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GRAVITY AERATION SYSTEM IN AQUACULTURE

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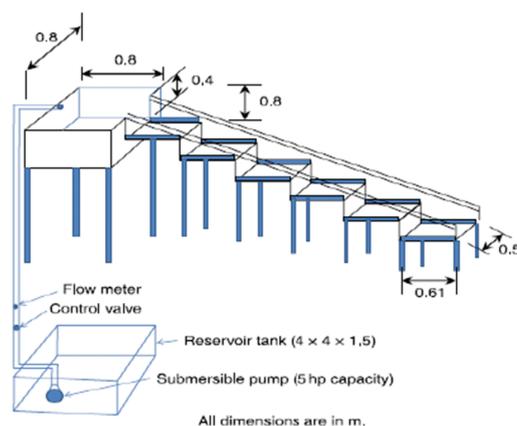
The oxygen in the air is absorbed and circulated in the form of bubbles over the water body is known as aeration. The aeration process increases the dissolved oxygen (DO) concentration after-treatment of the sewage discharge, agricultural run-off, aquaculture water body, etc., simultaneously remove dissolved gases such as CO², H₂S, volatile organic chemicals (VOCs), and dissolved metals. Aeration can be accomplished through the infusion of air into the water column. Natural aeration and artificial aeration are the two main types of aeration practices used to increase DO levels in water bodies. The two processes involved in improving the DO level naturally in natural aeration are atmospheric diffusion and plant photosynthesis. However, in order to increase productivity, fish farmers have been intensifying the culture in recent years, resulting in an increasing trend of DO requirements. Simultaneously, in the case of natural aeration, DO concentrations decrease during the night, posing a problem for culture species respiration. To avoid all these negative issues, it has been observed that artificial aerators are widely applicable in aquaculture operations. Basically, an artificial aeration system increases the contact area between air water interfaces so that more amount of oxygen from the air can mix in water by agitating it. Generally, the artificial aeration could be achieved by three methods: (1) surface aeration by the paddle wheel aerators, spiral aerators, pump-sprayers, and vertical pumps; (2) diffused aeration by the propeller-aspirators and submersible aerators; and (3) gravity aeration by the cascade aerators. The cascade aerators provide better aeration due to the high turbulent mixing, long exposure time, and substantial

air bubble entrainment. The cascade aerators improve the water quality by displacing the water from bottom to top and removing volatile organic contents present in the pond bottom. It has no moving parts; hence, less maintenance is required. Cascade aerator, a type of gravity aerator, is very popularly used in water treatment plant to remove iron and manganese or various dissolved gases or volatile organic compounds. One of the best advantages of cascade aerators is that the energy consumption is very less compared to other type of aerators. In this article, the classification and detailed discussions have been made for different gravity aeration systems.

Types of Gravity Aeration System

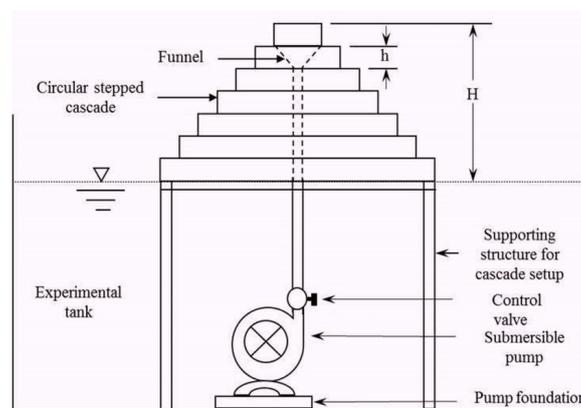
Cascade Aeration System: Aeration by cascading is a suitable and attractive way of adding and mixing atmospheric oxygen into the water body. Cascade creates the turbulent condition in the steps, which extends the residence time and significant air bubble entrainment results in the higher amount of dissolved oxygen absorption.

Stepped Cascade Aerator: Stepped cascades have been utilized for the scattering of high speed of stream and air circulation execution. Basically, it is used for pre or post aeration purposes. There are number of steps through which water flows. Because of the water fall on the steps, the disturbance made on the water surface breaks the air water interface and transfers oxygen and evacuate unpredictable natural substances, viz., methane, chlorine, disintegrated iron, manganese, carbon dioxide, and hydrogen sulfide. Stepped cascade aerators are only successful to remove 60–70% of carbon dioxide, but quite effective in raising the DO content of water. The stepped cascade aerators are not popularly used in aquaculture ponds. This may be due to the fact that the efficiency of the cascade aerator is significantly lower than that of other existing aerators. Therefore, stepped cascade can be used in conjunction with another system to get the desired result.



