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Water Quality Management in Fish Ponds for Optimum Fish Production

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Abstract

Water quality is a key factor determining the success of aquaculture because it has a direct effect on the health, growth and productivity of fish. Low fish yield and financial losses can occur due to stress (due to low water quality), indirectly leading to diseases and death. Phytoplankton is a part of the natural food web in aquatic systems and is consumed by zooplankton and grazers, which are favourable for fish metabolism and survival if dissolved oxygen, pH, ammonia, turbidity and temperature are maintained within acceptable thresholds. Physico-chemicals imbalances can impair physiological functions and decelerate growth and they contribute to susceptibility to infections. Maintaining water quality is indispensable for good health of aquatic organisms and periodic monitoring and timely management is essential to avoid unwanted conditions and maintain a stable aquatic environment. Through maintaining appropriate water conditions, fish farmers can increase survival rates, improve growth performance and improve profitability. As such, water quality management is not only a necessary condition for healthy fish farming but also a significant factor for long-term sustainability and profitability in aquaculture.

Keywords: Aquaculture, Fish production, Pond, Water quality

Introduction

Water quality is one of the primary parameters in the aquaculture practices since it is crucial for the growth and survival of the cultured organisms. The pond water quality affects fish growth, health and the productivity level of the fish farm, hence, it constitutes a major factor for success or failure of fish farming. Pond's physico-chemical characteristics have been reported to influence pond ecology, thus affecting fish metabolism, feeding efficiency, growth and survival. Some of the most important water quality parameters to monitor regularly are water temperature, pH, dissolved oxygen, alkalinity, hardness, ammonia, nitrite, and so on. Water pH is said to decide the alkaline nature of the pond water; turbidity would affect the light penetration. Dissolved oxygen (DO) is one such most important water parameter as oxygen in dissolved state in the water is vital for respiration of the fishes and thus for the survival of the aquatic lives. Depletion in DO concentrations can always lead to stress for fishes and further leading to mortality due to hypoxia. Free carbon dioxide levels in the pond should also be closely monitored. If the CO_2 levels are elevated, it can cause the quality of water to degenerate by altering the pH and therefore, affecting fish respiration. The alkalinity and hardness of the pond water give a buffering capacity and hence, promote the balancing and stability of pH in the pond. Nitrite and ammonia concentrations need to be handled because these must be present in pond waters at very low levels. Higher levels of these nitrogenous compounds lead to eutrophication and may further cause toxicity towards fish. Hence, regular monitoring and proper management of these water quality parameters is highly indispensable for maintaining a healthy pond environment, which is in turn a necessity for achieving optimum fish growth and production (Xu and Boyd, 2016).

Article History

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Temperature

Water quality is a matter of concern in aquaculture and the water temperature has been recognized as one of the most significant water quality parameter because it is a crucial element that affects physico-chemical and biological processes in aquatic ecosystems especially fish ponds. Respiration, metabolism, growth and other physiological processes in fish is directly affected by air temperature. The metabolism of fish body also increased due to the rise in temperature during the summer months, which will increase the fish growth rate. But more importantly, fish metabolism rate is lowered in the colder winter months, which does causes a reduced growth rate. Increased water temperatures result in reduced concentrations of dissolved oxygen and increased concentrations of ammonia (Anonymous, 2024), resulting in fish stress and ammonia toxicity. Temperature regulates phytoplankton abundance, the first-order link of the food chain of aquatic animals of the pond ecosystem to a greater extent. Temperature of 24-30 °C is optimum range for fish pond, feeding, reproduction, health and growth. It is necessary to regulate pond water temperature for growing cultured fish in stable pond environment as it is also known to be influenced by temperature on daily or seasonal basis.

