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AERATION SYSTEMS USED FOR THE OPERATION IN OPTIMAL PARAMETERS OF FISHING PONDS

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Abstract: Intensive fish farming practices involve efficient management of aquatic ponds, in order to obtain high and sustainable production yields. In order to maintain the maximum production levels and to ensure quality products, ponds operating staff have to address to a wide range of major importance issues such as water quality, disease and pathogens control, aquatic vegetation, sedimentation, and fish control strategies. Managing dissolved oxygen levels in ponds is a major concern in aquaculture because involves understanding the aeration principles and natural pond dynamics, attributable to biological and chemical processes. Aeration equipment functioning is dependent on a number of external factors such as fish and plants density season, the type of pond that is being used and weather patterns. This paper presents practical information related to the use of aeration equipment in ponds, the importance of artificial aeration in aquaculture, as well as the impact of aquaculture on the environment.
Keywords: aquaculture, aeration, dissolved oxygen, pump sprayer aerator

INTRODUCTION

Aquaculture is an economic activity that uses a set of well-established techniques used to transform aquatic natural resources, such as fish, shellfish, mollusks, aquatic plants into commodities for society (Troell et al., 2013). In order to meet the growing demand for food, the growth and sustainable development of the aquaculture sector, which plays a key role worldwide, has an essential role (Kobayashi M et al., 2015). The ecological conditions for fish development depends on certain water quality parameters, such as: dissolved oxygen, total ammonia-nitrogen ratio, total alkalinity, free CO_2, total hardness and planktonic life in the pond (Hepher and Pruginin, 1981; Ali et al., 2000).

A wide variety of aquatic culture organisms are used worldwide in aquaculture, they can grow in different types of environment such as: freshwater, saltwater and marine. Freshwater aquaculture is carried out in fish farms, in fish cages, in ponds or rice paddies, while saltwater aquaculture is usually carried out in fish ponds in coastal areas (Perry L. Oakes et al., 2011).

Artificial aeration is a method that has a positive impact on pond productivity, thus increasing the growth and production of fish at high storage densities, and the use of aeration equipment in aquaculture ponds depends on a very well-developed management (Perry L. Oakes et al., 2011).

In an intensive aquaculture system, increased fertilization, overfeeding and high storage density lead to insufficient natural aeration, and this may become a limiting factor for production. Therefore, a very good method is artificial aeration, being a beneficial alternative for the survival of flora and fauna, since it leads to a rapid and healthy growth of crop species (Tanveer et. al., 2018).

In fish ponds with large stocks and artificially fed, numerous problems frequently occur, such as organic pollution, oxygen deficiency, increased levels of free carbon dioxide and the total increase in the ammonia-nitrogen ratio. Aeration is an appropriate way to address them (Agarwal, 1999; Boyd, 1995).

Boyd (1990) reported that the aeration system is one of the best methods of oxidizing ammonia to nitrates or adjusting the pH and volatilization of ammonia in water.

Artificial aeration is a suitable way to eliminate the negative effects that can frequently occur in ponds, such as high CO_2 levels, organic pollution, increased ammonia-nitrogen ratios and oxygen deficiency. It is one of the best methods for stabilizing the pH of water, oxidizing ammonia and volatilizing ammonia (Agarwal, 1999; Boyd, 1995)

— The importance of aeration in fish ponds

Air is a vital element for the maintenance of life, and the need for dissolved oxygen in aquaculture ponds is obtained by photosynthesis of aquatic plants, by diffusion from the atmosphere on the water surface, and by artificial aeration systems, which keep dissolved oxygen in normal parameters when it decreases. Dissolved oxygen from aquaculture ponds is one of the most critical limiting parameters and is a very important factor in terms of water quality and underwater life, as aquatic organisms require a constant supply of oxygen to perform respiration and other biological activities, and food waste from water will be oxidized efficiently (Tanveer M., 2017).

When the dissolved oxygen supply increases, the anaerobic decomposition in the pond is performed in optimal conditions, as well as the nitrification process and other processes.

The aeration of the pond makes a significant contribution to the cultured fish, thus satisfying their normal metabolic demand, and ensuring optimal oxygen levels (worldfishcenter.org).

Depending on the decrease in dissolved oxygen concentration, risks may occur: fish may become more

prone to infectious diseases, consume less feed and process it less efficiently, the growth rate of fish will decrease, and there is a risk of suffocation of fish, causing their death. In addition to all these negative effects caused by the decrease in dissolved oxygen in aquaculture basins, that decrease will affect the entire aquatic ecosystem.

