## **Water quality parameters and their management in aquaculture**

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## **Abstract**

The water quality directly impacts the survival, growth, and general health of aquatic species raised for food. One of the most important factors influencing the success of an aquaculture culture is water quality. The water's physical, chemical, and biological qualities are the three primary factors that determine its quality. However, even a slight parameter variation like pH, temperature, or DO can stress the organism and result in behavioural or physiological effects. Water quality changes or degradation will affect growth and reproductive potential. Disease susceptibility is also elevated in such an environment. Water quality management solutions aim to improve the quality of the water. To reduce problems related to water quality and efficiently use water resources from economic and environmental sustainability, business owners and fish farmers in the aquaculture sector should be conversant with the principles of water quality management techniques.

**Keywords:** Aquaculture, Water Quality Management, Growth, Phytoplankton, Water Exchange

**1. Introduction**

"Water quality" for aquaculturists refers to the properties of water that facilitate the successful reproduction of the target organisms. The specific organisms to be grown specify the required water quality, which comprises many interdependent elements. The complex relationships between components necessitate addressing the composition of the full array, even though a component may occasionally be handled independently. Growth and survival are influenced by many ecological conditions and management strategies, which ultimately determine the output. High fish or crustacean stocking densities usually exacerbate problems with pond water quality and sediment deterioration.

Fish and other aquatic species carry out their regular activities, such as feeding, swimming, spawning, metabolism, fish body development, and excretion, in the physical, biological, and chemical environments known as water quality parameters. In many world places, fish and other aquatic species are recognised as significant cash crops and can be distributed through this approved method. Since the aquatic environment governs fish life, aquaculture requires desired water quality. When the environmental parameters are not within the range required for healthy fish growth, it can impact fish culture. A fish farmer should be primarily concerned with handling water quality problems that can result in poor fish development or even fish death (Boyd, 1978). Water quality management aims to regulate environmental elements to provide the perfect environment for fish growth and survival. Water availability has a major impact on an aquaculture business's potential to succeed or fail. The aquatic environment is composed of numerous aquatic factors. Aquaculture fishermen have to be aware of what can cause fish stress. According to Das *et al*. (2015), the variables might also be useful in determining the underlying reasons for problems in fish rearing.

**2. Water Quality Management**

The water environment and its effects on fish and other aquatic species are shaped by a dynamic network of physical, biological, and chemical factors that compose water quality. Water quality is a multifaceted concept when it comes to pond fish culture. Fish will often be larger and healthier in a pond with high water quality than in one with poor quality. Piper et al. (1982) assert that water quality has a major role in determining whether a fish culture operation succeeds or fails. Key factors that affect water quality include temperature, turbidity, oxygen, CO2, nitrogen, ammonia, pH, alkalinity, hardness, and others.

**2.1. Temperature**

The temperature of water is a physical attribute that indicates how hot or cold it is. Solar radiation immediately affects the temperature of the water and air. The chemical and physical characteristics of water can vary with temperature. Light energy is absorbed exponentially with depth in water; therefore in the upper layers, most of the heat is absorbed by dissolved organic matter and particle matter. The temperature of the water affects its density. Water temperature affects aquatic animals' growth, reproduction, and metabolism. Temperature is a hint that many animals use to plan their migration and breeding seasons. All living things have a maximum temperature, although plants and animals generally grow more swiftly in warmer climates. The ideal growth temperature of congenial species should be considered while selecting them for aquaculture. Water samples should be measured as soon as feasible by immersing a calibrated mercury or digital thermometer in the water and taking a reading.

**2.2. Turbidity**

The decomposition of organic waste produces humic compounds, suspended particulates, and planktonic organisms, collectively called "turbidity". As opposed to suspended particle turbidity, planktonic turbidity in aquaculture ponds is typically beneficial (McCombie, 1953). However, the effective area of the producing zone is reduced because thick blooms obstruct the entry of light and heat. It is stated that between 30 and 40 cm, secchi-disc visibility of fish ponds is optimal. According to Romaire and Boyd (1978), fish may get stressed or die at night when dissolved oxygen concentrations in ponds with Secchi-disc visibility of 10 to 20 cm drop. Applications of 500–1000 kg/ha of organic manure, 250–500 kg/ha of gypsum, or 25–50 kg/ha of alum can all help reduce turbidity from suspended solids.

