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The Key Water Parameters for Sustainable Aquaculture: Keeping an Eye on Water that Supports Healthy Fish Growth

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Sustainable aquaculture depends on maintaining ideal water quality conditions to guarantee the wellbeing, development and output of aquatic species. The parameters such as, temperature, dissolved oxygen, pH, ammonia, nitrite, nitrate, salinity, alkalinity, hardness and turbidity, among other crucial water factors that influence metabolic processes, immunological reactions and the general equilibrium of the environment. The primary causes of low output and worse water quality in aquaculture systems are toxic algal blooms, overstocking, excessive feeding, the use of pesticides, antibiotics and pollution sources. Stress, disease outbreaks and reduced productivity are all consequences of poor water quality that can harm aquaculture enterprises' ability to be environmentally and economically sustainable. Fish behavior and farm health are also influenced by water quality characteristics. Reducing ecological impacts and encouraging ethical aquaculture methods require routine monitoring and control of these parameters. This article demonstrates the significance of each parameter, appropriate thresholds, interdependencies and methods for routine monitoring and control.

Key words: Alkalinity, Ammonia, Hardness, Nitrite, Nitrate, pH, Salinity and Water Quality.

Introduction

Aquaculture, a crucial part of the world's food production, is the farming of aquatic organisms including fish, crustaceans, mollusks, aquatic plants etc. As the demand for seafood is rising, it is more crucial than ever to ensure the sustainability of the aquaculture system (Yamin *et al.*, 2024). Water quality is one of the main determinants of aquaculture's sustainability and success. Aquatic species use water as a medium to release waste materials, obtain nutrients, and obtain oxygen in addition to using it as a habitat (Tundisi, 2018). In many parts of the world, fish and other aquatic organisms are either explicitly or implicitly important cash crops. The physical, biological and chemical support that they require to carry out their daily activities such as feeding, buoyancy, metabolism, fish body development, and excretion make water quality a cost-effective source of protein.

Many researchers have observed problems with lentic (standing or slow-moving water like lakes and ponds) and lotic (flowing water like rivers and streams) water bodies (physical, chemical and biological) after acquiring different kinds of pollutants which affect water quality (Verma *et al.*, 2022). Rapid industrialization and the careless use of chemical pesticides and fertilizers in agriculture are causing widespread and varied contamination in aquatic ecosystems, which is lowering water quality and depleting aquatic biota. The usage of contaminated water causes water-borne illnesses in the human population. Therefore, it is crucial to periodically verify the quality of the water (Gorde and Jadhav, 2013).

The following categories of water quality parameters can be identified:

- Physical Water Quality Parameter
- Chemical Water Quality Parameter
- Biological Water Quality Parameter

1. Physical Water Quality Parameter

Physical parameters of water quality are those characteristics that can be measured that affect the water's appearance, behavior and appropriateness for aquatic life. The various physical parameters of water quality are as follows:

i. Temperature

Temperature is the amount of heat or cold that an aquatic organism's body experiences, whether it is on land or in water. We know that solar radiation has a direct impact on water temperature (Prema et al., 2020). When it comes to aquaculture, water temperature is crucial since fish are cold-blooded (poikilothermic) creatures whose body temperature varies with their surroundings. The temperature range in which each species of fish grows, reproduces and survives is specific. The water's temperature has an impact on disease resistance, feeding habitat and metabolic processes. Because of the increased need for oxygen, the microbiota's rate of respiration and metabolic activity both increase with temperature. Figure 1 illustrates how to use a thermometer to measure the temperature of water.

Fig.1. Digital Thermometer

Turbidity

Turbidity is the term for the suspended particle matter that ranges in size from colloidal to coarse dispersions and decreases water's capacity to transmit light. The amount of light that enters the water can be influenced by the degree of turbidity, which can have an impact on fish visibility, temperature regulation and aquatic plant photosynthesis. There are advantages and disadvantages to high turbidity levels for fish farming. However, moderate turbidity can help some species by providing them with food sources, predator protection, and a more natural habitat. Turbidity in fish ponds caused by planktonic organisms is preferable to turbidity caused by suspended clay particles. The suspended clay particles obstruct light penetration and stunt plant growth. Filter alum treatment (aluminium sulphate or Al_2 $(SO_4)^3$) is a more effective way to remove clay turbidity because suspended clay particles will coagulate and precipitate out of the water when exposed to alum (Boyd and Pillai, 1985). The success of fish farming depends on maintaining ideal turbidity levels. As seen in figure 2, a secchi disc is used to measure the water's turbidity.

