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A Study on Water Quality for Management of Pond Fish Culture

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***Abstract:** The Optimum fish production is totally dependent on the physical, chemical and biological qualities of water to most of the extent. Hence, successful pond management requires an understanding of water quality. Water quality is determined by variables like temperature, transparency, turbidity, water colour, carbon dioxide, pH, alkalinity, hardness, unionised ammonia, nitrite, nitrate, primary productivity, BOD, plankton population etc. In the present chapter water quality management principles in fish culture have been reviewed to make aware the fish culturist and environmentalist about the important water quality factors that influence health of a pond and are required in optimum values to increase the fish yields to meet the growing demands of present day scenario of the world, when the food resources are in a state of depletion and the population pressure is increasing on these resources.*

***Keywords:** Assessment and Monitoring, Culture, Fish productivity, Parameters, Water quality*

1. INTRODUCTION

Fish is an inexpensive source of protein and an important cash crop in many regions of world and water is the physical support in which they carry out their life functions such as feeding, swimming, breeding, digestion and excretion (Bronmark and Hansson, 2005). Water quality is determined by various physico-chemical and biological factors, as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Moses, 1983). Many workers have reported the status of water bodies (lentic and lotic) after receiving various kinds of pollutants altering water quality characteristics (physical, chemical and biological). All living organisms have tolerable limits of water quality parameters in which they perform optimally. A sharp drop or an increase within these limits has adverse effects on their body functions (Davenport, 1993: Kiran, 2010). So, good water quality is very essential for survival and growth of fish. As we know fish is an important protein rich food resource and there has been sharp increase in demand of fish products due to increasing population pressure in this century. Thus to meet the demand of present food supply, water quality management in fish ponds is a necessary step that is required to be taken up.

In most of the countries, fishes are cultivated in ponds (lentic water) but unfortunately such culturists are not so aware of importance of water quality management in fisheries. If they are properly guided and make aware about water quality management practices, they can get maximum fish yield in their ponds to a greater extent through applying low input cost and getting high output of fish yield. The role of various factors like temperature, transparency, turbidity, water colour, carbon dioxide, pH, alkalinity, hardness, ammonia, nitrite, nitrate, primary productivity, biochemical oxygen demand (BOD), plankton population etc. can't be overlooked for maintaining a healthy aquatic environment and for the production of sufficient fish food organisms in ponds for increasing fish production. Therefore, there is the need to ensure that, these environmental factors are properly managed and regulated for good survival and optimum growth of fish. The objective of the present chapter is to review and present a concise opinion regarding the optimum levels of water quality characteristics required for maximum fish production.

2. DISCUSSION

Fish do not like any kind of changes in their environment. Any changes add stress to the fish and the larger and faster the changes, the greater the stress. So the maintenance of all the factors becomes very essential for getting maximum yield in a fish pond. Good water quality is characterised by adequate oxygen, proper temperature, transparency, limited levels of metabolites and other environmental factors affecting fish culture. The initial studies of water quality of a fish pond in India were probably conducted by Sewell (1927) and Pruthi (1932). After that many workers have studied the physico-chemical condition of inland waters either in relation to fish mortality or as part of general hydrological survey (Alikunhi *et al*., 1952: Upadhyaya, 1964). The details of various pond ecosystems also have been studied by workers (Mumtazuddin *et al*., 1982: Delince, 1992: Garg and Bhatnagar, 1999: Bhatnagar, 2008). Bhatnagar and Singh (2010) studied the pond fish culture in relation to water quality in Haryana. However, the present chapter would provide the basic guidelines, parameter wise for the fish farmers in obtaining high fish yield in low input via maintaining water quality of their ponds.

Temperature is defined as the degree of hotness or coldness in the body of a living organism either in water or on land (Lucinda and Martin, 1999). As fish is a cold blooded animal, its body temperature changes according to that of environment affecting its metabolism and physiology and ultimately affecting the production. Higher temperature increases the rate of bio-chemical activity of the micro biota, plant respiratory rate, and so increase in oxygen demand. It further cause decreased solubility of oxygen and also increased level of ammonia in water. However, during under extended ice cover, the gases like hydrogen sulphide, carbon dioxide, methane, etc. can build up to dangerously high levels affecting fish health.

Desirable limits

According to Delince (1992) 30-35^{0}C is tolerable to fish, Bhatnagar *et al.* (2004) suggested the levels of temperature as 28-32^{0}C good for tropical major carps; <12^{0}C – lethal but good for cold water species; 25-30^{0}C – ideal for *Penaeous monodon* culture; < 20^{0}C – sub lethal for growth and survival for fishes and > 35^{0}C- lethal to maximum number of fish species and according to Santhosh and Singh (2007) suitable water temperature for carp culture is between 24 and 30^{0}C.

