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Application of aerator in aquaculture: A review

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ABSTRACT

Dissolved oxygen (DO) is one of the most important water quality parameters and its control is also vital in aquaculture water treatment practices. Dropdown of DO creates several problems for the aquatic life, like respiration, growth etc. even leading to deaths. Therefore, artificial aeration is necessary to maintain adequate DO level in the water bodies under culture practice. Artificial aeration system is presently the most common and effective way of increasing DO concentrations in aquaculture or general water treatment process. Artificial aerator has also added advantage of better mixing, breaking of stratifications of water quality parameters (DO, temperature, salinity, nutrient, etc.) and removal of various harmful gases. A comparative performance and features of various aerators used in aquaculture or general water treatment have been reviewed in this paper. This study demonstrates the requirements, several types and effective use of aeration practices for the betterment of aquaculture water treatment practices.

Keywords: Aerator, dissolved oxygen, water quality

INTRODUCTION

Water is essential for existence of human or animal life. The growth of human population has led to industrial development to produce necessary commodities and utilization of natural resources, including water. The presence of biodegradable organic compounds reduces oxygen levels in natural water bodies like lakes and rivers, resulting in bad odours and death of aquatic animals. Other organic materials *viz.* pesticides, detergents, fat, oil, grease, and solvents create toxic effects, aesthetical inconvenience and bioaccumulation in the food chain. Due to the problems mentioned above, the treatment of water becomes necessary (Nadayil et al., 2015). However, water quality is totally dependent on physical, biological and chemical parameters that affect the growth of aquatic flora and fauna. It also affects the general conditions required to maintain health and growth of culture organism. Dissolved Oxygen (DO) is the amount of gaseous oxygen (O_2) dissolved in water. Any method for adding oxygen into water can be considered a type of aeration (Ahmad and Boyd, 1988). Oxygen enters into the water body by absorption from the atmosphere or by plant photosynthesis. It is removed by respiration of organisms and decomposition of organic matter.

General wastewater can be defined as liquid waste, and includes domestic or municipal wastewater, and industrial wastewater (McGhee and Steel, 1991). It can be classified into strong, medium or weak depending on the concentration of different contaminants (McGhee and Steel, 1991). Industrial wastewater is the liquid discharged from industrial applications, such as manufacturing, dairy, food processing, textile (McGhee and Steel, 1991).

Nowadays aerators are widely used in large-scale aquaculture operations and in general water treatment plant. Purpose of artificial aeration is to increase the contact area between air-water interfaces, so that more amount of oxygen from the air can mix in water by agitating water. In

the absence of mechanical or artificial aeration facility and at the time when premature harvesting is not possible the splashing of water with the help of bamboo sticks will also help improve the dissolved oxygen level up to a certain level. The aerators work on two basic principles: (1) aeration by splashing water into the air i.e. paddle wheel aerator, spiral aerator, vertical pump, pump sprayer, gravity aerators, etc. or (2) aeration by bubbling/ diffusors air into water i.e. propeller aspirator, diffused aeration system etc. In aquaculture, paddle wheel aeration system, diffused-air aeration system, propeller-aspirator-pump aeration system and vertical-pump aeration system are generally used. A type of gravity aeration system, cascade aeration system is commonly used as pre or post-aeration system in general wastewater treatment. Keeping in view the above points the current review was carried out to focus on the need and importance of aeration and the different types of aeration practices for aquaculture and general water treatment.

APPLICATION OF AERATOR FOR WASTE WATER TREATMENT

One of the most common methods for water treatment is the activated sludge process. The activated sludge process is a suspended - culture system that has living, or active been in use since the early 1900s. The process derives its name from the fact that settled sludge containing, microorganisms is returned to the reactor to increase the available biomass and speed up the reactions. It may be either a completely mixed or plug flow process. The process is aerobic, with oxygen being supplied by dissolution from entrained air. Activated sludge processes consist of a tank within which the biological reaction occurs, a settling tank, a recycle pumping system, and an aeration system. An activated sludge plant is characterized by four elements (Fig. 1):

- An aeration tank equipped with appropriate aeration equipment, in which the biomass is mixed with wastewater and supplied with oxygen.
- A final clarifier, in which the biomass is removed from the treated wastewater by settling or other means.
- Continuous collection of return sludge and pumping it back into the aeration tank.
- Withdrawal of excess sludge to maintain the appropriate concentration of mixed liquor.

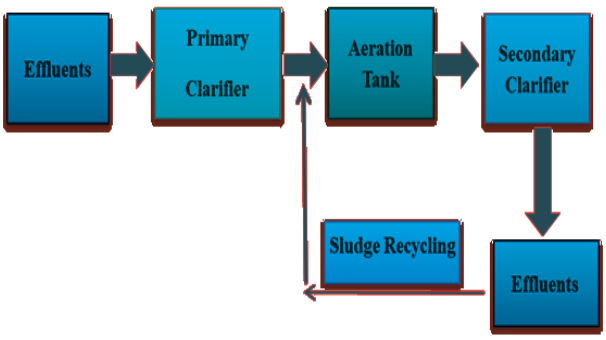

Fig. 1. Schematic diagram of activated sludge process

Water treatment of surface aerator

Paddle wheel and spiral aerator

Paddle wheel aerator is the most widely used surface aerator in the world (Boyd, 1998). It mainly consists of a number of paddle blades rotated in a vertical plane to spray large volumes of water into the atmosphere for oxygen transfer. The high velocity spray induces a turbulent flow on the surface creating a white water effect due to the large volume of entrapped air bubbles. This flow is also the driving force for convective mixing in the wastewater, which leads to uniform mixing of DO throughout the water (Moulick et al. 2005, 2009).

