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AN ESTIMATION OF TIME AND RATE OF AERATION TO INCREASE AND SUSTAIN DISSOLVED OXYGEN IN LAKE WATER MODEL

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ABSTRACT : Thermal Stratification, one of the physical parameters of the lake has a definite effect on the other chemical and biological process of the lake. Dissolved Oxygen is one of such parameter which is related to temperature distribution along the depth of waterbody. Thermocline is a region, which cutoff the dissolved oxygen supply from epilimnion region to hypolimnion region. This phenomenon causes death of fishes and other aquatic lives. So to enhance the quantity of dissolved oxygen in different layers of lake aeration process is required. In this paper an attempt has been made to estimate the required aeration time and rate, so that water can sustain required amount of dissolved oxygen for required time period.

INTRODUCTION : Water quality is closely linked to the water and energy budget, mixing, thermal stratification and other physical aspects of lake. Thermal stratification regulates different biological and chemical process in lakes, thus govern lake production and decomposition. Generally lake water stratifies into three different layers, well mixed upper layer, called epilimnion. The cooler and denser layer called hypolimnion. In between these two layers a narrow transition zone exists, which is called metalimnion. Where a sharp change in temperature gradient occur and is called thermocline, which prevent dissolved oxygen supply from epilimnion to hypolimnion [1]. The solubility of oxygen in water is affected by pressure as well as by temperature. Therefore, the equilibrium of oxygen of the atmosphere with the oxygen concentration in the water depends on the atmosphere partial pressure of oxygen. Hence, the elevation of the inland water body also influences the concentrations of oxygen [Wetzel, 1983] In extreme summer aquatic lives, especially fish are unable to stay at the epilimnion region and they have to stay in hypolimnion region. For the presence of thermocline region depletion of oxygen level takes place due to decomposition of aquatic life. To increase the oxygen level in the zone of deficiency of oxygen a engineering control is needed. There are several methods of engineering control which are stated below [2].

1. Point and non-point reduction sources of CBOD and NBOD through reduction of effluent concentration and/or effluent flow.
2. Aeration of the effluent of a point source to improve initial value of DO.
3. Increase in river flow through low flow augmentation to increase dilution.
4. Instream reaction by turbines and aerators.
5. Control of SOD through dredging or other means of inactivation.
6. Control of nutrients to reduce aquatic plants and resulting DO variations.

Among the above method aeration through pump is used here. The objective of the study described herein is to estimate the rate and time of pumping so that desired oxygen level can be achieved. An attempt also made to estimate the cost for aeration for certain surface area of water.

CONCLUSION : To maintain the DO level up to the desired level if aeration is necessary, then the chart developed from the experimental result would be helpful. Since the experiment has been done in a laboratory setup, in reality there would be an effect of scale factor and effect of other parameters of sources and sinks of DO influencing sustenance of DO in a lake, in spite of that it would be able to predict the behaviour of DO sustenance in lake. It is seen from the experiment that, to maintain the required DO level for a given period of time, continuous aeration is not required. Hence a suitable chart of DO variation for different time duration of aeration would be very helpful for the economy and cost effectiveness in view. An extensive study is needed for generation of such site specific chart.
An estimation of time and rate of aeration to increase and sustain dissolved oxygen in lake water

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Abstract: Thermal Stratification, one of the physical parameters of the lake has a definite effect on the other chemical and biological process of the lake. Dissolved Oxygen is one of such parameter which is related to temperature distribution along the depth of waterbody. Thermocline is a region, which cutoff the dissolved oxygen supply from epilimnion region to hypolimnion region. This phenomenon causes death of fishes and other aquatic lives. So to enhance the quantity of dissolved oxygen in different layers of lake aeration process is required. In this paper an attempt has been made to estimate the required aeration time and rate, so that water can sustain required amount of dissolved oxygen for required time period.

Keywords: Thermal Stratification, Thermocline, Dissolved Oxygen

1. Introduction

Water quality is closely linked to the water and energy budget, mixing, thermal stratification and other physical aspects of lake. Thermal stratification regulates
different biological and chemical processes in lakes, thus govern lake production and decomposition. Generally lake water stratifies into three different layers, well mixed upper layer, called epilimnion. The cooler and denser layer called hypolimnion. In between these two layers a narrow transition zone exists, which is called metalimnion. Where a sharp change in temperature gradient occurs and is called thermocline, which prevent dissolved oxygen supply from epilimnion to hypolimnion. The solubility of oxygen in water is affected by pressure as well as by temperature. Therefore, the equilibrium of oxygen of the atmosphere with the oxygen concentration in the water depends on the atmosphere partial pressure of oxygen. Hence, the elevation of the inland water body also influences the concentrations of oxygen [Wetzel, 1983]. In extreme summer aquatic lives, especially fish are unable to stay at the epilimnion region and they have to stay in hypolimnion region. For the presence of thermocline region depletion of oxygen level takes place due to decomposition of aquatic life. To increase the oxygen level in the zone of deficiency of oxygen a proper mixing (i.e. stirring) of oxygen rich layer with oxygen deficit layer is required or aeration is required. Aeration can be done by pumping water through air. Oxygen has an affinity to water. The solubility of oxygen is affected nonlinearly by temperature and increases considerably in cold water [Wetzel, 1983]. The objective of the study described herein is to estimate the rate and time of pumping so that desired oxygen level can be achieved. An attempt also made to estimate the cost for aeration for certain surface area of water.