— Oxygen consumption by fish

The different fish species have become adapted to different living conditions during their evolution. There are fish species with high oxygen requirements, for which only small variations in the amount of oxygen can cause major developmental damage, while some other species such as Cyprinids are less demanding of oxygen. In addition, in some tropical areas there are species of fish that have the ability to breathe through the skin, and other species have internal organs with specific functions similar to the lungs.

Standard oxygen consumption is the quantity of oxygen needed by fish for subsistence, consumed without swimming and feeding. Have been noted that standard oxygen consumption is not dependent on oxygen saturation of the water but it is significantly influenced by water temperature.

— Principles of aeration

Normally, aeration of an aquaculture pond is accomplished by transferring gaseous oxygen from the atmosphere to the pond water, where dissolved oxygen concentrations have dropped below normal. Depending on certain factors, such as the amount of turbulence in the water, the ratio of the pond surface to its volume and how far the measured DO concentration deviates from the saturation concentration (ie, when the relative amount of oxygen in the atmosphere is equal to DO concentration in water), this deviation is called either saturation deficit or surplus, depending on the measured concentration of dissolved oxygen.

Especially salinity and temperature are the water quality parameters that predominantly influence the dissolved oxygen saturation. Mechanized aerators are machines that improve the mixing of water in the pond, therefore it reduces thermal stratification and can increase the content of dissolved oxygen needed by aquatic organisms, but at the same time helps to distribute feed and eliminate waste from the pond (Hargreaves et al., 2004).

TYPES OF AERATORS

The best choice of aeration system is normally made, depending on the following factors: seasonal changes, pond shape, pond depth, its size, aerator efficiency, fish harvesting methodologies, power supply availability and type of aeration. Aerator performance is measured as standard oxygen transfer rate (SOTR) or standard aeration efficiency (SAE).

SOTR is the amount of oxygen added to water within 1 hour under standard conditions, and is expressed in kg / hour of O_2. The SAE is the standard oxygen transfer rate divided by the power (CP) of the unit, expressed in kilograms of O_2 / hp-hour transferred to water (Boyd C.E, 1998).

The correct location and positioning of the aerators in the ponds aim at obtaining a good water circulation and the distribution of saturated oxygen water on the entire surface of the pond (Tanveer M. and Nadu T, 2017). Aquaculture aerators are similar to those used in wastewater aeration. However, modified aerators have been developed for aquaculture that are less expensive than those for wastewater.

This equipment helps to increase the turbulence in the body of water and the surface of the water in contact with the air, thus influencing the rate of oxygen transfer from air to water. The most common types of aerators used in aquaculture require electricity or fuel-powered motors (tractors or pumps), these are: pump sprayers, vane wheels, vertical pumps, propeller-vacuum pumps, spiral wheel aerator and air systems diffuse (Wurts W.A., 2019).

PUMP SPRAYER AERATORS

Pump-sprayer aerators are simple, low-maintenance equipment, being a suitable choice for emergency aeration operations, with good efficiency on a small area of the pond and can be powered by an electric motor or power take-off (Tucker C., 2005).

Figure 1. Pump sprayer aerator in operation (http://extension.msstate.edu/news/feature-story/2017/smaller-catfish-ponds-intensify-production)

Spray aerators have a high pressure pump with which artificial aeration is performed. This pump discharges water at high speed through one or more of its holes, the water is pumped upwards, and then falls to the surface of the water in an umbrella pattern (Boyd C.E, 1998). These are mobile equipment, easy to transport from one pond to another and can operate even at shallow depths, provided that the pump inlet is sufficiently submerged in water (Tucker C., 2005).

The disadvantage of pump sprayers is that they can improve the concentration of dissolved oxygen only in their vicinity and are more effective in aerating the bottom of the pond, but they can also be combined with other types of aerators for higher efficiency (Rogers G.L., 1989).

In the case of this type of aerator, the dissolved oxygen concentration is improved only near the equipment, and the

water regions in the distance remain unventilated (Rogers G.L., 2009).

According to the literature review, research on performance evaluation and economic analysis of a pump spray aerator is limited to none.

VERTICAL PUMPS

Vertical pump aerators operate on the same principle as pump sprayer aerators and consist of a relatively small electric motor with one or two rotors, which rotate at 1730 or 3450 rpm, which are attached to the motor and suspended on the surface of the water with the help of a float.

Due to the fact that this type of aerator has a relatively small engine, its use is limited to ponds smaller than 1 acre. These aerators are manufactured in sizes <1 to 50> Kw, but aquaculture units are rarely larger than 2 Kw (Boyd C.E., 1998).