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| **Secchi disk reading** | **Remarks** |
| < 20 cm | Pond too turbid. If pond is turbid withphytoplankton, there will be problems withlow dissolved oxygen concentrations. Whenturbidity is from suspended soil particlesproductivity will be low. |
| 20 - 30 cm | Turbidity becoming excessive |
| 30-45 cm | If turbidity is from phytoplankton, then pond is in good condition |
| 45 - 60 cm | Phytoplankton becoming scarce |
| >60 cm | The water is too clear. Inadequate productivityand danger of aquatic weed problems. |

**Table 1. Guidelines to evaluate Secchi disk visibilities for pond aquaculture**

**2.3. Dissolved Oxygen (DO)**

The atmosphere and photosynthetic plankton are the two primary sources of oxygen in water. Because of the poor solubility of oxygen in water, which also decreases with increasing temperature, increasing salinity, low air pressure, high humidity, and plankton blooms, getting enough oxygen is more difficult for aquatic creatures than terrestrial ones. Fish deprived of oxygen in the water are more likely to starve to death, stop their growth, and die from starvation (Bhatnagar and Garg, 2000). Aquatic species are affected by dissolved oxygen in terms of their physiology, behaviour, distribution, growth, and survival (Solis, 1988). Low DO conditions cause fish to swim very slowly, and they suffer damage if they get to the top of the water and the secchi disc value is less than 20 cm. When fish are gulping on the water's surface, there is a lack of DO in the pond.



**Fig 2. Relation between DO and Survival rate of fish**

**2.4. Biochemical Oxygen Demand (BOD)**

When bacteria break down organic materials like food particles or sewage, they require a total of dissolved oxygen, measured by the BOD. Due to excessive industrial and domestic sewage from non-point sources and excess phosphate, rural ponds may have a high organic load, which boosts the BOD level.

**2.5. Carbon dioxide (CO2)**

The microscopic organisms that comprise the fish pond biota and fish respiration are the primary producers of carbon dioxide in fish ponds. Organic waste decomposition is one of the primary sources of carbon dioxide in fish ponds. Fish producers are understandably worried about ensuring acceptable levels of dissolved oxygen. The potential toxicity of carbon dioxide is a concern because of the daily variations in the quantities of dissolved oxygen and carbon dioxide. Carbon dioxide concentrations are highest when there is least dissolved oxygen. The largest carbon dioxide concentrations are found in the winter, and the lowest during the summer. Wintertime dissolved oxygen concentrations are usually significantly greater than saturation levels, hence carbon dioxide is rarely a problem. According to Boyd (1978), freshwater fish ponds should have a moderate free CO2 content of 3 mg/litre, even if they can tolerate high levels of CO2. Aeration and pH elevation can be used to lessen the excess CO2 concentration. An experiment suggests that 1.68 mg/liter of free CO2 may be eliminated by hydrated lime at a dose of 1.0 mg/liter (Adhikari, 2006).

**2.6. pH**

The negative logarithm of the hydrogen ion concentration can be used to compute pH. The acidic gas carbon dioxide concentration has a major impact on the pH of natural streams (Boyd, 1979). Fish blood pH normally ranges from 7.4 to 8.5, although occasionally a small departure from this range—between 7.0 and 8.5—is more appropriate and beneficial for developing fish growth and reproduction activities. In water with a pH range of 4.0 to 6.5 and 9.0 to 11.0, fish can become stressed; at pH values of less than 4.0 or even higher than 11.0, fish mortality is all but certain.

**Fig 3. Relation between pH and Survival rate of fish**

Acid sulphate soil, an acidic water supply, and other factors will impact the pH in a pond environment.

* Precipitation rate close to pond areas
* Water with inadequate buffering
* The density of stocking resources
* The rate of sludge buildup and pond bottom feeding.
* The existence of macro/microorganisms in pond water, including phytoplankton.
* The rate of production of carbon dioxide in pond water

**2.7. Alkalinity**

Alkalinity is the capacity of water to neutralise acids without increasing pH. Total alkalinity is the total of the bicarbonate and carbonate alkalinities. Only bicarbonate alkaline, not carbonate alkaline, may be present in some water. Fish growth depends on the carbonate buffering system, regardless of the production technique. Carbonate and bicarbonate are buffering system storage regions for excess carbon dioxide. They would never be a limiting factor that may restrict photosynthesis, reducing oxygen production in pond production, where photosynthesis is the primary natural supply of oxygen. However, the buffering system prevents notable daily changes by storing carbon dioxide. The pH level could drop to 4.5 at night if there is no buffering system because free carbon dioxide will create a lot of weak acid, or carbonic acid. The pH level will rise above 10 because the phytoplankton will mostly consume carbon dioxide while photosynthesis is at its height. Pond water with less than 300 mg/L and less than 20 mg/L of CaCO3 is worthless. The ideal range for total alkalinity in freshwater fish ponds is between 50 and 300 mg/liter of CaCO3.