2. Experimental Setup

To observe the dissolved oxygen phenomenon in a lake an experiment has been performed in a tank of dimension $1.7m \times 1.8m$ and depth of water was $0.8m$ which
can be considered as a prototype model of a water reservoir or a lake. For aeration centrifugal pump of specification 50 Hz, 1 HP, Head of 22.0m, Capacity range of 4.10-2.20 has been used. Aeration process lasts for 0.667 hours. Decay of oxygen has been allowed for 23.333 hours. Dissolved Oxygen measurements have been taken by DO Meter. Using these results an attempt has been made to estimate cost of aeration to enhance the dissolved oxygen content of lake water, which is stated in result and discussion part.

3. Methodology

The experiment has been done in a tank of 1.327 m² surface area. The water has been thrown in position O as shown in Figure 1. The measurements have been taken in different position along the depths which is shown in Figure 2.

![Figure 1. Schematic diagram of the position of surface area of pumping (aeration).](image1)

![Figure 2. Schematic diagram of the (depth wise).](image2)

4. Results and Discussion

The experimental values are graphically plotted in fig. 3 and fig. 4. Fig. 3 shows the different behavior of DO in different phase of pumping. Fig. 4 indicates the average
overall DO content in the experimental tank. Thus both figures show the extent of solubility, retaining capacity of water and decay behaviour. If dissolved oxygen is represented by $do$ and pumping time is represented by $t$, then it can be said that $do = \psi(t)$ and using polynomial curve fitting method in Matlab 6.1 we get equation 1 for 0.667 hour pumping duration, equation 2 for 0.5 hour pumping duration and equation 3 for 0.333 hour pumping duration.

![Dissolved oxygen variation during and after pumping (aeration)](image)

Fig 3. Dissolved oxygen variation during and after pumping (aeration)
Fig 4. Dissolved oxygen variation for different pumping duration.

In fig 3, variation of dissolved oxygen (DO) is shown in different time interval of aeration and from fig 4, it is clearly seen that for the first session of aeration DO increase rapidly and after cutting off the aeration DO increases for certain duration. After reaching the peak, DO starts to decay. Fig 4 indicates that if certain level of DO is required, then different values of $t$ can be obtained after solution of the equation 1, equation 2 and equation 3. The positive real roots of the solutions would indicate the duration of sustenance time of required DO level. Thus suitable curve for required DO level with required sustenance period could be chosen. It may also be determined from the figures directly. From fig.4, it is seen that to achieve a given level of DO for a required sustenance period, continuous aeration is not required. It is non-scientific and non-economical also. Keeping the economical aspect in view, a calculation to estimate the cost of aeration for running the air pump has been attempted for three modes of power (electricity, diesel and petrol) available to run the engine.
Calculation for estimation of cost of Pumping (aeration):

The calculated value of cost estimation of aeration is tabulated in Table 1

<table>
<thead>
<tr>
<th>Cost Estimation</th>
<th>Pumping duration 0.677 hr.</th>
<th>Pumping duration 0.500 hr.</th>
<th>Pumping duration 0.333 hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity @ Rs. 2.52/- per kW-hr</td>
<td>Rs.3.35/-</td>
<td>Rs. 2.51/-</td>
<td>Rs. 1.67/-</td>
</tr>
<tr>
<td>Diesel @ Rs. 25/- per litre</td>
<td>Rs.6.28/-</td>
<td>Rs.4.68/-</td>
<td>Rs.3.13/-</td>
</tr>
<tr>
<td>Petrol @ Rs. 41/- per litre</td>
<td>Rs.14.56/-</td>
<td>Rs.10.89/-</td>
<td>Rs.7.27/-</td>
</tr>
</tbody>
</table>

From Table 1 it is seen that the electricity is the most economical power generation source for all cases (different time duration of aeration). But in rural scenario where electricity is not available, there diesel would be most economical power generation source.

5. Conclusion

From the simulated thermal profile, a simulated dissolved oxygen profile can also be obtained, which could be helpful for the fishermen to understand that whether the DO level is sufficient or not for the sustenance of aquatic life. If aeration is necessary, the chart developed from the experimental result would be helpful. Since the experiment has been done in a laboratory setup, in reality there would be an effect of scale factor and effect of other parameters of sources and sinks of DO influencing sustenance of DO in a lake, in spite of that it would be able to predict the behavior of DO sustenance in lake. It is seen from the experiment that, to maintain the required DO
level for a given period of time, continuous aeration is not required. Hence a suitable chart of DO variation for different time duration of aeration would be very helpful for the fishermen keeping the economy and cost effectiveness in view. An extensive study is needed for generation of such site specific chart.

References