Figure 2 – A vertical pump aerator in action (Boyd C.E, 1998) (https://kascomarine.com/blog/the-fluidity-of-evaporation/)

These are surface aerators operated by a propeller, and water is sprayed into the air from the center of the float through an opening. The entire equipment is suspended just below the surface of the water with the help of the float. The float in the component of the vertical pumps must have in its component two anchor points to maintain stability and to prevent the rotation of the unit during operation. The anchoring is done with the help of cables fixed to the edge of the pond or to a heavy object on the bottom of the pond. This type of aerator does not circulate the water in the pond, so that difficulties may occur in the total mixing of the thermal stratification, and the lower layers remaining anoxic. That is why these vertical aerators are used exclusively in shallow ponds for trout and tilapia crops. The minimum operating depths vary from 53 to 122 cm, depending on the pumping efficiency and the size of the unit. (worldfishcenter.org)

PADDLE WHEELS

This aeration equipment is generally of two types: aerodynamic with paddle wheels and floating electric aerators. The electric aerator with paddle wheels is conditioned by the availability of electricity in the aquaculture pond. Electric paddle aerators are usually mounted on floats and anchored on the shore of the pond. The paddle wheel of such an aerator helps to spray water into the air to increase the aeration rate.

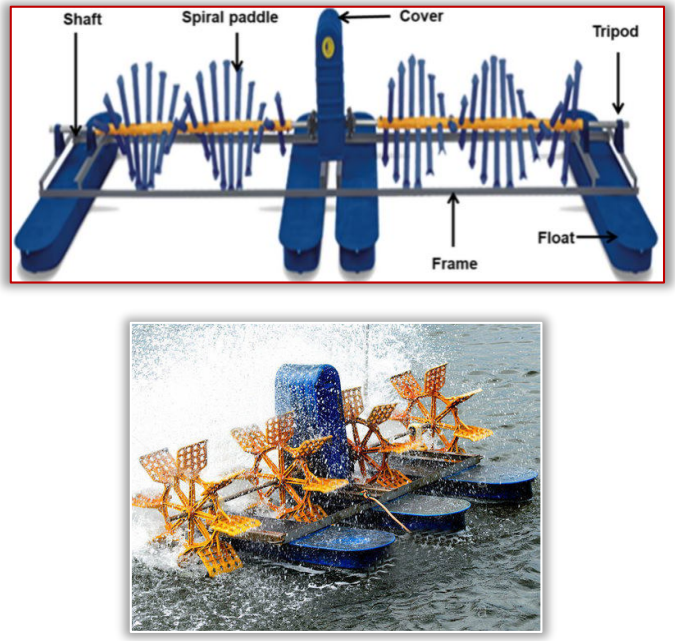

Figure 3 –Designs of paddle wheel aerator (Subha M. Roy 2021; https://www.indiamart.com/proddetail/aquaculture-paddle-wheel-aerator-20206411230.html)

This aerator model is composed of a frame, wheel with blades and bearings, floats, motor, speed reduction mechanism and coupling. Pallet aerators are the most common types of aerators used in large ponds, and the paddle wheel or their rotor is made mainly of polyvinyl chloride (PVC) or stainless steel, and PVC floats (Ahmad T. and Boyd C.E, 1988).

The motor is connected to a gearbox to reduce the speed through a shaft, coupling and bearings. Several wheels are connected to the shaft, and the engine and gearbox are positioned in the center of the frame. The whole assembly is fixed on the frame, and the frame is mounted on two floats.

The floats are designed so that the rotors of the paddle wheels are partially submerged. Rotating the blade on a vertical plane helps to release water into the atmosphere to absorb oxygen from it to increase the DO content of the water. Increasing the DO content of water and throwing water into the atmosphere to absorb oxygen from it is done by rotating the blade on a vertical plane. PTO-powered paddle wheels for tractors usually have a very high power and can have standard oxygen transfer rate (SOTR) values of 40 kg O_2 / h or higher).

These types of aerators are very effective when an acute lack of DO concentration is detected in the pond water. Due to the fact that most tractors have a much higher power than would be necessary in the operation of an aerator, a large fraction of the available power is lost, and therefore the aeration efficiency is very low.

These types of aerators are very useful in case of emergencies, because they can be moved quickly and easily to the place of need, and in most cases, wheels with paddles operated by PTO usually have a paddle immersion of 75 to 100 mm (Roy Subha M, 2021).

Ahmad T. and Boyd CE 1998 did research and found that the most suitable design for the electric aerator, which forms an interior angle of 135 degrees in cross section.

DIFFUSE AIR SYSTEMS

Diffuse air systems have a high-volume blower that acts at low pressure to supply air to speakers that are suspended in water or are located at the bottom of the pond.