Remedies

1. By water exchange, planting shady trees or making artificial shades during summer's thermal stratification can be prevented.
2. Mechanical aeration can prevent formation of ice build-up in large areas of the pond.

Turbidity

Ability of water to transmit the light that restricts light penetration and limit photosynthesis is termed as turbidity and is the resultant effect of several factors such as suspended clay particles, dispersion of plankton organisms, particulate organic matters and also the pigments caused by the decomposition of organic matter.

Desirable limits

Boyd and Lichtkoppler (1979) suggested that the clay turbidity in water to 30 cm or less may prevent development of plankton blooms, 30 to 60 cm and as below 30 cm - generally adequate for good fish production and there is an increase in the frequency of dissolved oxygen problems when values above 60 cm, as light penetrates to greater depths encourage underwater macrophyte growth, and so there is less plankton to serve as food for fish. According to Bhatnagar *et al*. (2004) turbidity range from 30-80 cm is good for fish health; 15-40 cm is good for intensive culture system and < 12 cm causes stress. According to Santhosh and Singh (2007) the secchi disk (fig.1) transparency between 30 and 40 cm indicates optimum productivity of a pond for good fish culture.

Remedies

Addition of more water or lime (CaO, alum $Al_2(SO_4)_3 14H_2O$ at a rate of 20 mg L^{-1} and gypsum on the entire pond water at rate of 200 Kg/ 1000m^3 of pond can reduce turbidity

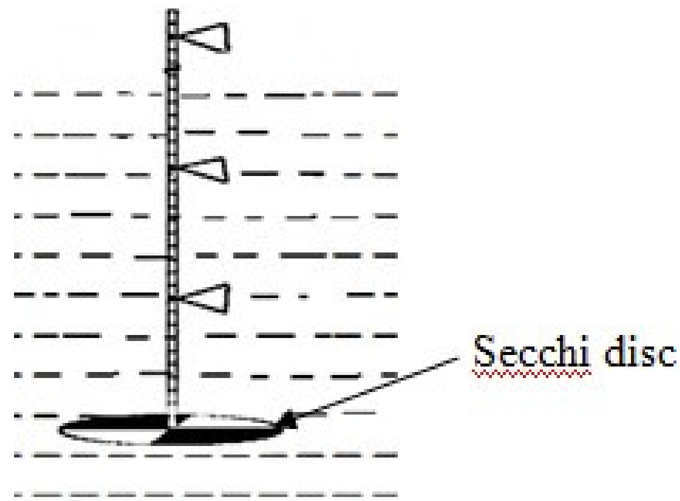

Fig. 1. Measurement of turbidity using Secchi disc

Water Colour

The colour of an object is defined by the wavelengths of visible light that the object reflects.

Desirable limits

National Agricultural Extension and Research (1996) states pale colour, light greenish or greenish waters suitable for fish culture and according to Bhatnagar *et al*. 2004 dark brown colour is lethal for fish/shrimp culture, light green colour- good for fish/shrimp culture, dark green colour is not ideal for fish/shrimp culture and clear water is unproductive for fish/shrimp culture. Delince (1992) stated that the abundance of phytoplankton and zooplankton is responsible for the determination of colour of an aquatic body and Green, bluish green/ brown greenish colour of water indicates good plankton population hence, good for fish health.

Remedies

Application of organic and inorganic fertilizers in clear water ponds may increase productivity.

Dissolved Oxygen (DO)

Dissolved oxygen affects the growth, survival, distribution, behaviour and physiology of shrimps and other aquatic organisms (Solis, 1988). The principal source of oxygen in water is atmospheric air and photosynthetic planktons. Obtaining sufficient oxygen is a greater problem for aquatic organisms than terrestrial ones, due to low solubility of oxygen in water and solubility decreases with factors like- increase in temperature; increase in salinity; low atmospheric pressure, high humidity, high concentration of submerged plants, plankton blooms. Oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and more fish mortality, either directly or indirectly (Bhatnagar and Garg, 2000).

Indication of low Dissolved oxygen

If fish comes to the surface of water (figure 2) and secchi disk reading falls below 20 cm, fish swim sluggishly and are weakened.