Fig.2. Secchi Disc

ii. Solids

The various kinds of organic and inorganic particles that are either dissolved or suspended in water are referred to as solids. Total solids, total suspended solids and total dissolved solids are the three categories for solids. The sum of the dissolved and suspended solids is referred to as total solids. It shows the total amount of solid particles in the water. Particles suspended in water that can be captured by a filter are referred to as total suspended solids (TSS). These consist of fish waste, algae, leftover feed, slits, and other debris, among other things. The term "Total Dissolved Solids" (TDS) describes particles that dissolve in water and can be filtered. These mostly contain salts, minerals, and ions, among other substances. Total dissolved solids aid in determining the water's general quality in aquaculture (Elmi *et al.*, 2024). It has shown in figure 3, a TDS meter is used to measure it.

Fig. 3. TDS Meter

2. Chemical Water Quality Parameter

The term "Chemical Water Quality Parameter" refers to the characteristics of water that can be used to quantify the amount and presence of chemicals that impact what is suitable for aquatic life. The various chemical parameters of water quality are as follows:

pH: The pH scale, which indicates how acidic or alkaline a solution is, measures the concentration of hydrogen ions (H^+) in water. the pH scale, which goes from 0 to 14. 7 is the pH number that is neutral. Therefore, water with a pH of 7 is neither basic nor acidic, while water with a pH of 5 or above is basic and water with a pH of less than 7 is acidic. The pH of natural waterbodies is highly affected by the amount of the acidic gas carbon dioxide present (Boyd and Lichtkoppler, 1979).

The pH of fish blood is 7.4, with a small variance usually ranging between 7.0 and 8.5, which is better for fish health. Fish may become stressed by water that has a pH between 4.0 and 6.5 and 9.0 and 11.0. The pH of pond water varies during the day as a result of plant photosynthesis and vertebrate respiration. pH is frequently lowest at dawn and highest at dusk because respiration raises carbon dioxide concentrations at night, which then react with water to generate carbonic acid and lower pH. This could reduce the oxygen-delivery capability of fish blood (Ekubo and Abowei, 2011). A pH meter is used to test pH, as illustrated in fig. 4.

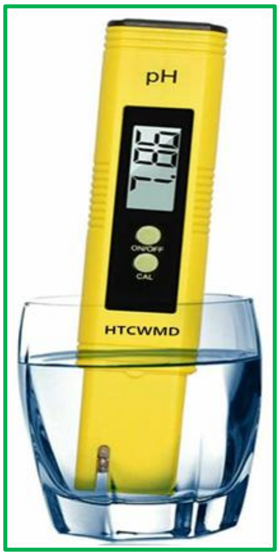

Fig.4. pH Meter

Salinity: Salinity is the total concentration of all dissolved ions in natural water. It is critical to fish health, growth, and reproduction. Which aquatic animal species should be found in a given body of water depends on its salinity. According to Meck (2000), fish species generally show poor tolerance to significant variations in water salinity, whether in fresh or salt water. While adding water can lower high salinity, liming and the addition of specific mineral salts can correct very low salinity concentrations in freshwater ponds (Mishra *et al.,* 2024). Figure 5 illustrates how to use a refractometer to determine salinity.

Fig. 5. Refractometer Meter

Dissolved Oxygen: The entire amount of oxygen that is dissolved in water and accessible to aquatic life for respiration. DO is its abbreviation. This measure is crucial for evaluating the quality of water because it primarily affects aquatic species that live in water. Photosynthetic plankton and atmospheric air are the main sources of oxygen in water. In aquatic habitats, oxygen depletion causes fish to be underfed, starve, grow less, and die more frequently, either directly or indirectly (Bhatnagar and Garg, 2000).

Fig.6. DO Meter

The solubility of DO decreases as water temperature and salinity increase. Therefore, maintaining an aquatic environment's dissolved oxygen content at its ideal level is crucial. Fish that reach the water's surface are negatively impacted and show noticeably slower swimming rates when DO levels are low, especially when the secchi disc reading falls below 20 cm. The low DO level can be controlled with various aerators. The DO in water is measured using a DO meter device, as seen in fig. 6.