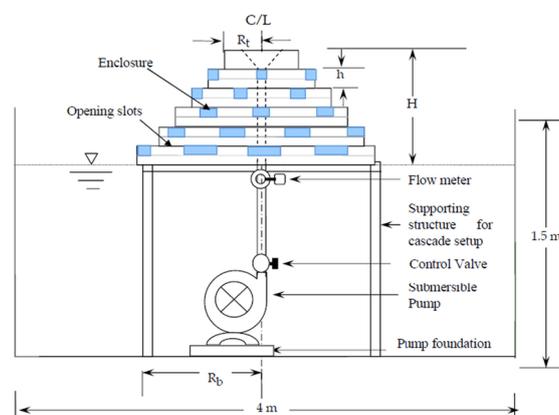
All dimensions are in m.
Source: Stepped cascade aerator (Moulick *et al.* 2010)

Circular Stepped Cascade: A circular stepped cascade in combination with a pump is the key of the main aeration unit. Basically, this type of aeration system is used in wastewater treatment plant or in aquaculture pond. Being a simple device with only static components, such a system will reduce the cost of maintenance as well as energy consumption when compared to other existing aeration systems. Circular stepped cascade consists of circular steps in which water allows falling from the upper step to subsequent next and finally to bottom step in a uniformly distributed manner. The submersible pump attached to the control valve is placed below the circular stepped cascade and regulates the water flow. Circular stepped cascade is used for fish hatcheries, and intensive aquaculture operations.



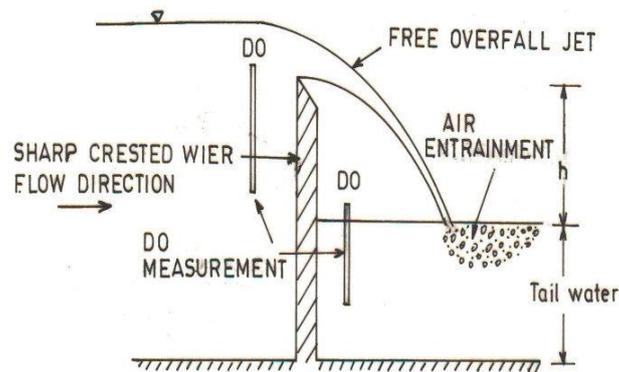
Source: Circular stepped cascades (Singh 2010)

Pooled Circular Stepped Cascade: Pooled circular stepped cascade (PCSC) is the modified version of the circular stepped cascade. The PCSC aerator had the barriers in each step of the cascade, and the distance between the barriers was optimized. The water flow over PCSC aerator in a zigzag manner increased the dissolved oxygen content into the water body. Hence, it was expected to increase the oxygen transfer rate as well as the higher efficiency of the aeration system.



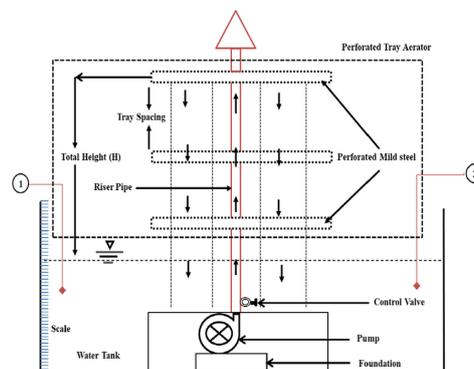
Source: Pooled circular stepped aerator (Kumar et al. 2013b)

Weir Aeration System: Weir aeration process was first introduced by Gameson (1957). It is one of the popular gravity aeration systems for water treatment purpose or aquaculture operation. It has different cross-sectional geometry like triangular and rectangular labyrinth. Aeration occurs over a weir with a splashboard that breaks the water droplets by gravity and then flows over the various screens. The free over fall water in the form of the jet from the weir plunging into downstream water causes entrainment of air bubbles, hence, accelerates the aeration process. Weir aeration is economically inexpensive compared to other aeration systems such as surface aeration, even when energy costs for pumping the water are included.



