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Performance Evaluation of Inclined Cascade Aerator (ICA)

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Abstract—*Aeration system is very much essential for the management of pond. Various types of aeration systems have been developed over the years to maintain the oxygen level in a pond but economical, efficient and eco-friendly is the urgent needed for the time being. Inclined cascade aeration system will be the best alternative for that. In this system of aeration, standard oxygen transfer rate and standard aeration efficiency is very much higher as compared with the other type of aeration system. It is found that the SOTR value is range from 0.02 to 0.069 Kg O_2/ h and the SAE value range from 0.007 to 0.018 Kg O_2/ KWh. The best result drawn in this investigation for the standard aeration efficiency is value as 0.069 Kg O_2/ KWh with provided seven numbers of barriers of height 10 cm and slope height. The standard oxygen transfer rate maximum is found as 0.069 Kg O_2/ h with provided seven numbers of barriers of height 10 cm and slope height of 2m.*

Keywords: *Aeration, Standard aeration efficiency, Standard oxygen transfer rate*

1. INTRODUCTION

Aeration is the primary means by which the wastewater replenishes its oxygen content. It is often required in water bodies that suffer from anoxic conditions, such as sewage discharges, agricultural run-off or in wastewater treatment plants. Aeration can be achieved through the infusion of air into the bottom of the water bodies or by surface agitation. Aeration provides wastewater with its requirement from oxygen to support aerobic treatment and stabilization of wastewater. Cascade aerators are probably most widely used aerator in the field of waste water treatment. Cascade aerator introduced air into a water flow in order to oxidize iron and reduce dissolved gases. With Cascade Aerators, aeration is accomplished by natural draft units that mix cascading water with air that is naturally inducted into the water flow. Cascade water is pumped to the top of the aerator, and cascades over a series of trays. Air is naturally inducted into the water flow to accomplish iron oxidation and some reduction in dissolved gasses.

Aeration typically raises the dissolved oxygen content of the raw water. In most cases, this is beneficial since a greater concentration of dissolved oxygen in the water can remove a flat taste. However, too much oxygen in the water can cause a variety of problems resulting from the water becoming supersaturated. Supersaturated water can cause corrosion (the gradual decomposition of metal surfaces) and sedimentation problems [1]. In addition, air binding occurs when excess oxygen comes out of solution in the filter, resulting in air bubbles which harm both the filtration and backwash process.

Aeration can also cause other problems unrelated to the supersaturated water. Aeration can be a very energy-intensive treatment method which can result in overuse of energy. In addition, aeration of water can promote algal growth in the water and can clog filters.

Many research works have been conducted on stepped cascade, which are mainly concerned about dam spillway. To date, no literature exists on the development of an inclined cascade system. In aquaculture the inclined cascade may be used for preaerating the groundwater or surface water before discharging into the pond or as a post aeration unit [4], i.e., aerating the effluent again before discharging into surrounding water bodies. The inclined cascade design may also be adopted in raceway system provided the topography allows for the necessary slope for gravity aeration. For the economical point of view, there is urgent need for the economic and more efficient aerators system. In this project, efficiency and economic is given more importance.

1.1 Objective

Keeping in view of the above points, the present investigation was focused on determining the effect of various geometric conditions on inclined cascade aerator with the following specific objective:

Determine the SOTR and SAE at different slope with barrier and without barrier condition.

2. MATERIALS AND METHOD

This part comprises the details characteristics of the inclined cascade aerator, experimental tank, pump, motor, chemicals, instruments and methods used for measuring the dissolve oxygen concentration, power consumption.

2.1 Components of Inclined Cascade Aerator system

The inclined cascade aerator consists of inlet and outlet tank, slope, barrier, speed control unit and supporting structure. The inclined cascade aerator consists of inlet tank, outlet tank, slope and barriers. The water from the inlet tank passes through the slope and jump over the barrier, in this way, water comes in contact with air, the oxygen from the air mix water and increases the level of dissolve oxygen in the water and this water collect into the outlet tank. The water from the outlet tank is circulated by the pipe which is connected with the inlet tank, with help of pump and the above process is continued and in this way aeration takes place.

