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Review Article

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Physicochemical Characteristics of Inland Aquaculture: A Review

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ABSTRACT

Production of fish in any aquaculture system depends upon several factors. It has been found that parameters like temperature, dissolved oxygen, pH, hardness, nitrate nitrogen, phosphate phosphorus, chemical and biochemical oxygen demand (COD and BOD) have a critical role in fish production. An optimum value should always be maintained for these parameters for good production. Unfortunately, it is not retained due to several reasons including human activities. The parameters also differ according to seasons and other conditions. Poor physicochemical characteristics can result in poor production and economic loss. It is essential to know the standard level of these parameters and assess the value before using any water body for fish production.

Keywords: *Aquaculture, Fish, Physicochemical parameters, Sewage*

INTRODUCTION

Fish is a nutritious food item consumed by a large population of India. It is cultured in the majority of the inland water bodies in our country. But, unfortunately, this water is among the most vital resources which man has exploited in various ways. Almost all human activities have left an impact on water resources. It is unfortunate that the water bodies are being increasingly used as natural dustbins for discharges of all sorts of community wastes. As a result, the environment and ecosystem are greatly affected. Many times, the water bodies can't fulfill the required conditions for fish cultivation. It exerts a negative impact on both fish production and human health. So, it is important to know about the physicochemical characteristics of inland aquaculture. The role of various factors like temperature, dissolved oxygen, pH, hardness, nitrate nitrogen, phosphate phosphorus, chemical and biochemical oxygen demand (COD and BOD) etc. can't be overlooked for maintaining a healthy aquatic environment and for the production of sufficient fish food organisms in ponds (Bhatnagar & Devi, 2013).

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These parameters vary according to seasons and several other environmental factors. A major difference is observed between the cultured ponds and sewage fed ponds. Many times, the sewage water and wastewater affect the parameters greatly. A number of studies have been carried out to study these physicochemical parameters of water bodies of India. In this review, we have briefly discussed the variation of the parameters and how they can affect productivity.

2. Temperature and Dissolved Oxygen

Temperature is defined as the degree of hotness or coldness in any substance. Higher temperature increases the rate of biochemical activity of the microbiota, plant respiratory rate, and so increase in oxygen demand. It further causes decreased solubility of oxygen and also increases the level of ammonia in water (Bhatnagar & Devi, 2013). Bhatnagar and coworkers (2004) suggested the levels of temperature as 28-32^{0}C is good for tropical major carps; < 20^{0}C is sub-lethal for growth and survival for fishes and > 35^{0}C is lethal to a maximum number of fish species (Bhatnagar et al., 2004). According to some researchers, a suitable water temperature for carp culture is between 24 and 30^{0}C (Santhosh & Singh, 2007).

Dissolved oxygen affects the growth, survival, distribution, behaviour and physiology of shrimps and other aquatic organisms (Solis, 1988). Oxygen produced by the photosynthetic planktons and the atmospheric oxygen are the main sources of DO. As oxygen is less soluble in water, aquatic organisms suffer more from oxygen deficiency compared to terrestrial ones. There are several factors responsible for the decrease in oxygen solubility. These include increased temperature, increased salinity, low atmospheric pressure, high humidity, plankton bloom etc. Oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and more fish mortality, either directly or indirectly (Bhatnagar & Garg, 2000).

Banerjea (1967) found that the dissolved oxygen between 3.0-5.0 mg/l in ponds is unproductive and for average or good production it should be above 5.0 mg/l (Banerjea, 1967). It may be incidentally mentioned that very high concentration of DO leading to a state of supersaturation sometimes becomes lethal to fish fry during the rearing of spawn in nursery ponds (Alikunhi et al., 1951). According to some researchers DO level >5 mg/l is essential to support good fish production (Bhatnagar et al., 2004, Bhatnagar & Singh, 2010). They also suggested that 1-3 mg/l has a sub-lethal effect on growth and feed utilization; 0.3-0.8mg/l is lethal to fishes and >14 mg/l is lethal to a fish fry, and gas bubble disease may occur. DO less than 1 causes death of fish, at less than 5 fish survive but grow slowly and will be sluggish, 5 and above is always desirable.

