## WATER, SANITATION AND HYGIENE: CHALLENGES OF THE MILLENNIUM

## Rational approach for design of Cascade aerator

C.S. Thakre and M.N. Hedaoo, India

THE TERM AERATION in Water Treatment practices is applied to that process in which water is brought into intimate contact with air. In the present day practice, aeration finds wide application to improve the physical and chemical characteristics of water for its domestic, commercial and industrial use. Cascade aerators are the most widely used aerators in the water treatment practices. Many varieties of cascade aerators are in use.

Pilot plant studies are often desirable in connection with an engineering analysis of the applicability of aeration process to water treatment problems. Results of few pilot plant runs, using relatively simple equipment, may if properly analyzed, provide useful aerator design criteria.

The literature on design practice of aerator reveals that systematic studies to rationalize the design of this unit have not been made. At present the design of cascade aerator is carried out purely on empirical basis. The design of cascade aerator is usually carried out on the basis of 0.015 to 0.045 sq.m of plan area per cum/ hour of flow . It does not speak of any oxygen transfer requirements of water treatment plant.

The paper presents the rational approach for cascade aerator design based on oxygen addition on the basis of actual plant studies conducted at three different water works having 100 MLD, 30MLD \& 20 MLD capacity.

The present paper highlights the data and the results obtained during the study conducted at Wena water works, Nagpur of 30 MLD capacity.

## Methodology

In general the Methodology for determination of oxygenation capacity of cascade aerator consists of assessment of dissolved oxygen at various positions of the aerator using modified winkler's method as per standard methods. An assessment of time of exposure is separately carried out by using tracer studies with respect to flow.

The performance of cascade aerator would certainly depend on the time of exposure. In a practical system however, this exposure time may be significantly different than the theoretical values. The conventional methods of estimation of residence time can not be used, since the magnitude of the time is only a few seconds. Tracer studies have been conducted to assess the actual exposure time at Wena water works, Nagpur by using equipment of high precision.

Sectional view of the cascade aerators along with the sampling position is presented in Figure. 1.


Figure 1. Sectional view of Cascade aerator

## Observations

Time of Exposure in aeration system
The time of exposure in the aeration system is the time taken by water to flow from the upstream to downstream positions of the system. For this purpose a graphs have been plotted using the data collected doing the tracer studies undertaken at Wena water works. The nature of sponding to any desired flow through the system.


It also reveals that as the flow through cascade aerator increases, the time of exposure decreases for all positions. This is evident from the converging nature of the curve.

During the study, it was also observed that the actual time of exposure at the plant is significantly higher than the theoretical time of exposure.

## Dissolved oxygen changes through the aerator

The data collected during the studies regarding D.O. values has been classified to observe the oxygen level changes with reference to temperature ranges of 20-24;24-28 and 28-32 ${ }^{\circ} \mathrm{C}$. and flow ranges of 4.5-6.5 and 6.5-8.5 MGD for the system 1-6 and 1-7. The abstract of these observations for D.O. increase with flow and temperature is presented in Table- 1.

## Assessment of reaeration constant and oxygenation capacity

The assessment of Reaeration constant at $20^{\circ} \mathrm{C} .\left(\mathrm{KLa}_{20}\right)$ and Oxygenation capacity at $20^{\circ} \mathrm{C}$. (Oco) has been carried out by using computer model for the entire data collected during the study. The whole data is finally complied at the end of the program. The program also includes the determination of standard deviation and $95 \%$ confidence limits.

## Correlation of data

It is observed that it is not possible to satisfactorily correlate the entire data between $\mathrm{KLa}_{20}$ and $\mathrm{A}_{\mathrm{P}}$ or $\mathrm{A}_{\mathrm{T}}$ This fact is also substantiated by the low correlation index ( 0.444 for $\mathrm{KLa}_{20}$ $\mathrm{v} / \mathrm{s} \mathrm{A}_{\mathrm{p}}$ and 0.405 for $\mathrm{KLa}_{20} \mathrm{v} / \mathrm{s} \mathrm{A}_{\mathrm{T}}$ ). The systemwise variation of $\mathrm{KLa}_{20}$ with respect to $\mathrm{A}_{\mathrm{P}}$ or $\mathrm{A}_{\mathrm{T}}$ indicates that the $\mathrm{KLa}_{20}$ value is vary specific with respect to a particular system.


Figure 3. Sectional view of Cascade aerator

By taking clue from correlation for $\mathrm{Oco} \mathrm{v} / \mathrm{s} \mathrm{A}_{\mathrm{p}}$ or $\mathrm{A}_{\mathrm{T}}$ for a typical result, an attempt is made to correlate the entire data for Oco v/s $A_{P}$ and Oco v/s $A_{T}$. The variation of oxygenation capacity ( Oco ) with plan area $\left(\mathrm{A}_{\mathrm{p}}\right)$ and total area $\left(\mathrm{A}_{\mathrm{T}}\right)$ is presented in Figure-3.

The line of best fit using least square method is also depicted in figure 3 for the entire data collected.

## Discussion

The data presented in table 1 indicates that as the temperature increases, there is increase in dissolved oxygen addition. Similarly the dissolved oxygen increase in cascade aerator is inversly proporional to the flow.