2.1.1 Inlet tank

Inlet tank is made of iron metallic sheet. The dimension of inlet tank is length 0.6m, breath 0.5m, height 0.6 m.

Fig. 1: Inlet Tank

2.1.2 Outlet tank

This tank is made of iron metallic sheet of dimensions, length 1.5 m, breath 1.5m and height 0.5 m. This tank is used to collect the aerated water.

Fig. 2: Outlet tank

2.1.3 Inclined part

The length of the inclined part is 3.68 m, breath is 0.5m. This inclined part is connecting the inlet and outlet tank. The water from the inlet tank is flows over through the inclined part and reaches the outlet tank.

Fig. 3: Inclined part

2.1.4 Barriers

The barriers are made of plywood, of different height 6cm and 10cm of 50.5 cm thickness. These barriers are fixed in the inclined part with the help of L-angle bar.

2.1.5 Metallic sheet

Metallic sheet are used for constructing the outlet and inlet tank.

2.1.6 Centrifugal pump

Centrifugal pumps are the most preferred hydraulic pumps used in domestic and industrial world. Centrifugal pumps are used to induce flow or raise pressure of a liquid. It is used to raise the pressure of the water so that the water flows from ground level to inlet tank. 5hp and 3 phase electric pump is used here.

2.1.7 Barriers

The barriers are made of plywood, of different height 6cm and 10cm of 50.5 cm thickness. These barriers are fixed in the inclined part with the help of L-angle bar. The barriers is inserted or used in this project mainly for the aeration of water. In order to make the turbulent flow and so that the water jump over the barrier and comes in contact with the air presents in the atmosphere, in which more surface of water will exposed to the air and hence more aeration.

2.2 Parameters of Inclined Cascade Aerator system

In this project, the following parameters are used

2.2.1 DO meter

DO meter is used to measure the dissolved oxygen (DO) present in the water, it is also measure the saturation level of oxygen, percentage of saturation. It is placed in the water present in the outlet tank.

2.2.2 Chemicals Used in the Experiment

In the experiment, two types of chemicals were used to deoxygenize the water, the chemicals are, sodium sulphite and cobalt chloride. Sodium sulphite used 10mg per litre volume of water and 0.1 mg cobalt chloride used per litre of water. Cobalt chloride is act as a catalyst in the experiment.

Fig. 4: Cobalt Chloride and sodium sulphite

2.2.3 Supporting Structure

In this project setup, two types of supporting structures are there, one is for support the inlet tank and another is for the outlet tank. The structure which supports the outlet tank is constructed by bricks of 1.2 m length and 2.4 m width and the inlet tank is placed on the supporting structure which made of iron angle bar, brick and cement mortars.

Fig. 5: Supporting Structures

2.2.4 Supporting software

In this experiment, a supporting software named as HYDRA S3 LT is used to operate the hydro meter. This software connects the hydro meter with the computer. This gives the readings of the different parameters such as temperature, level of oxygen (LDO), percentage of saturation level of oxygen (LDOs).

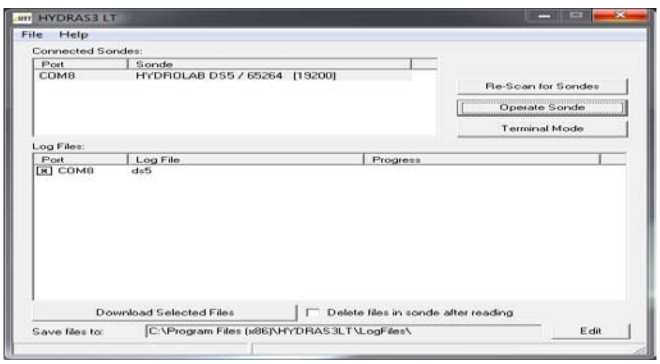


Fig. 6: Display of HYDRAS3 LT

2.3 Methods

2.3.1 Determine the SOTR and SAE at different slope with barrier and without barrier condition.

First pump the water into the outlet tank with the help of centrifugal pump, then measure the volume of water and dissolve oxygen (DO).

