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APPLICATION AND IMPORTANCE OF AERATION SYSTEM IN AQUACULTURE POND: A REVIEW

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Abstract– Pond aeration systems have been developed to sustain vast fish and invertebrate biomass during the past decade. These aeration systems are alterations of standard wastewater aeration systems. Aeration-performance testing has been significant in selecting design features to provide cost-effective yet well-organized aquaculture pond aerators. Aerators enhance the oxygen requirement for fish growth, and it is crucially important in the intensive pond stocked with high densities. Dissolved oxygen concentrations have been linked to the water quality of the pond, Fish Growth and Survival, Reproduction, Feed utilization and microorganisms. Paddlewheel aerators and propeller-aspirator-pumps are probably most widely used. Aerators usually are placed in ponds to provide maximum air circulation in water. This article summarises the importance of mechanical aeration of aquaculture ponds for fish farmers.

INTRODUCTION

Aerators are vital in semi-intensive and intensive aquaculture ponds to maintain optimum dissolved oxygen suitable to the physiological needs of the farmed Aquatic organisms. Aeration plays a crucial role in intensive culture ponds /tanks because, atmospheric oxygen diffusion is not sufficient to meet the oxygen demand of biota in intensive fish culture units (Koch *et al.*, 1975).

Aerators enhance the interfacial area between air and water, facilitating oxygen transfer and creating water circulation, ultimately preventing stratification in the water body (Boyd and Martinson, 1984). Different varieties of aerators have been designed over the years to support the desired level of dissolved oxygen (DO) concentration in pond water to maximize the energy efficiency of the oxygen mass transfer process. The selection of aerators is critical to optimizing profit and reducing the production cost, accounting for around 15%. After post larvae and feed, it is the third most expensive expenditure in an intense aquaculture system. The choice of an aeration system depends mainly on technical and economic aspects other than specific requirements because artificial aeration involves high energy costs and requires large apparatus (Koch *et al.*, 1975).

The least aeration cost is achieved only when the rotational speed of the spiral aerator(a modified design of the paddlewheel aerator) is only 70 rpm for pond volumes up to 700 m^3, and it ranges from 120 to 220 rpm for pond volume exceeding 700 $m^3$of aquaculture ponds (Roy *et al.*, 2017)**.**

Dissolved oxygen is one of the vital water quality parameters, and it determines oxygen present in water. Thus according to (Shultz *et al.*, 2011), dissolved oxygen is essential to the process of aquatic life. As a result, Aerators enhance the oxygen requirement to fish growth, and it is crucially important in the intensive pond stocked with high densities (Sultana *et al.*, 2017). The circulation and aeration of surface water with pumps or by stirring with the boat or outboard motor prevented fish kills due to phytoplankton blooms, particularly of the species *microcystis* and *Anabaena* (Swingle, 1968).

Dissolved oxygen concentration measured either milligrams of gas per liter of water (mg/l) or parts per million (ppm) and also measured in percent saturation (i.e., a relative measure of the amount of oxygen dissolved in water) (Baker *et al*., 2014). Boyd, 1998) stated that dissolved oxygen concentration in water at saturation differs with water temperature, salinity and barometric pressure. Aerators influence the oxygen transfer rate from air to water by increasing water's turbulence and surface area in contact with air (Boyd, 1998). Aeration may also be a suitable method for managing thermal stratification (Miles and West, 2011). Aerators can increase fish and shrimp production in ponds, but few generally accepted guidelines on how best to apply aeration in ponds (Boyd, 2001& 2003; Tucker, 2005; Tucker and Robinson, 1990).

This document presents information about managing production using an aeration system in aquaculture ponds. In broad terms, this technical note converses dissolved oxygen dynamics in ponds, types of pond aerators, and the use of aerators in ponds.

Sources of dissolved oxygen (DO)

The atmosphere is the primary source of oxygen in a natural situation. The air we breathe contains approximately 20.946 per cent oxygen gas (O_2), 78.084 per cent nitrogen (N_2), 0.934 per cent argon (Ar), 0.032 per cent carbon dioxide (CO_2) and a trace of other gases (Colt, 1984).

Oxygen dissolves into the water from three primary sources:(i) the atmosphere, (ii) wind and wave motion, and (iii) photosynthesis by aquatic plants, algae, and some bacteria.

