D, 2-D, or even 3-D) have also been developed and extensively been applied to evaluate the response of a river water quality to several management scenarios. Many of these water quality models are basically extensions of the simple BOD-DO model (e.g., QUAL2K) whereas there are other more detailed analytical ecological models (e.g., MIKE-11-ECOLAB, WASP, DELFT 3D WAQ, SOBEK River and IWA River Water Quality Model). The main objective of the project is to determine the DO and BOD levels for different intervals in the Tank, and calculate the De-oxygenation and Re-aeration rate in the pond for different time intervals also Predict the Dissolved Oxygen by using Streeter Phelps Equation. The Scope of the project is the Water quality models can be valuable tools for the assessment and Management of Aquatic Ecosystem. Prediction of Dissolved Oxygen at various time intervals is a futuristic approach and can help us maintain optimum DO in the tank

### 1.1 DISSOLVED OXYGEN

The dissolved oxygen present in sewage is very important, because while discharging the treated sewage into some river stream, it is necessary to ensure at least 4 ppm of D.O. In otherwise, fish are likely to be killed, creating nuisance near the vicinity of disposal. The dissolved oxygen in fresh sewage depends upon temperature. If the temperature of sewage is more, the D.O content will be less. The solubility of oxygen in sewage is 95% of that distilled water. The D.O content of sewage is generally determined by the Winkler's method**.**

## 2. STREETER PHELPS PRINCIPLE

The classical way of solving for the dissolved oxygen sag equation is the Streeter – Phelps equation, which dates back to 1925 (Streeter – Phelps 1925; Tchobanoglous and Schroeder, 1984). The Streeter – Phelps equation is an algebraic equation derived by integrating the differential equation governing the oxygen sag. Thus, the numerical method is an all-around better predictor than the Streeter- Phelps model, applicable for all oxygenation and de-oxygenation constants, regarding of their values. The Streeter-Phelps model describes "as oxygen demand decreases in a river or stream along a certain distance by degradation of biochemical oxygen demand. Changes in the oxygen content of polluted waters over time can be studied by using the dissolved oxygen sag curve". In other words, "This differential equation states that the total change in oxygen deficit is equal to the difference between the two rates of de-oxygenation (K1) and re-aeration (K2) at any time"

## 2.1 OXYGEN SAG CURVE

The curve obtained when the concentration of dissolved oxygen in a river into which sewage or some other pollutant has been discharged is plotted against the distance downstream from the sewage outlet. Samples of water are taken at areas upstream and downstream from the sewage outlet. The presence of sewage reduces the oxygen content of the water and increases the biochemical oxygen demand. This is due to the action of saprotrophic organisms that decompose the organic matter in the sewage and the process use up the available of oxygen.
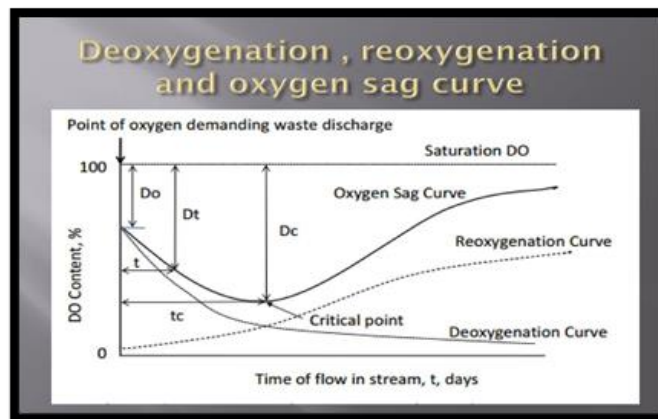