Purushothama & coworkers (2005) conducted a study on the water quality status of Kheladi tank (Hirekere) at Sagar Taluk, Karnataka (Purushotham et al., 2005). In their study they recorded the temperature ranged between 25 to 30^{0}C with the dissolved oxygen ranged between 1.62-13.78 mg/l, where the minimum temperature was encountered in September and maximum in March (30^{0}C). Chakraborty & coworkers (2004) found the range of temperature 16.6-25.9^{0}C and dissolved oxygen 3.7-14.9 mg/l during the analysis of water quality and plankton abundance in selected beels of Nadia district (West Bengal) (Chakraborty et al., 2004). It was reported that the temperature ranges 14.9-29.2^{0}C while studying the Limnological status of fish ponds in the Tarai Region of U.P (Mishra et al., 2003). Chakraborty & Chattopadhyaya (2003) recorded from the Mathura beel (West Bengal) that the water temperature varied between (21.4 – 30^{0}C) and dissolved oxygen was increasing orderly from February to May, however with a slight decrease on March (Chakraborty & Chattopadhyaya, 2003).

While studying the relationship between dissolved oxygen and temperature Pandey & Nand (2003) found that DO value (4.4–5.0 mg/l) reduced by higher temperature and may be due to contamination of groundwater with sewage and high level of water (Pandey & Nand, 2003). A similar trend of results was also obtained in the different water bodies by several workers (Sukumaran & Das, 2002, Bajpai et al., 2002). Bhatt & coworkers (1999) stated that the value of dissolved oxygen was below 6 mg/l only during summer which may be due to the higher anthropogenic activities and it increases during the rainy season (7.8 mg/l) and attained the highest value (10.2 mg/l) during winter (Bhatt et al., 1999). Rana & coworkers (1990) conducted an important study on the limnological characteristics of a well-managed (Kalyani lake segment-1) and an unmanaged water body (Kalyani lake segment-2) at Kalyani (West Bengal) (Rana et al., 1996). In their study, they recorded the variation of DO content with the change in temperature and found that in the well-managed water body DO content was maximum (8.01 mg/l) during the post-monsoon period (28.3^{0}C). While in unmanaged water body maximum DO (7.05 mg/l) was also during post-monsoon (24.8^{0}C) and minimum (5.57mg/l) during the pre-monsoon period (28.8^{0}C). A similar trend of results was obtained in the same water body (Kalyani Lake) by several other researchers(Bhowmik & Tripathi 1985, Saha et al., 1990).

3. pH

pH is measured mathematically by, the negative logarithm of hydrogen ions concentration. The pH of natural waters is greatly influenced by the concentration of carbon dioxide which is an acidic gas. A pH range of 7 to 8.5 is optimum for biological productivity. Fishes become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0 and death is almost certain at a pH of less than 4.0 or greater than 11.0 (Ekubo & Abowei, 2011). According to Santhosh & Singh (2007), the suitable pH range for fish culture is between 6.7 to 9.5 and ideal pH level is between 7.5 to 8.5 and above and below this is stressful to the fishes (Santhosh & Singh, 2007). Ideally, an aquaculture pond should have a pH between 6.5 and 9 (Bhatnagar et al., 2004, Wurts & Durborow, 1992). pH less than 4 or greater than 10.5 are lethal to fish/shellfish culture; 7.5-8.5 is highly congenial for *P.monodon;* 7.0-9.0 is acceptable limits and 9.0 -10.5 is sublethal for fish culture. In general, pH in culture ponds should be maintained in between 6.5-9.0 (Bergerhouse, 1992). The pH is minimum at or near dawn and maximum at the middle of the afternoon.

Mishra and coworkers (2003) found that the pH value ranges from 7.0 – 7.8 concentrations during cloudy days and was more in comparison to sunny days (Mishra et al., 2003). While studying the limnology of polluted urban pond, Bath & Singh (1998) reported that due to the presence of sewerage at the study site pH value of the pond may be high (7.44-8.42) (Bath & Singh, 1998). It was found that during January to February pH is nearly 6.5 in sewage fed fishpond at Kalidah of Aligarh city (Basheer et al., 1996). Low pH (6.97) during summer due to the absence of carbonates, as compared to monsoon (7.1) and winter (7.05) was observed in a temple pond of Kerala (Chandrasekhar & Jafer, 1998).