Source: Weir aeration system (Arun Goel, 2013)

Tray Aeration System: Tray aerator is useful in wastewater or aquaculture water treatment. It resembles a section wherein water is pumped via submersible pump through a riser pipe to the highest point of the segment, and water streams falling down due to gravitational force over a progression of tray found one underneath the other. The water is uniformly circulated all over the perforation of each and every tray until it reaches the level of the water body. This process confirms a large contact surface between the air and the water. Perforated tray aerator was particularly developed to solve the problem of low dissolved oxygen in aquaculture ponds and to minimize the energy consumption of the aeration system. For the removal of iron and manganese, multiple tray aerators were widely used.



Source: Tray aerator (Roy *et al.* 2020a)

Requirement of Aeration in Aquaculture Operation

The falling of dissolved oxygen (DO) concentration below 5.0 mg/L shows that the survivability of aquatic species is affected adversely. The fish mortality could be high if dissolved oxygen concentration remains below 1–2 mg/L for a few hours. Hence, the continuous supply of oxygen for maintaining the adequate DO concentration to the aquaculture ponds becomes a prerequisite for the healthy growth and survival of aquatic species. Due to this oxygen, depletion occurs at the bottom strata, causing threat to lake and pond aquaculture. Aeration also helps to control accumulation of metals in storage reservoirs and increased the DO.

Aerators are not needed in ponds with extensive culture and a low stocking density of less than 10 per m² of water spread area. However, partial water exchange at an advanced level to the tune of 10 to 20% is likely to produce good. Aerators may not be essential in ponds with a higher stocking density of 10 to 12 per m² and a targeted production level of 2 to 2.5 tons/ha in each culture with two cultures per year. However, sufficient water exchange, which may vary from 5% at the beginning to 50% towards harvest, may be necessary.

Aerators are required if the stocking density is high, on the order of 15 per m² and higher. In such cases, four paddle wheel aerators of 1 kW each are required for a pond with a common size of 4000 to 5000 m². Water exchange is also needed, which may vary between 20 and 30% per day. If the stocking density is very high, say 100/m², a large number of aerators is required. Pond sizes for such intensive culture are typically small, ranging from 500 to 1000 m². Such ponds need two to four aerators depending upon the feeding rate, pond size, and stocking density. The water exchange requirement in such ponds is very high, ranging from 50 to 100% depending on the stage of growth.

Location of Aerators in Aquaculture Ponds

Aerators not only increase the DO in the pond but also help in proper mixing and circulation of water body. This helps to create the air–water interaction into the water which finally enhances the oxygen transfer in the water body. Therefore, appropriate location of aerators plays a very important role in pond. Aquaculture ponds are normally in rectangular shape. In a rectangular pond, the aerator can be placed in the middle of one of the long sides. Placement of aerator needs to be such that water moves parallel to the shorter side. On the other hand, a poor placement could be in one corner, causing water to flow diagonally to the other

corner and preventing effective mixing. However, in order to effectively distribute the aerated water across the pond and produce water circulation, wise judgment should be employed in aerator placement.

Advantages of Gravity Aerators Over Other Existing Aeration Practices in Economic Point of View

The economical aerator is one that can meet the oxygen demand of a pond with the minimum cost. This cost includes both fixed and operating costs. An aerator with a high SAE value may result in lower operating costs but not necessarily in total minimum cost. When an aerator with a low SOTR value gives a high value of SAE, more numbers of such aerators are needed, which results in higher fixed costs. Therefore, coordination is required between SOTR and SAE for different pond sizes to achieve the optimum economic situation. Thus, an appropriate economic analysis must be performed before selecting the aerator for an aquaculture pond.

Conclusions

Dissolved oxygen is the most important factor in an aquaculture operation due to the vital need of all organisms living and having in water. Currently, the artificial aerators are widely used all over world due to their advantage for increasing dissolved oxygen concentration. In surface aeration system (paddle wheel aerator, spiral aerator) is subjected to high maintenance cost, wear and tear; therefore, as far as possible, it is better to use gravity type aerator as it involves gravity as the only means of adding oxygen to water. Typically, intensive aquaculture ponds with high stocking density of cultured aquatic species have pond volume from 1000 to 4000 m³. From management point of view, it is a practice to use small ponds for performing intensive culture. The use of gravity aerators offers a more practical option for places where land availability is a constraint, and cost of construction is low. From the energy consumption perspective, it is recommended that gravity aerators operate at an optimum efficiency range that corresponds to good aeration performance

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