A new modified design of the paddle wheel aerator is the spiral aerator (Roy et al., 2015, 2017). In this aerator, a number of handles fitted with cups at their two ends rotate inside the water surface in a vertical plane to effect aeration. These handles are attached to a shaft in a spiral pattern which is connected to a motor. As this spiral aerator works similar to that of a paddle wheel aerator, it appears that this aerator may also be useful in general water treatment and aquaculture water treatment.

Propeller aspirator pump and submersible aerator

The propeller-aspirator-pump aerator consists of a rotating, hollow shaft attached to a motor shaft. The submerged end of the rotating hollow shaft is fitted with an impeller which accelerates the water to a velocity high enough to cause a drop in pressure over the diffusing surface. Hence, atmospheric air is drawn into the hollow shaft. This air passes through a diffuser and enters the water as fine bubbles which are thoroughly mixed into the pond water by the turbulence created by the propeller and aeration takes place.

A modified design of propeller-aspirator-pump aerator is the submersible aerator (2 horse power, 3 phase, Make; Sagar Aqua Pvt. Ltd., Rajkot, India), The propeller-aspirator-pump aerator introduces atmospheric air through a rotating shaft, connected to an electric motor outside the water body and a propeller at the other end which is submerged under water. Basically the propeller rotates at a very high speed inside the water. This causes a drop in pressure inside the water. This pressure difference forces air to pass through a diffuser in the hollow shaft and enter into the water as fine bubbles. In case of submersible aerator, a submersible pump fitted with a propeller and also connected with a hollow pipe (mouth is above water), draws air from atmosphere and mixes air with water. It is presumed that this new aerator may also be useful in aquacultural ponds and general water treatment.

Cascade aerator

Cascade aerators, a type of gravity aerators, are generally used as pre- or post-aeration system. They consist of a number of steps over which water flows. The turbulence created on the water surface due to its fall over the steps, breaks the air-water interface and helps in oxygen transfer as well as removal of volatile organic contents such as methane and chlorine, dissolved iron and manganese, carbon dioxide, hydrogen sulphide, as well as the colour and tastes caused by volatile oils (Toombes and Chanson, 2005). A circular stepped cascade (CSC) aerator was developed by Singh (2010) at IIT Kharagpur. Performance evaluation of prototype CSC aerators was evaluated at optimum geometric condition.

Perforated tray aerator

The perforated tray aerator is also being used in aquaculture water treatment. It is like a column in which water is supplied through a riser pipe to the top of the column and water flows down under gravitational force over a series of trays located one below the other. This arrangement allows the water to fall from one tray to the next one in the form of water droplets. During the fall of water, air bubbles rise up. As air gets dragged in, gas exchange occurs between the air in the bubbles and the water. Oxygen diffuses from the air into the water and thus increases dissolved oxygen content of the water. Vertical distances between the trays are typically 10–25 cm, and the number of trays varies between 4, 5 and to 6. The effectiveness of the aerator increases with number of trays and distance between them. The water is distributed throughout the perforated tray and drops down from tray to tray until it reaches the level basin located under below the last one. When the water flows down through the holes in the perforated trays, drops are formed and this ensures a large contact area between the air and the water.

Comparative performance of aerators

Boyd and Ahmad (1987) tested a large number of electric aerators for oxygen-transfer efficiency. Propeller-aspirator-pump aerators, vertical pump aerators and diffused-air aeration systems also are widely used in aquaculture for aeration of small ponds (≤ 1 ha). Values of SOTR (kg O_2 h^{-1}) and SAE (kg O_2 kWh^{-1}) for different electric aerators have already been used in aquaculture (Boyd and Ahmad, 1987). Propeller-aspirator-pump-aerators are more suitable than the other aerators in case of small pond (Engle, 1989) described in Table 1.

Table 1. Summarized values of SOTR and SAE

Type of aerator	Number of aerators	Range of SOTR	SAE*	
			Average	Range
Paddle wheel	24	2.5 - 23.2	2.2	1.1 - 3.0
Propeller-aspirator-pump	11	0.1 – 24.4	1.6	1.3 – 1.8
Vertical pump	15	0.3 – 10.9	1.4	0.7 - 1.8
Pump sprayer	3	11.9 – 14.5	1.3	0.9 – 1.9
Diffused-air	5	0.6 – 3.9	0.9	0.7 – 1.2
Circular cascade	4	0.11 – 0.135	2.57	2.2 – 2.7

Note: * SAE is based on estimated brake power.

CONCLUSION

Aerators nowadays represent a commonly used device for the intensification of oxygen input into biological wastewater treatment plants. Dissolved oxygen is the most important factor in an aerobic biological process and aquaculture system due to the vital need of all organisms living and having an aerobic respiration in water. Currently, the mechanical aerators are widely used all over the world due to their advantage of increasing dissolved oxygen concentration. Main advantage of these types of aerators is to remove volatile organic matters, gases like sulphide, carbon dioxide etc. which are toxic to the aquaculture pond and thereby maintain the water quality.

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