pH

pH means the value of concentrations of hydrogen ions present in water. This article talks about the importance of suitable range of pH for healthy fisheries in freshwater pond ecosystem. pH also influences the fertility and productivity of the pond water as it controls hydrogen sulphide and ammonia levels in ponds. Therefore, pH is said to have a great influence on the fish growth and survival. Slightly alkaline water is considered to be productive for fish culture. A pH range of 6.5-8.5 is regarded to be optimum for optimum fish production in pond systems. At a pH between 6.0-9.0, the fish growth is optimum; between 4.0-6.0, the growth rate is slow; between 9.0-11.0, the fish growth is very slow and it can be sometimes lethal to fish if kept for an extended period. A pH value at 4 and 11 are known as acid death point and alkaline death point respectively. Hence, pH is an important parameter which needs to be closely monitored at regular intervals. For pH level regulation and management in fish ponds, liming is usually practised. It is recommended to carry out liming few weeks prior to fertilization and fish stocking. Typical liming materials are calcium carbonate [$CaCO_3$], dolomite [$CaMg(CO_3)_2$], calcium hydroxide or slaked lime [$Ca(OH)_2$] and calcium oxide or quick lime [CaO]. Agricultural gypsum is also recommended in ponds as it can adjust pond water hardness by correcting extreme high pH values. Liming enhances water quality by buffering acidity and improving alkalinity in ponds. The application of lime increases the soil pH which facilitates in improving the total alkalinity and hardness, always making sure that the value is above 40 mg L^{-1} as $CaCO_3$.

Turbidity

Suspended particles and planktonic life characterize pond water; soluble and colloidal humus are the by-products from the breakage and decomposition of organic matter, which leads to water turbidity. Turbidity induced by plankton is considered beneficial and advantageous while turbidity caused by the presence of suspended particles is regarded to be unfavourable for fish ponds. Although plankton-induced turbidity is encouraged in fish ponds, excessive algal blooms are not desirable as they limit and prevent light penetration and ultimately narrowing the pond's effective productive zone. The Secchi disk transparency ranging from 30 to 40 cm is considered optimum for fish ponds. In case of Secchi disk transparency below 30 cm, the dissolved oxygen levels get reduced drastically especially during night time causing mortality. Turbidity due to suspended solids can be managed with the application of materials such as organic manure, gypsum, alum, *etc*. Application of organic manure @ 500-1000 kg ha^{-1} helps in allowing the suspended particles to settle and thereby improving the clarity of the pond water. Gypsum, when applied at a rate of 250-500 kg ha^{-1}, has the capacity to flocculate the suspended particles, which can then be removed from the pond system. Alum is known to act as coagulant and can bind together with the suspended particles, allowing them to settle down. A dose of 25-50 kg ha^{-1} of alum is recommended in ponds.

Dissolved Oxygen

Dissolved oxygen in water is one of the most useful parameters which are necessary to all aquatic organisms. It is also required for decomposition and break down of organic matter at the pond bottom. It is an important water quality parameter for aquaculture because low levels can be lethal to fish, leading to suffocation and mortality. The ideal concentration of dissolved oxygen level for fish is 5 mg L^{-1} as the lower level of dissolved oxygen. It is typically recommended to maintain aeration in the pond given by different mechanical aeration techniques like paddle wheel aerators, airlift pumps, air diffusers, agitators, *etc*.

Carbon Dioxide (CO_2)

Carbon dioxide in ponds comes from fish and other aquatic organisms' respiration and organic matter decomposition. CO_2 levels are said to fluctuate daily with the highest levels of CO_2 occurring when the dissolved oxygen is the lowest. It is advised to maintain the free carbon dioxide levels below 3 mg L^{-1}. However, CO_2 levels between 5-15 mg L^{-1} are also acceptable for fish culture ponds. High levels of carbon dioxide adversely affect fish and may even lead to mortality at extreme levels. High CO_2 levels can be corrected and managed by providing aeration and correction of pH. According to Hemal *et al.* (2024), application of 1.0 mg L^{-1} of hydrated lime can neutralize 1.68 mg L^{-1} of free CO_2.

Ammonia

Ammonia in fish ponds is known to originate from excretion, degradation of organic matter and diffusion from pond sediments. It is regarded as a key indicator of water quality as well as a parameter to measure the effectiveness of biological filtration in ponds. An optimal concentration of unionized ammonia of 0.02-0.05 mg L^{-1} is acceptable for fish culture. However, beyond this range, fishes become sensitive towards unionized ammonia. The presence of high levels of ammonia in fish ponds have been found to negatively impact

fish metabolism resulting to reduced feed efficiency, fish lethargy and eventually leading to fish mortality. Ammonia also has adverse effects on fish growth, disease resistance, feed uptake and conversion efficiency even at sub-lethal concentrations. Ammonia toxicity can be reduced with the help of management measures such as providing regular aeration, maintaining healthy phytoplankton abundance and avoiding algal blooms. Biological filters are also advised as they are an important component of ammonia decomposition, with ammonia being converted to nitrite and then to nitrate *via* nitrification (Cole and Boyd, 1986).