Conductivity: The quantity of dissolved ions, including metals, salts and minerals, determines the conductivity of a water, which is a measurement of its capacity to carry an electrical current. Mobility, valence, relative concentration, temperature of the liquid, ions (Ca^{2+}, Mg^{2+}, HCO^{3-}, CO^{3-}, NO^{3-} and PO^{4+}) and their overall concentration all affect this capacity. According to Das (2019), conductivity, a metric of primary output, or chemical richness, can be used to calculate fish productivity. Because fish have varying capacities for osmotic pressure maintenance, the ideal conductivity for fish production differs from species to species. This range is ideal for fish pond culture: 100-2000 µSiemens/cm. A conductivity meter is used to measure conductivity, as illustrated in fig. 7.

Fig.7. Conductivity Meter

Alkalinity: The term "alkalinity" refers to the water's resistance to pH fluctuations and measures the overall concentration of bases in pond water, such as carbonates, bicarbonates, hydroxides, phosphates and borates, dissolved calcium, magnesium and other substances. Common substances that raise the alkalinity of water include hydroxides, phosphates, bicarbonates, and carbonates. It is generally given as milligrams per liter of calcium carbonate (mg/l as $CaCO_3$) and is tested by titrating with standardized acid to a pH of 4.5. 50–300 mg/l of alkalinity is the optimal range for fish culture (Santhosh and Singh, 2007).

Hardness: Hardness refers to the amount of alkaline earth elements, such as calcium and magnesium, as well as other ions, including aluminum, manganese, iron, zinc, strontium and hydrogen ions, in a body of water. For various metabolic processes, including the development of bones and scales, fish need calcium and magnesium. According to Swann (1997), the ideal hardness level for fish culture is at least 20 parts per million. Stress in fish is caused by hardness levels below 20 parts per million. (Stone and Thomforde, 2004) 50-150 ppm is the ideal range. Agriculture lime can be used to raise low hardness levels.

Ammonia: The bacterial decomposition of organic items, including sewage, dead planktons, excrement, food waste and fish excretion of protein metabolism both produce ammonia as a byproduct. A poisonous substance that can harm fish health is ammonia. There are two types of it: ionized ammonia (NH^{4+} and unionized ammonia (NH_3). When combined, the two forms of ammonia are known as total ammonia. The unionized form of ammonia (NH_3) is far more poisonous than the ionized form (NH^{4+}). As illustrated in Figure 8, nitrification is a biological process that transforms toxic ammonia into innocuous nitrates.

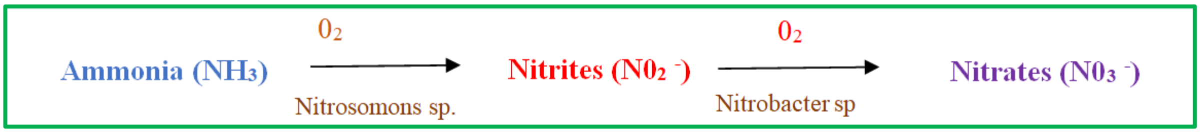

Fig.8. Nitrification Process

The toxicity of total ammonia rises as temperature and pH rise. Fish farms must maintain high fish densities, which increases the risk of ammonia toxicity, while in natural water bodies like lakes and rivers, ammonia may never reach high levels due to the low fish densities. For aquatic life, a total ammonia content of 0.1 mg/l is the ideal range (Meade, 1985). Increased oxygen consumption, gill damage, disease susceptibility, fish dwarfism and other issues were caused by elevated ammonia levels in water bodies. The phenol hypochlorite method is used to measure the total ammonia nitrogen in water using a spectrophotometer.

The phenyl quinone-monoimine produced by the reaction of phenol and hypochlorite in an alkaline solution with ammonia is then converted to indophenol. As the amount of ammonia in the sample increases, so does the intensity of the blue color that indophenol imparts to the solution. Sodium nitroprusside is used to achieve a deeper blue color. Since all ammonium is transformed to ammonia in a strong alkaline solution, there is a measurement for both ammonia and ammonium. This method can be used to estimate the amount of nitrogen in total ammonia.