**Fig -1: Oxygen Sag Curve**

## 3. STUDY AREA

For this study area, Thenkarai pond is located at vadaipatti taluk of Madurai district. As of a 2001 Indian census, had a population of 21,780. There is a bifurcated river of Vaigai runs south of the small township. Its paddy field and plantain field are source for the people who live around the pond. The catchment of the area in the Thenkarai Pond around 93.9 ha as shown below fig.
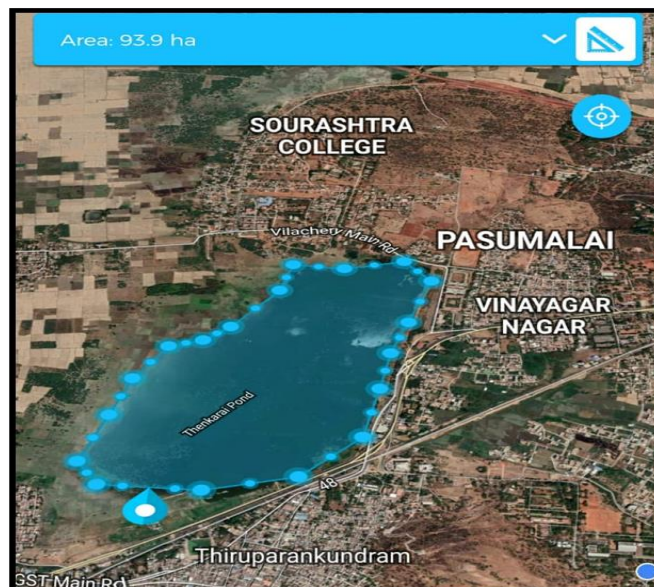


**Fig -2: Study Area**

## 3.1 SAMPLE COLLECTION

The Samples can be collected from the Thenkarai pond at early morning (6 am to 8am) at various location. Thenkarai is 25km west from Madurai city and is situated in the south bank of river Vaigai.

**Fig -3: Thenkarai Pond**



**Fig -4: Sample Collection**

## 3.2 MATHEMATICAL MODELLING

Based on the Streeter – Phelps principle, to derive the mathematical modelling of Dissolved oxygen. The rate at which DO disappears from the Streams coincides with the rate of BOD Exhaustion.

$$r_D = K_1 L_t$$

$$r_R = -K_2 D$$

$$\frac{dD}{dt} = r_D + r_R$$

$$\frac{dD}{dt} = K_1 L_t - K_2 D$$

Where,

$$L_t = L_0 e^{-K_1 t}$$

$$\frac{dD}{dt} = K_1 L_0 e^{-K_1 t} - K_2 D$$

$$\frac{dD}{dt} + K_2 D = K_1 L_0 e^{-K_1 t} \text{----------- (A)}$$

Multiply by $e^{K_2 t}$ on both sides, we get

$$\frac{dD}{dt} e^{K_2 t} - K_2 D (e^{K_2 t}) = K_1 L_0 e^{-(K_1 + K_2) t}$$

$$d (e^{K_2 t} D) = K_1 L_0 e^{(K_2 - K_1) t} dt$$

Integrating on both sides, we get

$$(e^{K_2 t} D) = K_1 L_0 \left[ \frac{e^{(K_2 - K_1) t}}{K_2 - K_1} \right] + C \text{--------- (B)}$$

Apply Boundary Condition, $D = D_0$ ; t = 0

$$(e^{K_2(0)} D_0) = K_1 L_0 \left[ \frac{e^{(0)}}{K_2 - K_1} \right] + C$$

$$C = D_0 - K_1 L_0 \left[ \frac{1}{K_2 - K_1} \right]$$

Sub the 'C' Value in equation (B),

$$(e^{K_2 t} D) = K_1 L_0 \left[ \frac{e^{(K_2 - K_1)t}}{K_2 - K_1} \right] + D_0 - K_1 L_0 \left[ \frac{1}{K_2 - K_1} \right]$$

Divide by $e^{K_2 t}$ on both sides, we get

$$D = \left( \frac{K_1 L_o}{K_2 - K_1} \right) \frac{e^{(K_2 - K_1)}}{e^{K_2 t}} + \frac{D_0}{e^{K_2 t}} - \frac{K_1 L_o}{K_2 - K_1} \left( \frac{1}{e^{k_2 t}} \right)$$

$$D = D_0 e^{-K_2 t} + \left( \frac{K_1 L_o}{K_2 - K_1} \right) e^{-K_2 t} \left[ e^{(K_2 - K_1)} - 1 \right]$$

$$D = D_0 e^{-K_2 t} + \left( \frac{K_1 L_o}{K_2 - K_1} \right) \left[ e^{-K_1 t} - e^{-K_2 t} \right]$$

On Re-arranging the above equation,

$$\mathbf{D = D_0 e^{-K_2 t} + \left( \frac{K_1 L_o}{K_2 - K_1} \right) \left[ e^{-K_2 t} - e^{-K_1 t} \right]}$$