Nitrite

Nitrite is a nitrogenous intermediate compound involved in the nitrogen cycle through the processes of nitrification and denitrification. Nitrite gets readily oxidized into nitrate with the help of nitrifying bacteria in case of oxygen-rich conditions. However, nitrite will get reduced to ammonia again through denitrification during oxygen deficient conditions. The typical concentration of nitrite in an aquatic system is very low and theoretically undetectable in a well-managed pond ecosystem. Nitrite, when allowed to build up, can be very toxic to the fish and other aquatic organisms in the system, by disrupting the transport of oxygen in the fishes specifically by affecting the haemoglobin and its functions. High nitrite concentrations can be avoided through adequate aeration, proper fertilizer application and removal of organic waste and silt.

Alkalinity

Alkalinity is the measure of the ability of the water to neutralize the acids (carbonates, bicarbonates, phosphates, hydroxides, borates, silicates, *etc.*). It is the water's buffering capacity and ability to withstand changes in pH. Generally, the alkalinity level of 50-300 mg L^{-1} as $CaCO_3$ is regarded as optimum for freshwater ponds. The pond waters are rated as low or high alkaline when the waters have lower than 20 mg L^{-1} or higher than 300 mg L^{-1}. In ponds with alkalinity below 20 mg L^{-1}, free carbon dioxide itself produces carbonic acid that decreases the pH of the water of pond into very low values, especially at night. Alkalinity is an important water quality parameter that helps to stabilize the pH in fish ponds and ensures healthy optimum fish growth and productivity.

Hardness

Alkalinity is the water's capacity to neutralize acids and maintain stable pH while hardness represents the concentration of dissolved minerals particularly divalent ions consisting primarily of calcium (Ca^{2+}) and magnesium (Mg^{2+}). Calcium carbonate hardness is generally referred to hardness. It refers to the amount of divalent salts in water and does not indicate whether calcium, magnesium or any other ions are responsible for the hardness. They are required for fish egg and bone development, growth and health, as well as for other vital physiological functions like enzyme activation, osmoregulation, *etc*. Hardness of 30 mg L^{-1} is suggested for optimum fish production. As both alkalinity and hardness are correlated, it is important to maintain appropriate levels of both these parameters which are favourable for optimum fish growth. Agricultural lime is recommended in cases of very low hardness levels. Table 1 provides a summary of key water quality parameters essential for fish culture ponds (modified from Boyd, 1998).

Table 1: Optimum water quality requirement for a fish pond

Sl. No.	Parameters	Optimum level
1	Colour (Colour unit)	Clear water, greenish hue < 100 colour units
2	Transparency (cm)	30-40
3	Turbidity (mg L^{-1})	< 30
4	Temperature (°C)	25-32
5	pH	6.5-8.5
6	Alkalinity (mg L^{-1})	50-300
7	Hardness (mg L^{-1})	30-180
8	Chlorides (mg L^{-1})	31-50
9	Dissolved oxygen (mg L^{-1})	5-10
10	Free CO2 (mg L^{-1})	<3
11	Ammonia (unionized) (mg L^{-1})	0-0.1
12	Nitrite (mg L^{-1})	0-0.5
13	Nitrate (mg L^{-1})	0.1-3.0
14	Total phosphorus (mg L^{-1})	0.05-0.40
15	BOD (mg L^{-1})	< 10

Conclusion

Good water quality is considered essential for the optimal growth and health of fish in fish ponds. It determines the degree of success of the fish farming venture and its undertakings. Therefore, fish ponds need regular monitoring and water quality needs constant keeping in an aquaculture farm. The water quality characteristics should be well maintained to their optimum or favourable levels in order to achieve the optimum fish productivity of a farm. However, maintenance of water quality of fish ponds is a time-consuming task which requires skilled manpower resources as well. Besides, most of the fish farmers do not have adequate knowledge on water quality parameters and their measurements. Thus, water quality testing used to be a major challenge in the earlier days for farmers even though most of the methods for their estimation are simple procedures. In the present day, a lot of simple but reliable water qualities testing kits have entered the aquaculture market. These have made water quality testing very much easy and accessible to the farmers. However, it is always recommended to take the advice of subject matter experts and relevant scientists or researchers while choosing the appropriate water testing kit. Besides, water quality monitoring regularly is equally important in order to ensure a good pond environment yielding optimum fish production.

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