Secondly, water present in the outlet tank first deoxygenated with 10 mg/L sodium sulphite and 0.1 mg/L cobalt chloride .Then the water allowed to flow through the slope, which is consists of barriers, where we can change the numbers of barriers .By varying the numbers of barriers we observe, in which condition we can get maximum efficiency. We also check the flow of water through the slope without barriers. We have to check in which condition we can get maximum efficiency i.e. in which condition the aeration of water takes place and saturation level will occur within short time. The readings are taken by DO meter, which measures level of dissolve oxygen (LDO), saturation percentage level of dissolve oxygen, temperature. We have taken three trials, then we have taken the average of LDO, from this we can determine the saturation level of dissolved oxygen (LDOs). By the following formula

$$\boldsymbol{LDOs = \frac{last\ value\ average\ of\ LDO}{\%\ saturation\ level}}$$

We have to calculate the ln(LDOs – LDO) i.e.

$$\mathbf{ln}(\boldsymbol{LDOs - LDO})$$

Plot the graph between $\ln(LDOs - LDO)$ vs. time (1 min interval).From the graph we get a linear equation

$$\boldsymbol{y = mx + c}$$

We have taken the value of m as oxygen transfer coefficient at temperature T^0C (K_La_T), here K_La_T in min^{-1}, we convert it in $hour^{-1}$ by multiplying it by 60. We have to determine standard oxygen transfer coefficient at temperature 20^0C (K_La_{20}) by following equation

$$\boldsymbol{K_La_{20} = K_La_T \times (1.024)^{(20-T)}}$$

K_La_{20} = Standard oxygen transfer coefficient at temperature 20^0C (h^{-1})

K_La_T = Oxygen transfer coefficient at temperature T^0C

Then standard oxygen rate transfer (SOTR) and standard aeration efficiency (SAE) can be calculated by

$$\boldsymbol{SOTR = K_La_{20} \times 0.9 \times V \times 10^{-3} \times 9.07}$$

Where

SOTR=standard oxygen rate transfer (Kg O_2/ h)

V= volume of water (m^3)

$$\boldsymbol{SAE = \frac{SOTR}{P}}$$

Where,

SAE= Standard aeration efficiency (Kg O_2/ KW h)

P= input power (KW)

2.2.2 Procedure to evaluate the performance of inclined cascade aerator .

To evaluate the performance we have to plot the graph between SOTR and number of barriers, and compare in which condition we get maximum efficiency. Same as above we have to plot the graph between SAE and number of barriers and compare the condition of maximum efficiency.

Then again the graph between SOTR and SAE plot, to evaluate the performance.

3. RESULTS AND DISCUSSION

In this chapter, results of the aeration experiments conducted on sloped cascades are presented. This paper shown the SOTR and SAE at different slope height with the same barrier height represents the variation by increasing or decreasing the barrier nos. The result is obtained by doing an experiment at different slope height by taking a different barrier numbers and barrier height are discuss below .

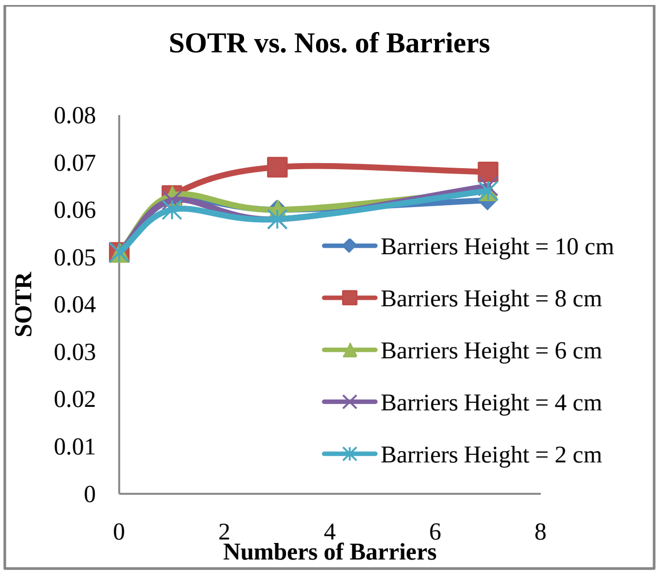
3.1 Determination of standard oxygen transfer coefficient (SOTR) with respect to numbers of barriers.