Where,

D   **-**   Oxygen Deficiency

$D_o$   -   Initial dissolved oxygen

$k_1$   -   Rate of De-oxygenation

$k_2$   -   Rate of Re-aeration

t   -   Time Consumed

$L_o$   -   Ultimate BOD Concentration

### 3.3 STANDARDS FOR $k_a$ & $k_d$ @ 20°C

a) De-Oxygenation Values:($k_d$)

      1) For Summer – 0.14 per day

      2) For Winter – 0.12 per day.

b) Re-aeration Values:($k_a$)

      The re-aeration value of the various water body are given below,

**Table -1: Standard Values for Re-aeration**

| SL. No | Water Body | $k_a$ @ 20°C (Per day) |
|:---:|---|:---:|
| 1 | Small Ponds | 0.1-0.23 |
| 2 | Sluggish and Large lake | 0.23-0.35 |
| 3 | Large lake with Low velocity | 0.35-0.46 |

| 4 | Large lake with High velocity | 0.46-0.69 |
|---|---|---|
| 5 | Swift Streams | 0.69-1.5 |
| 6 | Rapid and Waterfalls | More than 1.5 |

## 4. RESULTS AND DISCUSSION

### 4.1 SAMPLE CHARACTERISATION

The Characteristics of the samples like pH, Turbidity and Electric conductivity was calculated based on APHA standards.

1) The sample of the pH value is measured by using pH meter, for my sample they are Alkaline in nature.

2) The sample of the Turbidity value is measured by using Nephelometer based on APHA Standard. In these samples is normally more turbid, resembling dirty dish wash, fruit skins and soaps etc.

3) Electric conductivity can be measured by using Conductivity meter, they samples will be highly contaminated.

**Table -2: Characteristics of Samples**

| SL. No | Characteristics | Values |
|---|---|---|
| 1 | pH | 7.9 |
| 2 | Turbidity | 9.9NTU |
| 3 | Electric Conductivity | 524.1µs/cm |

### 4.2 DISSOLVED OXYGEN

The dissolved oxygen is the one of the most widely used indicators of overall ecological health of a body of water. The D.O content of the samples can be measured by using D.O probe, it is quantity of dissolved oxygen originally present. It is necessary to ensure at least 4 ppm of D.O, as otherwise all aquatic ecosystem mainly affected based on APHA standards.

**Table -3: DO Values**

| Days | Initial (mg/L) | Final (mg/L) | BOD @ 3days |
|---|---|---|---|
| 1st day | 3.5 | 1.5 | 2 |
| 2nd day | 2.4 | 1.6 | 0.8 |
| 3rd day | 5.8 | 2.5 | 3.3 |
| 4th day | 5.1 | 1 | 4.1 |
| 5th day | 3.7 | 1.8 | 1.9 |
| 6th day | 3.5 | 1 | 2.5 |
| 7th day | 4.8 | 1.6 | 3.2 |
| 8th day | 5.2 | 1.6 | 3.6 |

The dissolved oxygen in sewage is mainly depends upon the temperature. In my samples, the dissolved oxygen within permissible limits. In a volume of water that contains oxygen – demanding substrate and that is in contact with the air, both de-oxygenation and re-oxygenation will occur.
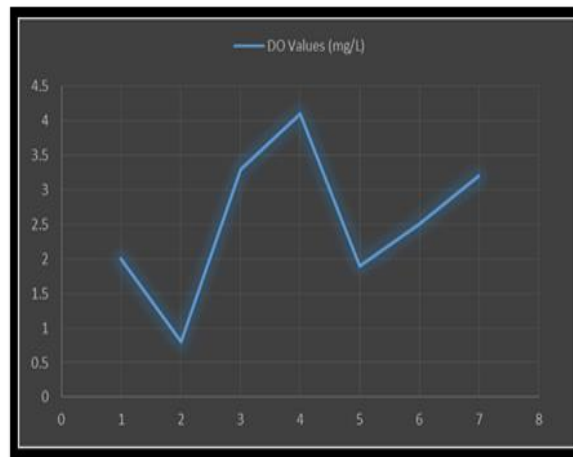
**Fig -5: Calibration of DO**

## 4.3 PREDICTION OF DO LEVELS

Based on the Streeter – Phelps equation, to calculate the Oxygen deficit, Critical Oxygen deficit and Critical time. A graph is drawn the various time vs. oxygen deficit. The following formula to be used for predicting the DO modelling.