Requirement of dissolved oxygen for fish

For optimal health of freshwater fish, a minimum DO concentration of 5 mg/l is recommended (McKee and Wolf, 1963; Swingle, 1969), and deaths can occur if the DO concentration goes below 2 mg /l (Noga, 2010). Critical DO stages are species-specific; nevertheless, for most ornamental fish species, DO levels at or near saturation (7.8 mg/l at 28°C) are advised (Lawrence, 2007). Several researchers concluded that dissolved oxygen concentrations have been linked to decreased hatching and growth rates, lower feed consumption and even mass mortality events in extreme cases (Buentello *et al*., 2000; Das *et al*., 2012).

Dissolved oxygen (DO) dynamics in ponds

The dynamics of dissolved oxygen in fish ponds is very complex. Then the decision of when and where to check to DO in ponds varies among fish farmers, but experience dictates that DO be checked several times daily. DO measurement should be made at least three times during the warmer months, at dawn, at dusk and about four hours after dark (Tucker and Robinson, 1990).

Effects of oxygen concentration on fish

The dissolved oxygen concentration requirements for different species are as follows:

Coldwater fish - 6 mg/l
Tropical freshwater fish- 5 mg/l
Tropical marine fish- 5 mg/l

These values are minimum requirements for healthy growth, tissue repair and reproduction (Svobodova *et al*., 1993). Most fish species will tolerate a drop of DO below these minimum values for a short period. The cold-water species are likely to tolerate a lower level than tropical fish.

Fish response to hypoxia

Hypoxia, also known as oxygen depletion, is a phenomenon that occurs in aquatic environments when the concentration of dissolved oxygen falls to a level that is harmful to aquatic organisms. DO levels of less than 80% should be rare in a "healthy" aquatic environment. Some species are much more tolerant of hypoxia than others, leading to differential survival during extended periods of hypoxia (Poon *et al*., 2002).

Fish response to hyperoxia

The state of water, when it contains a large amount of oxygen, is known as hyperoxia. In this water condition, oxygen molecules will begin to move around within the water column looking for a little elbow room. If it is not available, it will either return to the atmosphere or attach to organisms all over the place (Florida Lake Watch, 2004). If fish are exposed to such water, their blood equilibrates with the excess pressure in the water. Bubbles form in the blood, blocking the capillaries; in sub-acute cases, the dorsal and caudal fin can be affected, and bubbles may be visible between the fin rays. When the gas level in the blood is high, gases will diffuse from the blood to the bladder. When the water is supersaturated (hyperoxia), the bladder becomes over-inflated, leading to buoyancy problems, especially in small fishes (Groot *et al*., 1995).

Dissolved oxygen (DO) –growth

Dissolved oxygen (DO) is one of the most important physico-chemical parameters of water because low DO concentrations have a negative impact on fish growth, feed utilization, and even death. (Sultana *et al.,* 2017). The effect of aeration using a blower on the growth and production of tilapia (*Oreochromis niloticus*) in intensive aquaculture system in six (6) earthen ponds at BAU campus. The results suggested that aeration can be a potential mechanism of aqua-farming to enhance the growth and production of tilapia and DO content in pond water synchronizing other water quality parameters in ponds.

Water quality and dissolved oxygen

Water quality is a vital natural indicator for evaluating the feasibility of shrimp farming (Ma *et al.,* 2013; Sahrijanna and Sahabuddin, 2014). Dissolved oxygen (DO) is a major abiotic parameter for evaluating water quality in the intensive aquaculture system of vannamei shrimp (*Litopenaeus vannamei*), and it must be measured on a regular basis (Madenjian, 1990; Kuligiewicz *et al.,* 2015). DO has a negative relationship with the physico-chemical parameters temperature, phosphate, nitrite, TAN, and TOM, but no relationship with pH, salinity, CO_3^{-2}, HCO_3^{-}, and alkalinity. This is following the opinion of Bui *et al.,* (2013).

Dissolved oxygen –feed

Biosynthesis of waste and other organic materials, the level of DO consumption in shrimp ponds rises in tandem with the increase in feed input (Duy *et al.,* 2008; Mirzaei *et al.,* 2019). Hence, it is indicated that an immense amount of feed administered more often leads to greater levels of DO consumption in the waters (Ullman *et al.,* 2019). In the shrimp metabolic system, DO has more significant implications for the physiological response of shrimp than in the growth system (Qiang *et al.,* 2019). In white shrimp, the growth rate is influenced 75% by the effectiveness of nutrients from feed (Nunes *et al.,* 2006).