Saha & coworkers (1990) reported an inverse relationship between pH and free-CO_2 while studying the ecological changes in Kulia beel (West Bengal) (Saha et al., 1990). They observed maximum free-carbon-dioxide (3.9mg/l) at pH 7.6 and it was nil at pH above 8.2. Decrease in pH from 7.80 during monsoon to 7.30 during summer was also recorded by Baruah & Das (1998) in Kole beel (West Bengal), in which paper mill effluents were discharging (Baruah & Das, 1998). Similar trends of results were reported by them in a separate study in Elenga beel of Assam (Baruah & Das, 1997). Hydrobiological condition of a sewage fed pond was studied by Ghosh & coworkers (1974) and they found an inverse relationship of pH with dissolved organic matter (Ghosh et al., 1975).

4. Conductivity

Conductivity is an index of the total ionic content of water, and therefore indicates the freshness of the water (Ogbeibu & Victor, 1995). Conductivity is a good indicator of primary production (chemical richness) as well as fish production. The conductivity of water is influenced by the concentration of ions (Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, NO_3^- and PO_4^-), temperature and variations of dissolved solids. Distilled water has a conductivity of about 1µmhos/cm and the conductivity of natural water is 20-1500 µmhos/cm (Abowei, 2010). The conductivity of freshwater ranges between 50 to 1500 µs/cm (Boyd, 1979), but in some polluted waters it may reach 10,000 µs/cm and seawater has conductivity around 35,000 µs/cm and above. There is a species difference in the ability to maintain the osmotic pressure. So, the optimum conductivity is also different according to species. Kumar & Puri (2012) studied the monthly variation in Conductivity at Kotra wastewater treatment plant (Kumar & Puri, 2012). During the period of investigation, Conductivity varied from 0.615 µmhos/cm to 2.232 µmhos/cm in the raw sewage and 0.384 µmhos/cm to 1.438 µmhos/cm in the final treated water. During the period of investigation, conductivity varied from 0.615 µmhos/cm to 2.232 µmhos/cm in the raw sewage and 0.384 µmhos/cm to 1.438 µmhos/cm in the final treated water.

5. Total Hardness

Hardness is the measure of alkaline earth elements such as calcium and magnesium in an aquatic body along with other ions such as aluminum, iron, manganese, strontium, zinc, and hydrogen ions. Calcium and magnesium are essential to fish for metabolic reactions such as bone and scale formation. The recommended ideal value of hardness for fish culture is at least 20 mg/l and a range of 30-180 mg/l (Santhosh & Singh, 2007). According to Bhatnagar & coworkers (2004) hardness values less than 20 mg/l causes stress, 75-150 mg/l is optimum for fish culture and >300mg/l is lethal to fish life as it increases pH, resulting in non-availability of nutrients (Bhatnagar et al., 2004). However, some euryhaline species may have high tolerance limits to hardness.

6. Total Dissolved Solids

Several researchers reported that the total dissolved solids increase with increasing temperature followed by evaporation. They also assumed that higher values of turbidity (15.7 NTU) in summer may be due to higher planktonic mass at that time while studying the tropic status of Mathura beel (West Bengal) (Purushotham et al., 2005, Chakraborty & Chattopadhyaya, 2003, Paul et al., 2004). Pradhan (2002) reported that the Kulia beel of Kalyani (W.B) contained 54.5 – 227.58 mg/l totals dissolved solids and considered them as productive water body (Pradhan, 2002). The total dissolved solids in Singnallur Lake at Coimbatore were observed in high concentration during the monsoon period, which may be due to the addition of solids from runoff water (Shanthi et al., 2002). Increase in values of TDS indicates pollution by extraneous source (Kataria et al., 1996).