To determine the standard oxygen transfer coefficient (SOTR), the calculation is done as give formulae as mention early chapter materials and method. Here the calculated value of the SOTR with respect to the numbers of barriers. The height of the slope is variable from 0.5 m to 2 m. The numbers of the barrier is variable from 0 to 7 Nos. the height of the barriers is from 2 cm to 10 cm with the interval of 2 cm each.

3.1.1 Graph SOTR vs. Barriers number

In this part, graph is given below for slope height 2m and barriers height 10, 8,6,4,2 cm with respect to the SOTR value.

Graph for the height 2m and barriers height 0 to 10 cm with 2 cm of interval

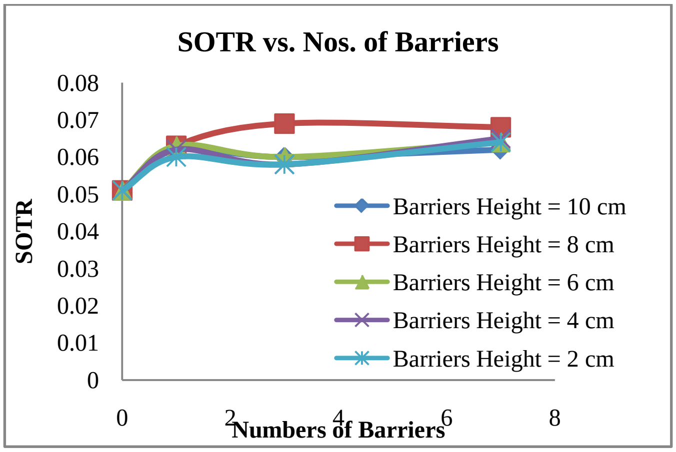


Graph 1: SOTR vs. Nos. of Barriers

From the above graph SOTR vs. Nos. of barriers, by varying the barriers height from 0 to 2 cm with interval of 2 cm as given above. By studying this graph, variation of SOTR value maximum of 0.07 kg O_2/h and minimum of 0.025 kg O_2/ h. The maximum value of SOTR value is 0.07 kg O_2/h at barriers height of 10 cm and barriers number 3-5 (in-between). From the above graph, the minimum value for the SOTR is 0.025 kg O_2/h at barriers height 2cm and barriers nos. 0-2 (in-between).

3.1.2 Graph for the height 1.5m and barriers height 0 to 10 cm with 2 cm of interval For 1.5 m of slope height

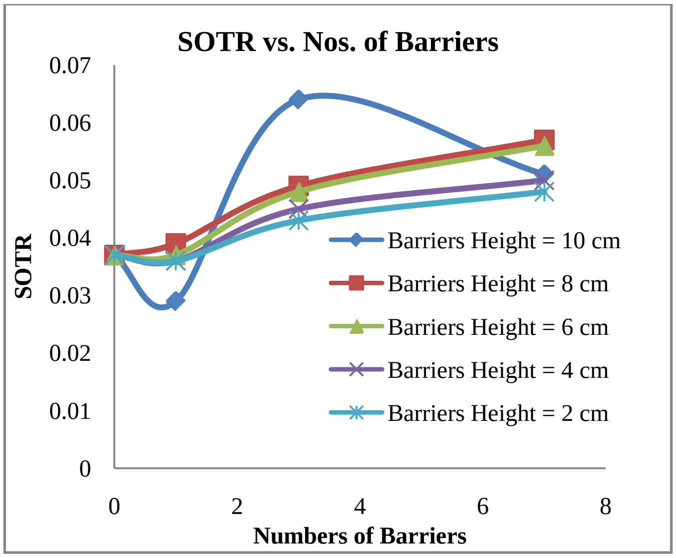
From the above graph SOTR vs. Nos. of barriers, by varying the barriers height from 0 to 2 cm with interval of 2 cm as given above. By studying this graph, variation of SOTR value maximum of 0.069 kg O_2/h and minimum of 0.05 kg O_2/ h. The maximum value of SOTR value is 0.07 kg O_2/h at barriers height of 10 cm and barriers number 3-5 (in-between). From the above graph, the minimum value for the SOTR is 0.05 kg O_2/h at barriers nos. 0 and barriers height 0 cm.