**2.8. Hardness**

Water hardness is more complicated than alkalinity, yet they are both comparable. It is an essential part of fish farming and a topic of frequent discussion regarding water quality. Not only is the hardness of calcium and magnesium tested, but other ions such as hydrogen, iron, manganese, strontium, zinc, and aluminium are also considered. The biological functions of fish depend on calcium and magnesium. Fish can absorb calcium and magnesium from their food or water. At least 30 mg/litre of hardness should be maintained for the optimal growth of aquatic species. Adding agricultural lime to the material can increase low amounts of hardness.

**2.9. Ammonia**

Ammonia measurements are used to establish the initial condition of the biological converter. Since fish are highly sensitive to unionised ammonia, the optimal range for this nutrient in pond water is 0.02-0.05 mg/liter. When ammonia concentrations rise to harmful levels, fish cannot effectively absorb energy from their diet. If the ammonia level becomes too high, the fish will become lethargic and eventually go into a coma and die. In well-maintained fish ponds, ammonia rarely reaches lethal levels. However, ammonia can have "sub-lethal" effects at quantities below the lethal threshold, such as reduced disease resistance, poor feed conversion, and stunted growth. The main cause of ammonia in fish ponds is fish faeces. Protein in the food is the main source of ammonia in fish-feeding ponds. In fish ponds, one of the main sources of ammonia is diffusion from the sediment. As this organic stuff decomposes, ammonia seeps into the water through the sediment. Two main processes might result in ammonia being lost or changed. The most important way that ammonia is absorbed is by algae and other plants. One nutrient that plants require for growth is nitrogen. One of the most important processes in fish pond ammonia transformation is called "nitrification." Bacteria transform ammonia into two different forms: nitrite (NO2) and nitrate (NO3). Aeration can reduce the toxicity of ammonia. Ammonia is removed from water by a healthy phytoplankton. The ammonia may also be decreased by formalin. In a fish pond, proper feeding management should be kept up. According to Cole and Boyd (1986), biological filters can purify water so that ammonia is converted to harmless nitrate through the nitrification process.



**Fig 4. Relation between ammonia and Survival rate of fish**

**2.10. Nitrite**

The second chemical indicator used to determine how well the biological converter functions is nitrite. A functional bio-converter should eliminate the presence of nitrite in pond water. Nitrosomonas, an autotrophic bacterium, uses ammonia and oxygen in the bioconverter and, to a lesser extent, on the pond walls to produce nitrite. Nitrite is the "invisible killer" that is referred to. It can be lethal in quantities as low as 0.25 ppm, especially for smaller fish. The most effective methods of preventing hazardous nitrite accumulation in pond culture are effective organic waste collection, suitable aeration, and optimum fertiliser delivery.

**2.11. Phosphorous**

The most crucial component for preserving pond fertility is often known to be phosphorus. It may resemble one of three things:

1. The inorganic phosphate soluble in water, phosphorus (PO4)
2. The particulate organic phosphorus found in plankton, detritus, and sedimentation.
3. Soluble organic phosphorus.

Form PO4, sometimes called dissolved phosphorus or soluble inorganic phosphate phosphorus, is the form utilised in production out of the three. The body needs it to divide cells, synthesise fat, protein, and high-energy molecules like AMP, ADP, and ATP. Acidic soil requires using phosphate fertilisers in addition to lime because phosphorus becomes inaccessible in acidic pond soil and stays in compound form with Fe, Al, Mn, and Zn.

**2.12. Hydrogen sulphide**

Fish ponds that are freshwater should not contain hydrogen sulphide. Fish undergo sub-lethal stress and lose balance at concentrations of 0.01 mg/litre of hydrogen sulphide. Frequent interchange of water can help avoid the accumulation of hydrogen sulphide. Hydrogen sulfide's toxicity can also be reduced by increasing the water's pH through liming. In addition, 6.2 mg/litre of potassium permanganate is added to the water to remove hydrogen sulphide.

**2.13. Redox Potential**

Redox potential is useful for determining how much oxidation or reduction has occurred. The anaerobic layer contains chemicals like H2S, CO2, NH3, H2SO4, and other substances, while the aerobic layer contains chemical components like oxygen, carbon dioxide, and minerals. The amount of oxidation or reduction is correlated with the existence of microorganisms. The degree of Eh is one measure that shows how effectively soil and water can support prawn biomass. Photosynthetic bacteria (PSB) are important in semi-intensive culture as opposed to the algal population's primary output by absorbing and converting organic matter into minerals and nutrients. PSB can significantly improve the cultural atmosphere and are especially common due to the high illumination and low oxygen levels.

