



Fisheries sector: Role of physico-chemical attributes of water in fresh water ponds

Shashi Parmar

Assistant Professor, Department of Zoology, SBP Government College, Dungarpur, Rajasthan, India

Abstract

Fisheries sector plays an important role in the socio-economic development of the country by providing livelihood to large number of fishers or people engaged directly or indirectly to it. Besides being easily available and valuable source of animal protein, fish can easily be cultured in the aquatic environment. Since water is an important resource that governs fish life, thus suitable water quality is the prime requirement for fish farming. It has been stated that "Water quality determines to a great extent the success or failure of a fish cultural operation" (Piper et al. 1982). There are many water quality parameters that affect fish culture. Optimum fish production can be achieved only when the required levels of the water quality parameters are effectively managed. The physical, chemical and biological characteristics of the water and their interactions play vital role in maintaining the health and well-being of their fish stock. This paper reviews a few physical and chemical parameters of water quality like temperature, pH, transparency, alkalinity, dissolved oxygen and various nutrients that are of importance to the Fisheries. These water quality parameters in culture fisheries provides adequate knowledge to manage our valuable fishery resources.

Keywords: water quality, fisheries, physical parameters, chemical parameters

Introduction

The fish species are one of the most important aquatic communities concerning humans. They perform all physiological activities like, breathing, excretion of waste, feeding, maintaining salt balance and reproduction in the water. Thus, water quality is the determining factor on the success or failure of an fish culture operation.

With the expansion of the fisheries sector, it is accepted that good water quality is needed for maintaining the desirable fish production. Since the aquatic environment is composed of many aquatic variables thus it is very necessary to know the variables that are potential sources of stress for the fish. Poor water quality can result in low profit, low product quality and potential human health risks. Production is reduced when the water contain contaminants that can impair development, growth, reproduction, or even cause mortality to the cultured species. Some contaminants may accumulate to the point where it threatens human health even in low quantities and cause no obvious adverse effects (Madan mohan SP, 2014). The quality of water offers the most favourable conditions for the existence of fish as well as other biota which constitute essential components of the food chain.

The objective of this paper is to present a brief overview of a few physical and chemical qualities of fresh water that are of importance to the fish culture practices.

Physical Factors

Temperature, Turbidity, Light and Transparency play an important role for survival of the organisms living in the water body. These all factors are stated as Physical factors.

- 1. Temperature:** water temperature depends upon the climate, sunlight and depth. In regards to their temperature tolerance, fish are categorised as cold-water, cool-water, warm-water and tropical. Most tropical fish, such as tilapia, cannot withstand a temperature below 8.9°C. and most salmonids (trout and salmon) die when temperatures exceed 80°F (25.7°C). Channel catfish, which are called warm water fish, survive from near freezing to about 32.2°C. Cold water species *Ctenophryngodon* tolerates the temperature up to 40°C but at the same time other cold water *Hypophthalmichthys sp.* shows signs of distress at 40°C (both of them preferring temperature below 30°C). Indian Major Carps thrive well at temperature between 20°C-37°C. (Gupta and Gupta, 2006) [3]. For each species, there exists upper and lower limits, as well as an optimum range for growth, which changes with development. The temperature for optimum growth of fish is called the 'standard environmental temperature' (SET). (Summerfelt RC, 1998) [10]
- 2. Turbidity:** when water contains suspended particles of silt or clay, plankton etc, it is called as turbid water. It affects productivity and fish life. Turbidity varies greatly with the nature of basin, degree of exposure, nature of inflowing sediments. It is observed that highly turbid waters are undesirable for fish culture while productive water bodies are found to have slightly turbid water. Studies on warm water fishes have shown that fishes did not show any behavioural reaction until the Turbidity approached 20,000 ppm. Most of the experimental fishes are known to have tolerated turbidity higher than 100,000 ppm for a week but finally

died at turbidities of 175,000 to 225,000 ppm due to gill clogging. To reduce the turbidity in a fish pond it is recommended to repeated application of Gypsum (200kg per 1000 m³) (Gupta and Gupta, 2006) ^[3].