Graph 2: SOTR vs. Nos. of Barriers

3.1.3 Graph for the height 1m and barriers height 0 to 10 cm with 2 cm of interval

For 1m of slope height



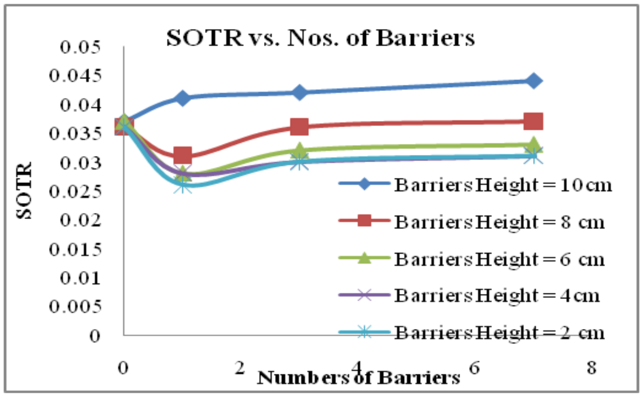
Graph 3: SOTR vs. Nos. of Barriers

From the above graph SOTR vs. Nos. of barriers, by varying the barriers height from 0 to 2 cm with interval of 2 cm as given above. By studying this graph, variation of SOTR value maximum of 0.065 kg O_2/h and minimum of 0.028 kg O_2/ h. The maximum value of SOTR value is 0.07 kg O_2/h at barriers height of 10 cm and barriers number 2-4 (in-between). From the above graph, the minimum value for the SOTR is

0.028 kg O_2/h at barriers height 2cm and barriers nos. 0-2 cm (in-between).

3.1.4 Graph for the height 0.5m and barriers height 0 to 10 cm with 2 cm of interval

For 0.5 m of slope height



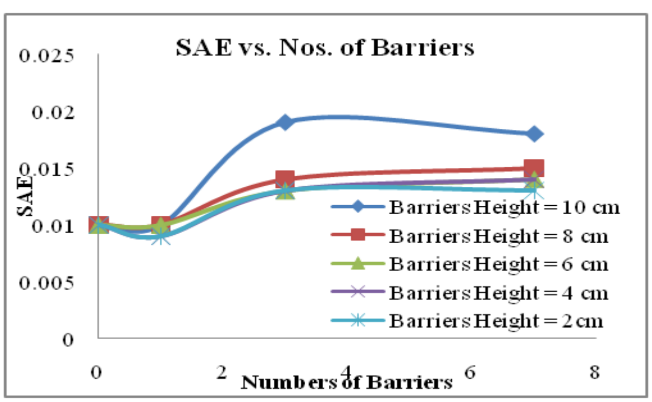
Graph 4: SOTR vs. Nos. of Barriers

From the above graph SOTR vs. Nos. of barriers, by varying the barriers height from 0 to 2 cm with interval of 2 cm as given above. By studying this graph, variation of SOTR value maximum of 0.044 kg O_2/h and minimum of 0.026 kg O_2/ h. The maximum value of SOTR value is 0.07 kg O_2/h at barriers height of 10 cm and barriers number 7. From the above graph, the minimum value for the SOTR is 0.026 kg O_2/h at barriers nos. 2 and barriers height 0-2 cm (in-between).

By studying about all graph for the SOTR vs. Nos. of barriers and barriers height, the maximum SOTR value is 0.07 Kg O_2/ h and minimum value is 0.025 Kg O_2/ h at 2m slope height with 10 cm barriers height, barriers numbers 3 and 2 m slope height with barriers height 2cm, barriers number 1 respectively.