The types of diffusers used in the component of diffuse air systems are varied and are made of various materials, these can be: porous ceramic tubes, perforated plastic pipes, ceramic dome diffusers, perforated rubber tubes or porous paper tubes. The location of these diffusers on the bottom of the pond contributes to the minimization of the suspended sediments in the pond. (Boyd C.E., 1998)

The minimum allowable pressure of a diffuser air system becomes higher as the water depth above the diffusers increases, as there must be sufficient pressure to force air through the duct system and to cause air to exit the diffuser against hydrostatic pressure at the discharge point.

Figure 4 – An air diffuser pond/tank aerator in operation (worldfishcenter.org)

Diffuse air systems that release small bubbles are usually more efficient than those that discharge coarse bubbles. This is because the fine bubbles have a larger surface area for the surrounding water than the larger bubbles. Oxygen diffuses into the water to the surface, so a large surface area facilitates more efficient oxygen transfer (Boyd C.E., 1995).

The depth of the diffuser also has an impact on the water circulation rates in the pond. As the bubbles rise to the surface and expand, water is entrained. This process creates a lifting air, which pumps bubbles and entrained water to the surface. Deeper water is usually colder and denser than surface water and spreads slowly and moves away from the column of growing bubbles, creating a vertical circulation.

The growth of the aquaculture sector will affect water quality by increasing nutrient loads, and high turbidity to chemical discharges, such as drugs and biocides. Increasing nutrient loads can lead to eutrophication of the pond water, and this process can cause the death of crop species, as well as the deterioration of water quality (Duff A, 1987).

Different types of microorganisms, such as bacteria, viruses, algae, fungi and parasites, can be present in effluents from the aquaculture sector and can create negative effects on health, when they are spread and come into contact with humans and other organisms in the environment.

Another negative aspect on the environment is the overfeeding of fish and marine life. This circulation cell has a limited horizontal extent and therefore diffuse aeration systems usually require several diffusers arranged in a network pattern to effectively ventilate and circulate the blockage. These aeration systems are more efficient in deeper ponds and are less common in commercial aquaculture ponds (Perry L. Oakes et al., 2011).

THE IMPACT OF AQUACULTURE ON THE ENVIRONMENT

Despite the benefits that the aquaculture sector offers, such as providing food and creating millions of jobs for the population, this activity also causes a negative impact on the global environment (Martinez-Porchas M., 2012).

The lack of a feeding plan combined with the lack of light can have negative consequences on the environment. Nutrients that remain unabsorbed by marine life are released into the environment and cause pollution of ponds in aquaculture. The food management program that aquaculture producers follow is absolutely essential because it is correlated with economic and environmental sustainability (White, 2013).

Aquaculture, like any other production activity, generates solid waste, such as uneaten or spilled feed and fish feces, as well as dissolved waste, especially carbon, nitrogen and phosphorus, together this waste reduces the quality of the water in the pond.

In flow systems such as ponds or cages, an artificial channel is created by continuously pushing water through the system to maintain a higher water quality for fish, constantly providing them with fresh water (Aero-Tube, 2014).

Urgent measures are needed to manage water quality and the negative impact on the development of this important sector on the environment. In this regard, worldwide, the competent institutions have imposed increasingly stringent standards and regulations for the discharge of effluents from aquaculture (Jegatheesan V., 2011).

CONCLUSIONS

Dissolved oxygen is the most important element concerning water quality in any aquaculture system, because all aerobic aquatic organisms need a constant supply of oxygen to survive.

Aeration equipment is used to increase productivity in aquaculture ponds, therefore understanding the mechanisms of oxygen production, transfer, and depletion is necessary to help pond operators in managing fishing development.

This document provided information regarding dissolved oxygen dynamics related to pond aerators and a brief description of the most widely used aeration technologies in fish farming.

Acknowledgement

This work was supported by the Romanian Research and Innovation Ministry, through NUCLEU Programme, Project "PN 19 10 02 03: "RESEARCH ON THE INTENSIVE GROWTH OF FISH IN THE POLYCULTURE SYSTEM AND THE COMPLEX VALORIFICATION OF THE BIORESOURCES (PLANTS) OF AQUATIC", contract no. 5N / 07.02.2019 and ADER 25.3.1 „RECIRCULATING AQUACULTURE SYSTEMS USED IN THE PRE-MARKING STAGE OF NATURAL WATER REPOPULATION WITH FISHING MATERIAL", contract no ADER 25.3.1 / 26.09.2019.

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research-Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research-Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021

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ISSN: 2067-3809