7. Biochemical and Chemical Oxygen Demand

Biochemical Oxygen Demand is the measurement of total dissolved oxygen consumed by microorganisms for biodegradation of organic matter such as food particles or sewage etc. The excess entry of domestic sewage from the nonpoint sources and similarly increase in phosphate in the village ponds may be attributed to high organic load in these ponds thus can use a higher level of BOD. Clerk (1986) reported that the BOD range of 2 to 4 mg/l does not show pollution while levels beyond 5 mg/l are indicative of serious pollution (Clark, 2001). According to Bhatnagar & coworkers (2004), the BOD level between 3.0-6.0 mg/l is optimum for normal activities of fishes; 6.0-12.0mg/l is sublethal to fishes and >12.0mg/l can usually cause fish kill due to suffocation (Bhatnagar et al., 2004). Santhosh & Singh (2007) recommended optimum BOD level for aquaculture should be less than 10 mg/l but the water with BOD less than 10-15 mg/l can be considered for fish culture (Santhosh & Singh, 2007). Bhatnagar & Singh (2010) suggested the BOD <1.6 mg/l level is suitable for pond fish culture (Bhatnagar & Singh, 2010). According to Ekubo & Abowei (2011) aquatic system with BOD levels between 1.0 and 2.0 mg/l considered clean; 3.0 mg/l fairly clean; 5.0 mg/l doubtful and 10.0 mg/l definitely bad and polluted (Ekubo & Abowei, (2011).

The high value of BOD is due to sewage pollution (Pandey & Nand, 2003). Paul (2003) reported the variation of BOD and COD in the seasonal water bodies of Kalyani (West Bengal) where COD was very much higher (245.2±3.35 mg/l) from October to January and thereafter through gradual decrease, COD reached its minimum value in September (108.00±2.45mg/l) (Paul, 2003). Comparatively high (62.56±3.2 mg/l) and low (9.4±0.66 mg/l) BOD contents were observed in December-January and in October-November respectively.

Hosmani (2002) reported that a sewage polluted lake (Mysore) showed highest BOD value of 24 mg/l and decreased to a low (4.8 mg/l) in the months of January to March (Hosmani, 2002). Pani & Mishra (2000) conducted a comparative study on the BOD and COD of lake Sahastradhara and Muussoorie with the Ganga water of Haridwar (Pani & Mishra, 2000). They found that high BOD and COD in both the lakes as compared to the BOD and COD of the Ganga water (BOD 1.8 mg/l and COD 11.2 mg/l) and considered the lakes as polluted water bodies. The Variation in high BOD (200 to 310 mg/l) and COD (142mg/l) values throughout the year in Salim Ali Lake indicating organic pollution (Throat & Sultana, 2000). Similar work on BOD and its relation with organic pollution were done by many workers throughout the country (Manna et al., 1997, Bhattacharjya et al., 1997).

Bhatt and coworkers (1999) recorded the maximum BOD in summer (32 mg/l) and minimum BOD value in winter (6.5 mg/l) in Taudaha Lake, Kathmandu (Nepal) (Bhatt et al., 1999). According to them, the high value of BOD in summer was due high organic decomposition rate and low BOD in winter was due to the fall of temperature (27.7^0C to 14.0^0C). Similar trends of results were also observed by Parvateesam & Gupta (1994) in Rajasthan. Kataria & coworkers (1996) assessed the BOD and COD values, which were ranged from 2.0 to 3.6 mg/l and 18.2 to 92.8 mg/l respectively (Kataria et al., 1996). Higher BOD value was observed in the pre-monsoon season due to higher microbial activity and higher temperature. Increases in COD values were due to the pollution of input zones of Kolar reservoir in Bhopal (M.P). Varghese & coworkers (1992) reported that summer recorded highest BOD (5.4 mg/l) followed by monsoon (4.8mg/l) and winter (1.2 mg/l) (Varghese & Naik, 1992). Maximum COD recorded in June (48 mg/l) and minimum in August (16mg/l) and it reflected the amount of dissolved oxidizable organic matter in the water.

An increase in BOD and COD values during summer (85 mg/l and 230 mg/l respectively) followed by winter (62 mg/l and 183 mg/l respectively) and decrease in monsoon (18mg/l and 76mg/l respectively) were recorded in Kole beel (W.B), contaminated with paper mill effluent (Baruah & Das, 1998).