3.2 Graph for SAE vs. Barriers number

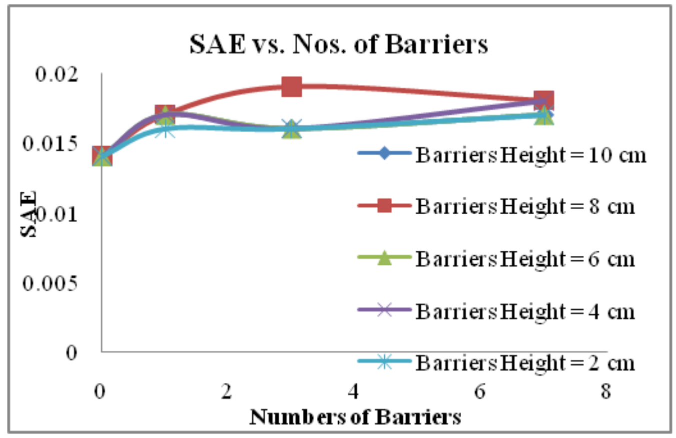
3.2.1 Graph for the height 2m and barriers height 0 to 10 cm with 2 cm of interval



Graph 5: SAE vs. Nos. of Barriers, for Height 2 m

It can be seen from the above graph that the SAE value maximum at 3 nos. of barriers with the barriers height 10 cm is 0.019 Kg O_2/ KWh and minimum value of 0.011 Kg O_2/ KWh at barriers nos. 1 and barriers height 2 cm.

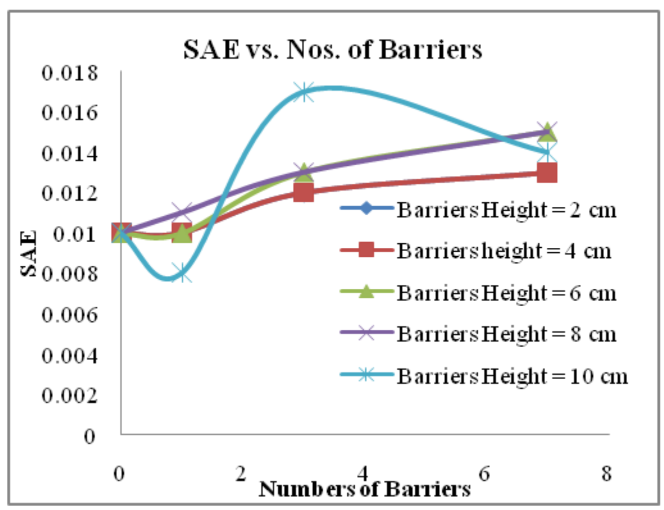
3.2.2 Graph for the height 1.5m and barriers height 0 to 10 cm with 2 cm of interval



Graph 6: SAE vs. Nos. of Barriers, for Height 1.5 m

It can be seen from the above graph that the SAE value maximum at 3 nos. of barriers with the barriers height 10 cm is 0.0167 Kg O_2/ KWh and minimum value of 0.0078 Kg O_2/ KWh at barriers nos. 1 and barriers height 2 cm.

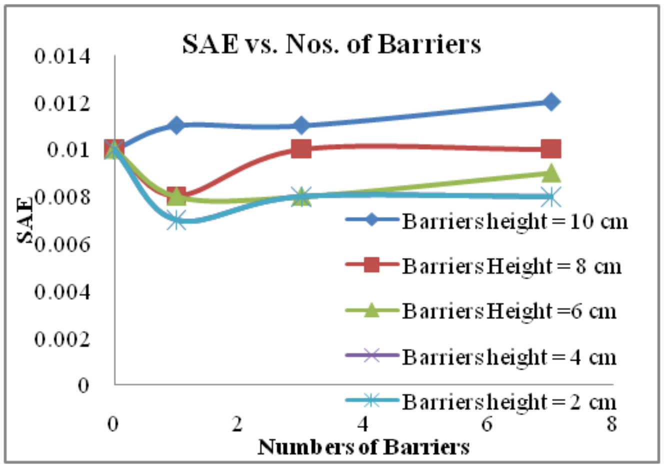
3.2.3 Graph for the height 1m and barriers height 0 to 10 cm with 2 cm of interval



Graph 7: SAE vs. Nos. of Barriers, for Height 1 m

It can be seen from the above graph that the SAE value maximum at 3 nos. of barriers with the barriers height 8 cm is 0.0184 Kg O_2/ KWh and minimum value of 0.014 Kg O_2/ KWh at barriers nos. 0 and barriers height 2 cm.