- 3. Light and transparency:** in a water body light penetration is to various depth is directly dependent on the suspended particulate matter. But light penetration depends basically upon the available intensity of the incident light which varies with the geographical location of the water body and the shades provided by the surrounding vegetation. The exposure of solar radiation at the water surface marks the beginning of the photosynthetic activity. Light quality, quantity and photoperiod ratio between length of the day and night are all important for plant growth and also considerable influence on animals as well. The onset of sexual development in animals is often related to temperature but may also be influenced greatly by photoperiod. Transparency of a water body can be measured by means of 'Sacchi disc' and the values between 25-70 cm are good for fish culture ponds (Boyd, 1990) ^[1]

Chemical Factors

- 1. The Potential Hydrogenii or pH:** The term pH was originally derived from a French word, "pouvoir hydrogene", which means "hydrogen power". This parameter shows the quantity of hydrogen ions (H⁺) in the water. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. At 25 °C, pH of 7.0 will be considered neutral, i.e. neither acidic nor basic, while values below 7.0 are considered acidic, and above 7.0 are basic. Natural waters range between pH 5.0 and pH 10.0 while seawater is near pH 8.3 (Aquaculture Asia). The pH is interdependent with other water quality parameters such as carbon dioxide, alkalinity and hardness. It can be toxic in itself at a certain level, and also known to influence the toxicity as well of hydrogen sulfide, cyanides, heavy metals, and ammonia (Klontz, 1993) ^[4]. For most freshwater species, a pH range between 6.5 - 9.0 is ideal but most marine animals typically cannot tolerate as wide range pH as freshwater animals, thus the optimum pH is usually between pH 7.5 and 8.5 (Boyd, 1998). Acid water (pH 5.0-5.5) can be harmful to the eggs, fry and adults. Acidity adversely affects the rate of decomposition of organic matter and inhibits Nitrogen fixation. Acidic water is responsible for reduction in appetite, growth and tolerance to toxic substances in the fishes (Lloyd, 1992) ^[6]. In acidic water fishes become prone to attacks of parasites and diseases and toxicity of H₂S, copper and heavy metals also increases. The most common method of correcting the low pH or acidity is by 'Liming' which neutralises the acidity. Excessive alkalinity (high pH>9.0) is also inimical for fish life. The higher pH values (9-10) are attained due to uptake of CO₂ in photosynthesis. Fishes are known to die at about pH 11 (Lawson, 1995) ^[5]. If pH value increases beyond limits, it can be controlled by the addition of organic manures or application of Mustard Oil cake @ 800-1200 Kg/ha (Gupta and Gupta, 2006) ^[3].
- 2. Total alkalinity:** Alkalinity is the measure of the capacity of water to neutralise or buffer acids using carbonate, bicarbonate ions, and in rare cases, by hydroxide, thus protecting the organisms from major fluctuations in pH. Without a buffering system, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that may potentially decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbon dioxide will be consumed by the phytoplankton and therefore, it drives the pH levels above 10.0. Since, fish grow within a narrow range of pH values and either of the above extremes will be lethal to them (Aquaculture Asia). For fish culture ponds, the alkalinity should be between 80 to 200 ppm in fresh water, although water of higher and lower alkalinity has often been used successfully by culturist. Higher values of alkalinity above 300 ppm adversely affect the spawning and hatching of carps (Gupta and Gupta, 2006) ^[3]
- 3. Total Hardness:** Hardness is often considered synonymous with the total alkalinity because both are expressed in terms of CaCO₃. In principal hardness is the total Soluble Calcium (Ca) and Magnesium (Mg) Salts present in water and expressed as its calcium Carbonate equivalent. Sulphates and Chlorides of Ca and Mg are also included in total hardness. Hardness is called temporary if it is caused by bicarbonate and carbonate salts of the cations. Permanent hardness is caused by Sulphates and chlorides of the metals. Total hardness is the indicator of 'Hard' and 'Soft' waters. Water bodies having a hardness of 15 ppm or above is are satisfactory for growth of fish. Waters with less than 5 ppm CaCO₃ equivalent cause slow growth, distress and eventual death of fish.
- 4. Dissolved Oxygen:** Oxygen is dissolved in water by diffusion from the atmosphere and photosynthesis. It can also be induced to dissolve through mechanical aeration. The dissolved oxygen is utilised primarily for respiration of aquatic flora and fauna and for decomposition of organic matter by micro-organisms in the water body (Gupta and Gupta, 2006) ^[3]. Oxygen is the first limiting factor for growth and well-being of fish. Fish require oxygen for respiration and the respiratory rate increases with increasing temperature, activity and following feeding but decreases with increasing mean weight. There are several important implications of these physiological facts for fish culture: 1) At a given temperature, smaller fish consume more oxygen per unit of body weight than larger fish or said in another way, for the same total weight of fish in the water body. Smaller fish require more oxygen than larger fish. 2) Actively swimming fish consume more oxygen than resting fish. In raceways, high exchange rates will increase energy expenditures for swimming and oxygen consumption. 3) Oxygen consumption of fish will increase after feeding, multiple feedings per day (3 or more) will result in less variation in oxygen demand than 1 to 2 feedings per day (Summerfelt RC, 1998) ^[10]. The fish culture pond should possess dissolved oxygen above 5ppm. Oxygen depletion is most often observed during summer season. Extended periods of cloudy weather, destruction of vegetation by