Nitrite: Nitrites (NO2-) are the intermediate byproduct of the aerobic nitrification bacterial process, which is generated by the autotrophic bacteria Nitrosomonas mixing oxygen and ammonia. It is an invisible killer of fish because it causes the bloodstream to oxidize hemoglobin to methemoglobin, which discolors the blood and gills brown, hinders breathing, and damages the fish's kidneys, liver, spleen, and nervous system. Above 0.5 mg/l, the nitrite levels shouldn't rise. Compared to fresh water, sea water has less nitrite toxicity because it has higher concentrations of calcium and chloride, which lower nitrite (Prema, 2009). Small additions of chloride salts, decreased stocking densities, increased aeration, and frequent water exchange all lower the nitrite level.

Nitrate: Nitrate is the last byproduct of the aerobic nitrification bacterial process, which is created when autotrophic bacteria called nitrobacter combine nitrite and oxygen. The fish were poisoned by both ammonia and nitrite, but even at high quantities, nitrate is not immediately harmful to aquatic life. Because it aids in the synthesis of proteins needed for the growth and reproduction of primary producers, it is a crucial nutritional content for the biological productivity of aquatic resources (Shah *et al.,* 2022). Nitrate levels between 0.1 and 4.5 mg/l are ideal. Reduced mobility and an inability to swim may result from the elevated nitrate levels. Ion exchange materials are used to lower the nitrate level.

Phosphorus: The chemical element known as phosphorous has the atomic number 15 and the symbol ”P” Phosphate (PO_4) is the form of almost all phosphorus found in aquatic bodies. One ingredient that helps fish farmers achieve high biological productivity is phosphate. Mostly found in surface water as abounding to either living or dead particles, it is found in soil as insoluble $Ca_3(PO_4)^2$. It is a crucial nutrient for plants since it encourages the growth of plants like algae and is frequently scarce. Its role in raising aquatic productivity is also widely acknowledged. According to Bhattagar *et al.* (2004), phosphorus levels between 0.05 to 3.0 mg/l are ideal for a productive aquatic ecosystem.

Calcium: A chemical element having symbol Ca and atomic number 20 is known as calcium. Calcium is mainly present in soil as carbonate and important environmental divalent salt in fish culture water. Fishes absorb calcium either from water or food. Optimum range for free calcium in culture waters is 25 to 100 mg/l (Wurts and Durborow, 1992).

Chlorine: Chlorine is a chemical element with the atomic number 17 and the symbol Cl. In order to control hazardous microorganisms, it is added to water as a disinfectant. Even though chloride is the same element in salt form, their chemical characteristics are very different. Most waters contain a significant amount of chloride, which helps fish maintain their osmotic balance. Davis (1938).

Hydrogen Sulphide: The term hydrogen sulfide refers to a colorless, toxic gas with the formula H_2S that has a characteristic rotten egg odor. Water has a relatively high solubility of hydrogen sulfide. It is created in certain anaerobic aquatic environments when sulfate (SO_4^{2-}) is changed into sulphide (SO_3^{2-}). Because of hydrogen sulfide toxicity rises with decreasing dissolved oxygen concentrations and the percentage of total sulfide present as H_2S rises with decreasing pH, H_2S toxicity is greater in acidic environments (Prema, 2002).

Chemical Oxygen Demand: In a water sample, chemical oxygen demand is a measurement of the amount of oxygen needed to chemically oxidize organic and inorganic materials. The abbreviation for this kind of metric is COD. Despite its limits in measuring organic carbon and its bioavailability, COD is a crucial biomarker of organic pollution in aquatic settings (Lv *et al.,* 2024).

3. Biological Water Quality Parameter

The use of living organisms mainly aquatic animals, plants and microorganisms as indicator to determine the health and quality of water body is known as Biological Water Quality Parameter. There are following different biological water quality parameter as follows:

Biological Oxygen Demand

Biological oxygen demand is a measurement of the oxygen-consuming capacity of aerobic biodegradable organic matter in water. BOD is the abbreviation for this kind of parameter. High phosphate levels and excessive residential and cow sewage from non-point sources may be linked to a substantial organic load in rural ponds, which raises the BOD level. Nonetheless, considerable organic enrichment is supported by water with low BOD levels. Maintaining an optimal BOD level in pond water is essential for pisciculture success because it allows for a prolonged release of the right concentration of nutrients in the water without altering the levels of dissolved oxygen (Chattopadhyay *et al.*, 1988).