3.2.4 Graph for the height 2m and barriers height 0 to 10 cm with 2 cm of interval



Graph 8: SAE vs. Nos. of Barriers for Height 0.5 m

It can be seen from the above graph that the SAE value maximum at 3 nos. of barriers with the barriers height 10 cm is 0.012 Kg O_2/ KWh and minimum value of 0.007 Kg O_2/ KWh at barriers nos. 1 and barriers height 2 cm.

4. RESULTS

By studying above all graph and table, after analysis the data, the results drawn from the investigation.

It is found that the SOTR value is range from 0.02 to 0.069 Kg O_2/ KW and the SAE value range from 0.007 to 0.018 Kg O_2/ KWh. The best result drawn in this investigation for the standard aeration efficiency is value as 0.069 Kg O_2/ KWh with provided seven numbers of barriers of height 10 cm and slope height. The standard oxygen transfer rate maximum is found as 0.069 Kg O_2/ KW with provided seven numbers of barriers of height 10 cm and slope height of 2m.

In order to find out the most efficient, among them is by provided seven numbers of barriers with barriers height 10 cm.

5. CONCLUSIONS

Inclined cascade aerator was tested with an aim to evaluate the optimum conditions that would result in maximum efficiency of the aerator. Based on the standard aeration efficiency (SAE) and Standard Oxygen Transfer Rate (SOTR), is find out. It is found that the SOTR value range from 0.02 to 0.069 Kg O_2/ KW and the SAE value range from 0.007 to 0.018 Kg O_2/ KWh, with increasing the barriers numbers and the slope height of the inclined cascade aerators , the SOTR and SAE value increases. For the more efficiency, it is recommended to provide more barriers and steeper the angle of inclination. Numbers of barriers for more efficiency should provide barriers (3-7) numbers.

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REFERENCES

[1] Ahmad, S. Packed-Tower Aerators put end to VOCs. Water Engg. & Mgmt. (Nov. 1985).

[2] Avery, S. T., and Novak, P. 1978. “Oxygen transfer at hydraulic structures.” J. Hydraul. Div., Am. Soc. Civ. Eng., 10411, 1521–1540.

[3] Cargill, G.D.(1994).’Water Quality in the Windy City.” Water Environ. & Technol., Vol 6, No 6, No 9, pp. 52-56.

[4] Chanson, H. and L. Toombes, 1997. Flow aeration at stepped cascades. Research Report No. CE155, Department of Civil Engineering, University of Queensland, Australia, pp: 1-110.

[5] Chanson, H. (1996). Prediction of the Transition Nappe/Skimming Flow on a Stepped Channel. Jl of Hyd. Res., IAHR, Vol. 34, No. 3, pp. 421-429.

[6] Chanson, H. and Gonzalez, C. A. (2005). Physical modelling and scale effects of air-water flows on stepped spillways. Journal of Zhejiang University Science 2005 6A(3):243-250.

[7] Hauser, G.E. and D.I. Morris, 1995. High-performance aerating weirs for dissolved oxygen improvement. Proceedings of the International Conference on Hydropower, Volume 2, July 25-28, 1995, San Francisco, USA., pp: 1695-1705.

[8] Hauser, G.E. and D.I. Morris, 1995. High-performance aerating weirs for dissolved oxygen improvement. Proceedings of the International Conference on Hydropower, Volume 2, July 25-28, 1995, San Francisco, USA, pp: 1695-1705.

[9] Hauser, G.E., J.A. Niznik, W.G. Brock and R.M. Shane, 1992. Innovative reregulation weirs. Civil Eng., 62: 64-66.

[10] Robinson, R. (1994). “Chicago’s Waterfalls.” Civil Engineering, ASCE, Vol, 64, No. 7, pp. 36-39.

[11] Toombes, L , H. Chanson, 2005. Air-water mass transfer on a stepped waterway. J. Environ. Eng., 131: 1377-1386.

[12] Toombes, L., H. Chanson, 2000. Air-Water Flow and Gas Transfer at Aeration Cascades: A Comparative Study of Smooth and Stepped Chutes. In: Hydraulics of Stepped Spillways, Minor, H.E. and W.H. Hager (Eds.). A.A. Balkema Publishers, Netherland, ISBN-13: 9789058091352, pp: 77-84.