herbicides treatment and collapse of phytoplankton bloom also cause depletion of dissolved oxygen. At times, dissolved oxygen level increases and may reach to super-saturation levels. This may create gas bubble diseases. Oxygen depletion can be controlled by artificial aeration, spraying water over the surface of ponds or by spraying 5ppm of potassium permanganate solution on the water surface (Gupta and Gupta, 2006) ^[3].

5. Nutrients

- a. Nitrogen: Through rainfall, in-situ N₂ fixation, river run-off, diffusion from sediments, uneaten feeds, and fish wastes nitrogen enters into the water body. Nitrogen is largely controlled by redox reactions mediated by phytoplankton and bacteria. The processes include remineralisation, ammonification, nitrification, denitrification and fixation.
- b. Ammonia-Nitrogen (NH₃-N) : Ammonia is the initial product of the decomposition of nitrogenous organic wastes and respiration. Nitrogenous organic wastes come from uneaten feeds and excretion of fishes. Thus, the concentration of ammonia-N is positively correlated to the amount of food wastage and the stocking density. Total Ammonia Nitrogen is a parameter that measures the un-ionised (NH₃) and ionised (NH₄⁺) forms of ammonia present in the aquaculture system (Boyd, 1990) ^[1]. High concentrations of ammonia causes an increase in pH and ammonia concentration in the blood of the fish which can damage the gills, the red blood cells, affect osmoregulation, reduce the oxygen-carrying capacity of blood and increase the oxygen demand of tissues (Lawson, 1995) ^[5]. Generally, NH₄⁺ is harmless and can dissipate into the atmosphere easily, however, NH₃ can be extremely toxic. However, the level of NH₃ can be reduced and be converted into harmless nitrates through biological processes. Nitrogen below 0.1 ppm does not indicate a good production. While in the range 0.1-0.20 ppm an average production is expected, above 0.2 ppm (0.2-0.5) may be considered favourable in the water bodies for fish culture.
- c. Nitrite-Nitrogen (NO₂-N) ⁺ : Nitrite is a by product of oxidised NH₃ or NH₄⁺, an intermediary in the conversion of NH₃ or NH₄⁺ into NO₃. This process is completed through nitrification which is done by the highly aerobic, gram-negative, chemoautotrophic bacteria found naturally in the system. The conversion is quick, thus high nitrite concentrations are not commonly found. However, if high levels do occur, it can cause hypoxia, due to deactivation of haemoglobin in fish blood, a condition known as the “brown blood disease” (Lawson, 1995) ^[5]. In fresh water fish culture system good concentration of nitrite is between 0.1-0.5 ppm. It is found out that increasing pH, low dissolved oxygen and high ammonia can increase the toxic effect of nitrite. Other evidence also shows that high nitrite concentrations plus low chloride levels can result to reduced feeding activities, poor feed conversions, lower resistance to diseases and susceptibility to mortality (Lawson, 1995) ^[5]. To counteract nitrite toxicity of fish is to treat water with sodium chloride or calcium chloride to reduce molar ratio of nitrite to chloride. The suggested treatment is to add 3 mg/L of chloride (usually in the form of NaCl = 62% Cl) for every 1 mg/L of nitrite (Aquaculture Asia).