**3. Nutrients**

Nutrients, an essential part of protein, regulate the aquatic environment. Phosphorus is sometimes considered the most crucial element alone in sustaining aquatic productivity, while being a very small component. Dissolved inorganic nitrogen in the range of 0.2 to 0.5 mg/litre and phosphorus fertility for aquatic production in the range of 0.05 to 2.0 mg/litre are considered appropriate ranges for fish productivity. Silicate is still found in natural water in its silicate form, which is important for diatoms' structure. Moore (1946). The nutritional state of the soil and water in fish ponds has the greatest impact on the development of plankton organisms (Banerjea, 1967). The ponds' nutrient levels can be increased by adding organic and inorganic fertilisers in carefully measured doses. However, as they can cause excessive plankton formation, algae blooms, and oxygen deprivation, increased nutrient levels have the potential to be harmful.

**4. Management**

Water quality indicators should be examined to ensure proper pond management and to avert circumstances hindering prawn growth. These elements can help identify problems and help develop solutions by aiding in diagnosis. Even though single statistics are usually not very informative, a combination of factors can indicate dynamic activity in the pond. Microbe and phytoplankton populations control the number of metabolites and oxygen in the pond. pH, CO2, and DO variation—especially in its vertical profile—are indicators of their population. Because the primary factor influencing pH dial variation is CO2, monitoring pH fluctuation may be adequate. In addition, quantifying CO2 is more complicated.

Every day, measures are taken in the afternoon, between 2 and 3 pm, and in the morning, between 5 and 6 am. This is equivalent to the times immediately preceding and following the photosynthetic peak. Thus, these parameters' greatest and minimum values occur throughout this period. Since the other metrics don't have a distinctive dial pattern, they can only be checked once a day, ideally at a consistent time. Alongside indicators of water quality, feeding and growth data must be displayed. This is because feeds provide the nutrients that cause algal blooms, and too much feed can quickly cause the quality of the water to decrease. Collecting data and conducting meticulous observation are useless if they don't influence judgements about water management. This becomes increasingly important as the cost of implementing different management techniques (aeration, water exchange, inputs) increases. Most problems with water quality can be rectified with enough water exchange. Therefore, if vast water supplies suitable for aquaculture were available, monitoring would not be as crucial and high production levels might be pursued. Pursuing more intense culture increases the likelihood of encountering problems with water quality and sickness when water is scarce.

**5. Water Exchange**

When stocking density increases, keeping the water supply steady and the water quality high is critical. Water exchange is currently the most efficient and widely used method to maintain good water quality, in addition to water quality boosters like sanitizers, zeolite, etc. Salinity, excess metabolite removal, oxygen delivery to algae, and pond temperature control are all commonly achieved through water exchange. Natural productivity levels, turbidity, stocking density, total biomass, production duration, and water supply and volume all impact the exchange rate. Changing the water in a way that results in a gradual change in quality rather than an abrupt one is the rationale behind water exchange. In semi-intensive systems, water is exchanged at a modest flow rate often, and sometimes even continuously. Small ponds may see sudden additions of large volumes of water, which could stress the cultivated organisms by disrupting their environment. Therefore, unless there is a rapid die-off of plankton, an extremely low oxygen level, or after chemical treatment, massive water replacement is not recommended. Continuous water exchange and paddlewheel activity are required to thoroughly mix the pond water. There will be wide regional differences in the pond's water quality, and the cultivated organisms' distribution on the pond bottom will be irregular. Reintroducing fresh water after the lowered level is not recommended, especially in the summer. It is possible for the water's oxygen content to be reduced and the pond bottom deterioration process to accelerate when the temperature is raised while the water level is lowered. Before adding fresh water to the pond at the prearranged exchange rate, the paddlewheel should be turned to homogenise the water throughout.

Surface and bottom water outflow are both worthy of consideration. The water quality at the lowest layer is usually worse than that of the upper layer. It is best to release surface water when there are scums, prawns or prawn droppings, or floating dead plankton. Freshwater with a lower density at the surface layer should be released to avoid salinity fluctuations during and after rainstorms. Reducing salinity by more than 5 ppt at a time with water exchange is not suggested. Sharp variations in salinity may cause the phytoplankton fauna and their population densities to alter, which could lead to ecosystem instability.

**6. Conclusion**

Water quality varies greatly between different geographic locations. Aquaculture can be practised in some salty waters, and fish can even drink water considered unsafe for human consumption. The quality of the water affects the growth and health of fish. Water quality should, therefore be a top priority for aquaculture. Since water quality might fluctuate over time, it needs to be periodically checked. Knowing how to evaluate the observed water quality is also essential to preserving the well-being and health of their fish population. Aquaculture practises must maintain critical water quality indicators within optimal ranges to guarantee a sustainable fish yield. In recent years, nanotechnology has profoundly changed every field. Nanotechnology can potentially eradicate illnesses from aquaculture hatcheries and ponds due to its antibacterial properties. Nanosensors may provide an additional means of early pathogen and metabolite identification to preserve a healthy pond environment.

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