Dissolved oxygen –microorganisms

Based on biological parameters, Dissolved oxygen negatively correlates with the TVC (Total Vibrio Count) and TBC (total bacteria count). The increasing level of bacteria abundance will make the availability of oxygen in the ponds become diminished due to its use in decomposition processes (Aldunate *et al.,* 2018). (Joseph *et al.,* 2017), stated that a lower concentration of bacteria in the pond is positively correlated with the decline in ammonia, nitrate, nitrite, DO and pH levels.

Oxygen balance and stratification

The depth of a pond, the surface area open to mixing by wind or mechanical aeration, and the biomass of plants and animals in the water column that may influence photosynthesis or decomposition rates all influence the degree to which a pond stratifies (Hargreaves, 2003). Shallow aquaculture ponds or lakes bodies (e.g., 3 to 8 feet deep) mostly stratify during the day and destratify or equalize the temperature of the water from top to bottom by mixing at night during the summer months. Ponds deeper than 10 feet may not be thoroughly mixed during the night, resulting in the persistence of a layer of cold water with very low DO near the bottom of the pond. Increased sunlight intensity near the pond's surface causes greater algal photosynthetic rates, which increases DO concentration. Thus, surface water usually contains much more DO than water near the bottom of a pond. For example, on a calm sunny summer afternoon, the DO concentration at the surface of a pond can be more than three times higher than the DO concentration along the bottom (Hargreaves, 2003).

Dissolved oxygen for the production

Dissolved oxygen levels in aquaculture ponds manage the metabolism and growth of aquatic organisms. Each species has different DO requirements depending on developmental stage, water chemistry and other environmental factors. (Tucker and Hargreaves, 2004; Hargreaves and Tomasso, 2004).

Aeration

Aeration function is to increase the area of contact between air and water so that oxygen can enter into the water surface, as mentioned by Petersen and Walker, (2002). They also concluded that the aerator function is similar to the 'lung' to driving oxygen into water, stripping carbon dioxide out, particularly for intensive aquaculture ponds.

Principles of aeration

Aerating an aquaculture pond water involves transferring gaseous oxygen from the large reservoir in the atmosphere into the water of the pond, where

DO concentrations have dropped to critical levels (Boyd, 1998). Aerators help mix pond water, reduce thermal stratification, and improve other water chemistry factors, notably DO content. Finally, combining by aeration can minimize organic matter accumulation that may increase BOD, reduce the density of algal blooms that can lead to oxygen depletion and fish health issues and shift the composition of algae blooms that may lead to flavour issues in finfish (Hargreaves, 2003).

Types of pond aerator

Various types of aerator systems have been developed over the years to improve the energy efficiency of the oxygen mass transfer process and maintain the desired level of dissolved oxygen in wastewater. Types of aerator techniquecan be classified into three types (Thakre *et al*., 2008)

1. Surface or mechanical aeration method increases the interfacial area by spraying water droplets into the air.
2. Diffuser aeration method releases bubbles beneath the surface of the water.
3. The Combined and turbine aeration method introduced larger air bubbles into the water and reduced their sizes mechanically.

Paddlewheel Aerators

The most widely used aeration method is paddlewheel aerators. An arrangement of paddles is attached to a rotating drum or shaft in these aerators. The aeration efficiency of the unit is affected by the pattern, length, and shape of the paddles. They're regarded as one of the most energy-efficient methods of increasing dissolved oxygen levels. Besides increasing the dissolved oxygen, they also increase pond water's horizontal and vertical movement. The combined effect of strong circulation and aeration allows the important oxidized surface sediment layer (Boyd, 1995).

Diffused-air aeration systems

The most common diffusers are glass-bonded, and silica stones, but diffusers made of porous plastic, synthetic perforated membranes, and ceramic are also used (Boyd, 1998; Tucker, 2005). The efficiency of diffused-air aeration systems is primarily a function of bubble size and diffuser depth. Diffusers that produce smaller bubbles, commonly known as fine-pore diffusers, are more efficient than diffusers that produce large or coarse bubbles. Because smaller bubbles have more surface area relative to their volume, which facilitates more efficient oxygen transfer. When the bubbles are released at a greater depth, these more profound release points allow more contact time for the bubbles to diffuse oxygen into the water column as they rise to the surface (Boyd, 1998; Tucker, 2005).

Aerator placement

Water circulation in large, rectangular ponds is optimized by placing paddlewheel aerators off the bank near the middle of the longer axis of the pond to direct currents across the short axis (Boyd and Watten, 1989). Another factor that influences the efficiency of an aeration system is the placement of the aerators within the pond, relative to both the type of aerator used and the need for aeration. Locating several aerators in a pond should be done according to site factors such as depth, the direction of prevailing winds, proximity to electrical power sources and accessibility for fueling and maintaining the equipment.