- d. Nitrate-Nitrogen (NO₃-N) : Nitrate is formed through nitrification process, i.e. oxidation of NO₂ into NO₃ by the action of aerobic bacteria. Nitrate not taken up directly by aquatic plants but it is denitrified in anaerobic sediments. In tropical systems, denitrification will be most intense in the following areas: (a) where detritus accumulates (b) in water bodies subject to enhanced nutrient loading from pollution (c) in water bodies with long residence times and (d) in wetland ecosystems subject to periodic drying, where oxygen inputs during drying periods stimulate coupled mineralization-nitrification-denitrification within organically rich sediments (Furnas, 1992) ^[2]. Generally, it is stable over a wide range of environmental conditions and is highly soluble in water. Compared with other inorganic nitrogen compounds, it is also the least toxic. However, high levels can affect osmoregulation, oxygen transport, eutrophication and algal bloom (Lawson, 1995) ^[5]. In fresh water bodies concentration of nitrite < 3 mg/litre is considered as the optimum level. (Piper et al, 1982) ^[9].
- e. Phosphorus: Phosphorus is found in the form of inorganic and organic phosphates (PO₄) in natural waters. Inorganic phosphates include soluble orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. Phosphorous is a limiting nutrient needed for the growth of aquatic plants and algae. Phosphates are not toxic to people or animals, unless they are present in very high levels. However, excess concentrations especially in rivers and lakes can result to algal blooms. A lake with a concentration of below 0.010 mg/L is considered as oligotrophic, while concentrations between 0.010 and 0.020 mg/L are indicative of mesotrophic, and concentrations exceeding 0.020 mg/L are considered as eutrophic (Muller and Helsel, 1999) ^[8]. Digestive problems could occur from extremely high levels of phosphates.

The common sources of phosphorous are wastewater and septic effluents, detergents, fertilisers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides. Aquaculture farms located near these sources can expect to have higher concentrations of phosphates in the water bodies. (Aquaculture Asia)

Phosphorous shows seasonal variations in fish ponds and the minerals get removed when the fish or the vegetation is removed from the water. Dissolved phosphorous below 0.05 ppm may be considered insufficient. While for the range 0.05-0.02 ppm, medium to high production is expected, highly productive fish ponds should have concentration above 0.02 ppm (Gupta and Gupta, 2006) ^[3].

Conclusion

Fish culture increasingly plays a more significant role in fisheries sector. Together with increasing culture practices comes increasing nutrient release into the holding waters with an effect on water column which leads to eutrophication. In addition, increasing nutrient output from domestic, industrial, agriculture, deforestation and livestock production also adds to the water nutrient load and these have an effect on production potential and carrying capacity of the water body. Generally, the concept of water quality monitoring is at the micro-level. There are also mechanisms that should be put in place in order to strengthen the effectiveness of the monitoring system. A high quality water testing kit is essential for measuring water quality on a regular basis. It is equally important to know how to interpret the water quality parameters that are measured to maintain the health and well-being of their fish stock.

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