8. Phosphate phosphorus

Almost all of the phosphorus (P) present in water is in the form of phosphate (PO_4^{3-}) and in-surface water mainly present as bound to living or dead particulate matter and in the soil is found as insoluble $Ca_3(P0_4)_2$ and adsorbed phosphates on colloids except under highly acid conditions. It is an essential plant nutrient as it is often in limited supply and stimulates plant (algae) growth and its role for increasing the aquatic productivity is well recognized. Bhatnagar & coworkers (2004) suggested 0.05-0.07 mg/l is optimum and productive; 1.0 mg/l is good for plankton/ shrimp production (Bhatnagar et al., 2004).

9. Nitrate nitrogen

Where ammonia and nitrite were toxic to the fish, Nitrate is harmless and is produced by the autotrophic Nitrobacter bacteria combining oxygen and nitrite. Nitrate levels are normally stabilized in the 50-100 mg/l range. Meck (1996) recommended that its concentrations from 0 to 200mg/l are acceptable in a fish pond and is generally low toxic for some species whereas especially the marine species are sensitive to its presence (Meck, 1996). Santhosh & Singh (2007) described the favorable range of 0.1 mg/l to 4.0 mg/l in fish culture water (Santhosh & Singh, 2007).

The physicochemical parameters of sewage fed ponds and beels in comparison to raw sewage has been shown in table 1.

Table 1: Physiochemical parameters of sewage fed ponds and Beels in comparison to raw sewage (Dutta et al., 2010)

Parameters	Sewage-fed Bhery	Rahara Sewage fed pond	Kulia Beel	Mathura Beel	Amda Beel	Raw Sewage
DO (mg/l)	3.3±0.24 (3-3.6)	3.52±0.42 (3.1-4)	6.9±0.41 (6.2-7.3)	7.56±0.64 (6.9-8.4)	6.4±0.48 (5.8-6.9)	1.21±0.20 (1-1.5)
COD (mg/l)	61±2.82 (58-65)	54.2±1.92 (52-57)	7.8±1.19 (6.6-9.5)	13.86±1.0 (12.215.1)	7.36±0.78 (6.2-8.1)	347.4±1.81 (345-350)
TDS (mg/l)	77.4±2.07 (75-80)	76.8±1.92 (74-79)	-	-	-	283.8±2.77 (280-320)
BOD (mg/l)	33.8±2.86 (30-37)	28.4±2.60 (26-32)	4.52±0.75 (3.6-5.5)	7.08±0.27 (6.9-7.5)	3.17±0.54 (2.48-3.9)	197.6±2.07 (195-200)
Temp°C	29.54±0.45 (29-30)	30.04±0.68 (30-31)	28.48±0.47 (28-29)	29.54±0.45 (29-30)	30.02±0.80 (29-31)	32.5±0.47 (32-33)
pH	8.06±0.06 (8.05-8.2)	7.45±0.04 (7.4-7.5)	7.46±0.27 (7.5-7.7)	7.68±0.08 (7.6-7.8)	8.02±0.08 (7.9-8.1)	7.58±0.14 (7.4-7.8)
NO_3-N (mg/l)	0.13±0.02 (0.1-0.15)	0.10±0.01 (0.1-0.12)	-	-	-	0.26±0.12 (0.2-0.3)
PO_4-P (mg/l)	0.17±0.01 (0.16-0.18)	0.10±0.01 (0.10-0.12)	-	-	-	0.25±0.01 (0.24-0.26)

[Values are mean ± S.D.]

CONCLUSION

It is clear from the above discussion that parameters like temperature, dissolved oxygen, pH, hardness, nitrate nitrogen, phosphate phosphorus, chemical and biochemical oxygen demand (COD and BOD) are very important to assess the condition of the aquaculture systems. It is also evident that pollution due to anthropogenic activities affect the factors greatly. It results in deteriorating the condition of the water as well as fish production. Many times, the fishes are infected and contaminated with several toxic elements. It can affect human also after consuming the fish. So, it is essential to assess these parameters before using any pond for fish cultivation. We should also take a step to reduce environmental pollution and save ourselves from the harmful effect of it.

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