$$L_0 \quad = \quad \frac{y_m}{(1-e^{-K_2 t})}$$

$$D \quad = \quad D_0 e^{-k_a t} + \frac{K_d L_o}{K_a - K_d}\left[e^{-k_d t} - e^{-K_a t}\right]$$

$$D_c \quad = \quad \frac{K_1}{K_2} L_0 e^{-K_1 t}$$

$$t_c \quad = \quad \ln\left(\frac{K_2}{K_1}\right)\left(\frac{1}{K_2 - K_1}\right)\left[1 - D_0 \frac{(K_2 - K_1)}{K_1 L_0}\right]$$

For calculation,

$$K_1 \quad = \quad 0.14/\text{day (for } 20°C)$$

$$K_2 \quad = \quad 0.23/\text{day (for } 20°C)$$

$$K_{1\,27°C} \quad = \quad K_{1\,20°C}\left[1.047\right]^{27°C\,-20°C}$$

$$= \quad 0.193/\text{day}$$

$$K_{2\,27°C} \quad = \quad K_{2\,20°C}\left[1.067\right]^{27°C\,-20°C}$$

$$= \quad 0.362/\text{day}$$

Generally, DO standard for $20°C$ = 9.17mg/L

To interpolation, we got DO for $27°C$,

$$\frac{9.17}{20°C} \quad = \quad \frac{A}{27°C}$$

$$A \quad = \quad 12.3795\text{mg/L} \,(D_o)$$

**Table -4: Predication of DO Values**

| Samples | $L_0$ (mg/L) | D (mg/L) |
|---|---|---|
| 1st day | 2.892 | 8.1996 |
| 2nd day | 1.553 | 5.6562 |
| 3rd day | 4.982 | 2.9109 |
| 4th day | 4.902 | 1.6396 |
| 5th day | 2.868 | 1.3160 |
| 6th day | 3.774 | 0.5506 |
| 7th day | 4.831 | -0.00077 |
| 8th day | 6.038 | 0.6500 |

The Oxygen deficit will be decreasing due to the temperature, de-oxygenation of the pond and other environmental conditions. Transfer of oxygen from the atmosphere to the pond is driven by an oxygen deficit in the water. According to the results, in order to achieve very low dissolved oxygen concentration, it is good for all aquatic ecosystem in the pond.
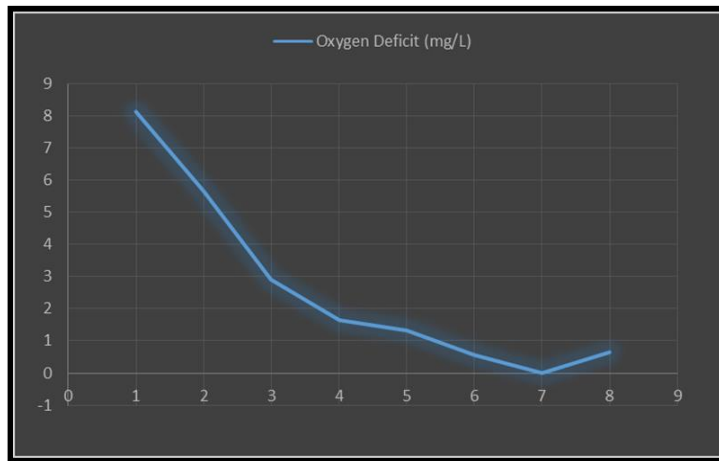


**Fig – 6: Predication of DO**

## 5. CONCLUSION

Based on the present study the use of simple water quality models as evaluating tools of alternative water resources management plans was evidenced. To predict the dissolved oxygen model was developed according to the basic principles of Streeter- Phelps equations. However, this study is an important step in the assessment of modelling parameters and characteristics of the sample is to be determined and compared with APHA standards. A fundamental feature of the classic Streeter– Phelps system of equations were derived in the pond. This study contributes towards a better understanding of pollution dynamics in the Thenkarai pond and draws attention to potential environmental problems that may occur. Based on the results, to predict the Dissolved oxygen modelling for the pond. From this study it was possible to support reliable models by mathematically and software tools like GLUE, QUAL 2K and improve the management of water resources.

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