While BOD levels exceeding 5 mg/l indicate substantial pollution, those between >2 and <4 do not indicate contamination. According to Clerk (1986), BOD levels of 1.0 to 2.0 mg/l were regarded as clean, 3.0 mg/l as fairly clean, 5.0 mg/L as dubious, and 10.0 mg/l as bad and polluted.

Plankton

Plankton are microscopic organisms that live in water, both fresh and marine, that drift with the currents rather than swimming against them. Because plankton propels primary production, it is essential to aquatic ecosystems. There are two different kinds of plankton:

a) **Phytoplankton:** The microscopic photosynthetic plant-like organisms known as phytoplankton are found in fresh and marine water, where they float and produce the majority of the oxygen in aquatic systems. In a pond, it is the foundation of primary productivity. Because it absorbs carbon dioxide from the atmosphere and provides food for zooplankton, it also plays a critical role in controlling the earth's climate. Among these are coccolithophores, green algae, cynobacteria, diatoms, and dinoflagellates (Brierley, 2017).

b) **Zooplankton:** The term "zooplankton" refers to microscopic organisms that resemble animals and dwell in fresh and saltwater water. Fish and other larger animals eat zooplankton, which eats phytoplankton and other smaller species (Brett *et al.*, 1996).

How to identify poor-quality pond water?

The following guidelines are given to a fish farmer to identify when pond water quality becomes poorer and, consequently, unsuitable for fish culture.

- Clear water shows very low or absent biological production, not fertile enough and fish will not grow well in it.
- Muddy water, characterized by a high concentration of clay particles, can obstruct fish gills with soil particles, potentially leading to mortality, which is not good to fish culture.
- Deep green water shows excessive plankton production, which provides food for fish but occur as a result of application of more than enough fertilizers, nutrient rich feeds to a pond.
- when a fish pond gives unpleasant odour, it shows pollution of pond water. Sources of pollution include addition of extra food to the pond or inflow of water from polluted rivers. The use of chemicals on the arable crops surrounding the pond site may potentially cause pollution.
- In an already stocked fishpond, if fish farmer observed the fish continuously struggling at the pond water surface to get oxygen then there is low DO level in the water.

Table No. 1: Water-quality criteria for freshwater aquaculture pond (Bhatnagar and Pooja, 2013; Das, 2019)

SL. No.	Parameter	Acceptable Range	Desirable Range	Stress
1.	Temperature (^{0}C)	15-35	20-30	<12, >35
2.	Turbidity (cm)	30-80	30-40	<12, >80
3.	pH	7-9.5	6.5-9	<4, >12
4.	Salinity (ppt)	0.01-1	0.02-0.05	>1
5.	Dissolved Oxygen (mg/l)	3-5	5	<5, >8
6.	Conductivity (mSiemens/cm)	100-2000	100-1500	<100, <2000
7.	Alkalinity (mg/l)	50-200	25-100	<20, >300
8.	Hardness (mg/l)	>20	75-150	<20, >300
9.	Ammonia (mg/l)	0-0.05	0 - <0.025	>0.3

10.	Nitrite (mg/l)	0.02-2	<0.02	>0.2
11.	Nitrate (mg/l)	0-100	0.1-4.5	<0.01, >100
12.	Phosphorus (mg/l)	0.03-2	0.01-3	>3
13.	Calcium (mg/l)	4-160	25-100	<10, >250
14.	Hydrogen Sulphide (mg/l)	0-0.02	0.002	Any detectable level
15.	Chemical Oxygen Demand (mg/l)	40-50	30-40	<50
16.	Biological Oxygen Demand (mg/l)	3-6	1-2	>10

Conclusion

The effectiveness of fish farming depends on efficient water quality control. Aquatic animals' health and productivity can be guaranteed by maintaining the right levels of oxygen, pH, temperature, and other crucial factors. Toxic buildups must be prevented to maintain the health of aquatic environments. This can be accomplished by routinely monitoring and regulating water quality metrics as ammonia, nitrite, and nitrate. Maintaining healthy fish populations requires using efficient filtration systems, keeping feeding and stocking rates appropriate, and properly handling waste. It's not only about maximizing yield; maintaining optimal water quality is ultimately a commitment to economic viability, environmental responsibility, and the long-term sustainability of aquatic food production systems.

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