The increase in D.O. addition at higher temperature may be attributed due to the increase in molecular diffusibilily at higher temperature. The decrease in D.O. addition through cascade aerator with increase in flow may be due to increase in thickness of liquid film and thus lesser area exposed per unit volume of water at higher flow rate.

Figure 3 shows that Oco varies with $A_{p}$ or $A_{T}$ more or less linerarly at
least in the initial stages. The result of the computer analysis for the typical run also indicates that the correlation index is 0.928 for Oco $v / \mathrm{s}_{\mathrm{p}}$ and 0.953 for

Oco v/s $\mathrm{A}_{\mathrm{T}}$. The Figure 3 indicates that the relashionship between Oco and $A_{p}$ or
$\mathrm{A}_{\mathrm{T}}$ can be expressed by the following equations.

- Oco= $0.19676 \mathrm{~A}_{\mathrm{p}}+0.5180$
- $\mathrm{Oco}=0.1123 \mathrm{~A}_{\mathrm{T}}+1.786$

This study indicates that the correlation index for Oco with respect to $A_{p}$ or $A_{T}$ is quite high. It may further be seen that the data of Oco with respect to $\mathrm{A}_{\mathrm{T}}$ orrelates slightly better than $A_{p}$. The total area expose may therefore serve better for design of cascade aerator than only the plan area.

## Conclusions

The following conclusions can be drawn from the study.

- As the flow through the cascade aerator increases, the time of exposure decreases for all position. This is evident from the converging nature of the curves.
- The actual time of exposure at the plant is significantly higher than theoretical time of exposure.
- Other factors being constant, the D.O added to the water by cascade aerator increases as the temperature in creases.
- D.O. addition to the water by cascade aerator is inversly proportional to flow of water.
- Satisfactory correlation can be shown between Oco and $\mathrm{A}_{\mathrm{p}}$ or $\mathrm{A}_{\mathrm{T}}$
- The total area of cascade aerator may serve better as design parameter in place of only the plan area.
- The relationship between the Oco an the total area of cascade aerator may serve more rationally as the basis of design of cascade aerator, compaired to the present practice of empirical design.
- Further studies on cascade aerator at different water works with reference to surface roughness may be

Table 1. Abstract of data for D.O. Increase with flow and temperature

| systems | Flow Range in MGDD | Temp Range in ${ }^{\circ} \mathrm{C}$ | Average D.O. increase $\bar{X}$ | SX | $\begin{aligned} & P_{1} \\ & 95 \% \text { confide } \end{aligned}$ | $P_{2}$ <br> ence limits |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1-6 | $\begin{aligned} & 4.5-6.5 \\ & (5.230) \end{aligned}$ | 20-24 | 1.2134 | $0.06614$ |  | 1.27954 |
|  |  | 24-28 |  |  |  |  |
|  |  | 28-32 |  |  |  |  |
|  |  | *(28.63) |  |  |  |  |
|  | $\begin{aligned} & 6.5-8.5 \\ & (7.855) \end{aligned}$ | $\begin{aligned} & 20-24 \\ & 24-28 \end{aligned}$ |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  | 28-32 | 1.1674 | 0.06155 | 1.10584 | 1.2289 |
|  |  | *(28.797) |  |  |  |  |
| 1-7 | $\begin{gathered} 4.5-6.5 \\ (5.85) \end{gathered}$ | 20-24 | $0.9012$ | $0.1800$ | $0.7212$ | $1.0812$ |
|  |  | 24-28 |  |  |  |  |
|  |  | *(27.1) |  |  |  |  |
|  | (5.48) | $\begin{gathered} 28-32 \\ *(28.56) \end{gathered}$ | 1.2366 | 0.1585 | 1.0789 | 1.39511 |
|  |  |  |  |  |  |  |
|  | $\begin{aligned} & 6.5-8.5 \\ & (8.338) \end{aligned}$ | $\begin{array}{r} 20-24 \\ *(23.1) \end{array}$ | 0.8551 | 0.3030 | 0.5520 | 1.1581 |
|  |  |  |  |  |  |  |
|  |  | 24-28 | 0.8809 | 0.09636 | 0.78454 | 0.97726 |
|  | (8.44) | *(25.915) |  |  |  |  |
|  |  | $\begin{gathered} 28-32 \\ *(28.86) \end{gathered}$ | 1.0243 | 0.09664 | 0.92766 | 1.1209 |
|  | (8.04) |  |  |  |  |  |

desirable for better understanding and developing appropriate rational approach for design of cascade aerator.

## References

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## Abbreviations

MLD - Million Litres per day
MGD - Million gallons per day
D,O. - Dissolved Oxygen, Kg/hr
$\mathrm{KLa}_{20}$ - Reaeration constant at $20^{\circ} \mathrm{C}$ per Sec.
Oco - Oxygenation capacity, $\mathrm{Kg} / \mathrm{hr}$
$A_{p}$ - Plan Area in sq. m.
$A_{T} \quad$ - Total area in sq. m.
C.S. Thakre and M.N. Hedaoo, India.