Design and performance of aerator systems in aquaculture ponds

Oxygen transfer depends on many factors, including the type, size, shape of diffusers, and tank geometry. Variation in the depth of water and the extent of the coverage area of the diffuser had a significant effect on the tested parameters (oxygen transfer capacity (OC), efficiency (E) and also on a percentage of oxygen absorption (ä)(Kossay, 2006).

In another research, Standard aeration efficiency was showed better results for the circular stepped cascade (CSC) and pooled circular stepped cascade (PCSC) aerators were found suitable for pond size less than 1000 m^3. However, for pond sizes, more than 5000 m^3, one-hp paddle wheel and two-hp paddlewheel aerators were found more efficient (Kumar *et al.*, 2013). (Roy *et al.*, 2016) have conducted a study on the performance evaluation of spiral aerators. It was found that the maximum SOTR (standard oxygen transfer rate) and SAE (Standard Aeration Efficiency) of 0.622 kg O_2/h and 1.0 kg O_2/kWh were obtained at the highest and the lowest operational speeds of 240 and 70 rpm, respectively. The oxygen transfer simulation curve for a double hub paddlewheel aerator was almost matched that of a single-hub paddlewheel aerator; in addition to that double- hub paddle wheel consumes more power than a single hub (Sanjib Moulick and Mal, 2009).

Dalla Santa and Vinatea, (2007) have

experimented evaluation of respiration rates and mechanical aeration requirements in semi-intensive shrimp *Litopenaeus vannamei* culture ponds. During the study period, the SR was significantly higher than WR, except for the third week of the culture period. SR showed a wide variation during the experiment, and the highest respiration rate occurred in the last week of the culture period. Temporal aeration requirements were characterized from SR and WR data and the shrimp mean respiration rate described in this study.

Nigeria developed a low-cost prototype paddle wheel aerator for catfish production, and they are usually made from locally available materials for small and medium-scale fish farmers. They concluded that adding oxygen to the water improved the water quality, increasing fish stock density, which was a significant setback for low-income fish farmers in Nigeria (Omofunmi *et al*., 2016). Similarly, in another study conducted by (Busch *et al*. 1984) to evaluate three paddlewheel aerators used for emergency aeration of channel catfish ponds. The rate of oxygen transfer increased linearly with the power requirement. The largest paddlewheel aerator produced the highest oxygen transfer rate when it was operated at its maximum paddle depth. A big spiral shape was best suited for air distributor shapes to supply fish ponds with enough dissolved oxygen concentration. In this way gas transfer increases in the aquatic pond may help to increase the fish yield (Bhuyar *et al*., 2009). Apud and Camacho, (1980) have studied the effect of water movement and air-lift aeration on the survival and growth of *Penaeus monodon* and opined that the high survival rate obtained with aeration. Microbubble generator (MBG) as low cost and high efficient aerator for sustainable freshwater fish farming mostly it is used in intensive aquaculture. MBG aerator indicated faster degradation of organic content in the water and induced faster growth of the fish as measured by their length and weight (Budhijanto *et al*., 2017).

Xiangju Cheng *et al*., 2016) have conducted the research to study the effect of the different shapes of air diffusers on oxygen mass transfer coefficients in microporous aeration systems. The results showed that the optimal aeration efficiency had achieved by I-shaped diffuser followed by C-shape and disc-shaped diffuser, the poorest efficiency obtained by S-shape. Jayraj *et al*., (2017) have experimented on design characteristics of the submersible aerator. Aeration experiments were conducted on the original and modified submersible aerators to evaluate their performance and to optimize the aeration efficiency. The percentage increase in efficiency after modification was 92.50 %. Gray *et al*., (2011) have experimented on aeration system design for energy savings and results showed that successful operation of the system depends on the successful operating of all the components of the system. This study describes that a well-designed aeration system can save up to 25 to 40% of energy consumption.

CONCLUSION

The aeration of water can be carried out by various processes like Paddlewheel aeration, diffused air aeration, propeller diffuser aerator, vertical pump aerators, gravity aerators etc., which showed positive results such as growth and survival in the aquatic species. To obtain a better aeration effect every parameter like design of the system, rate of oxygen transfer in the water, proper selection of material in design of the system should be considered. Fine bubble generation and paddle wheel is the best way to transfer oxygen within the water. Further research is needed to assess the various type of Aeration efficiency, low cost design, low power consuming aerators with high performance in aquatic pond.

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