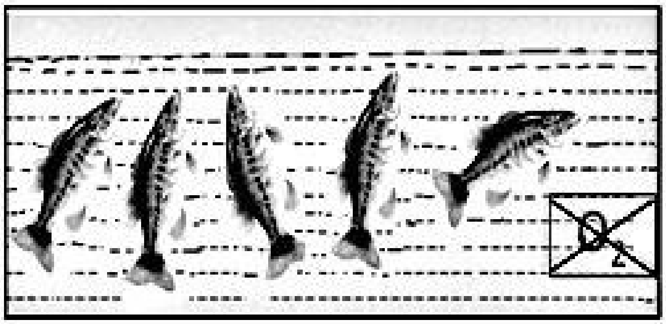

Fig. 2. Stressed fishes due to low DO levels at surface of water

Desirable limits

According to Banerjea (1967) DO between 3.0-5.0 ppm in ponds is unproductive and for average or good production it should be above 5.0 ppm. It may be incidentally mentioned that very high concentration of DO leading to a state of super saturation sometimes becomes lethal to fish fry during the rearing of spawn in nursery ponds (Alikunhi *et al*., 1952) so for oxygen, the approximate saturation level at 50° F is 11.5 mg L^{-1}, at 70° F., 9 mg L^{-1}, and at 90° F., 7.5 mg L^{-1}. Tropical fishes have more tolerance to low DO than temperate fishes. According to Bhatnagar and Singh (2010) and Bhatnagar *et al*. (2004) DO level >5ppm is essential to support good fish production. Bhatnagar *et al*. (2004) also suggested that 1-3 ppm has sublethal effect on growth and feed utilization; 0.3-0.8 ppm is lethal to fishes and >14 ppm is lethal to fish fry, and gas bubble disease may occur. DO less than 1- Death of Fish, Less than 5 -Fish survive but grow slowly and will be sluggish, 5 and above- Desirable. According to Santhosh and Singh (2007) Catfishes and other air breathing fishes can survive in low oxygen concentration of 4 mg L^{-1}. Ekubo and Abowei (2011) recommended that fish can die if exposed to less than 0.3 mg L^{-1} of DO for a long period of time, minimum concentration of 1.0 mg L^{-1} DO is essential to sustain fish for long period and 5.0 mg L^{-1} are adequate in fishponds.

Remedies (i) Avoid over application of fertilizers and organic manure to manage DO level

Physical control aquatic plants and also management of phytoplankton biomass (iii) Recycling of water and use of aerators. (iv) Artificially or manually beating of water. (v) Avoid over stocking of fishes. (vi) Introduction of the hot water gradually with pipes to reduce if DO level is high.

Biochemical oxygen demand (BOD)

BOD 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 cattle and domestic sewage from the non point sources and similarly increase in phosphate in the village ponds may be attributed to high organic load in these ponds thus causing higher level of BOD.

Desirable limits

Clerk (1986) reported that BOD range of 2 to 4 mg L^{-1} does not show pollution while levels beyond 5 mg L^{-1} are indicative of serious pollution. According to Bhatnagar *et al*. (2004) the BOD level between 3.0-6.0 ppm is optimum for normal activities of fishes; 6.0-12.0 ppm is sublethal to fishes and >12.0 ppm can usually cause fish kill due to suffocation. Santhosh and Singh (2007) recommended optimum BOD level for aquaculture should be less than 10 mg L^{-1} but the water with BOD less than 10-15 mg L^{-1} can be considered for fish culture. Bhatnagar and Singh (2010) suggested the BOD <1.6mg L^{-1} level is suitable for pond fish culture and according to Ekubo and Abowei (2011) aquatic system with BOD levels between and 2.0 mg L^{-1} -considered clean; 3.0 mg L^{-1} fairly clean; 5.0 mg L^{-1} doubtful and 10.0 mg L^{-1} definitely bad and polluted.

Remedies

1. Add lime/more, suspending use of fertilizers, removal of nonbiodegradable / floating organic matter from the pond surface, aeration, screening or skimming to reduce BOD level.

2. Before stocking, pondwater may be allowed to stabilize for few days (5-15 days).

3. Add safe quantities of manure accordingly local conditions of pond in terms of differences in type of manure, water temperature and normal dissolved oxygen.

Carbon-dioxide (CO_2)

Free carbon dioxide, highly soluble gas in water, main source of carbon path way in the nature, is contributed by the respiratory activity of animals and can exist in water as bicarbonate or carbonates in the dissolved or bound form in earth crust, in limestone and coral reefs regions.

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^- \Leftrightarrow 2H^+CO_3^-$$

When dissolved in water it forms carbonic acid which decrease the pH of any system, especially insufficiently buffered systems, and this pH drop can be harmful for aquatic organisms.

Desirable limits

According to Boyd and Lichtkoppler (1979) fish avoid free CO_2 levels as low as 5 mg L^{-1} but most species can survive in waters containing up to 60 mg L^{-1} carbon dioxide, provided DO concentrations are high. Swann (1997) suggested that fish can tolerate concentrations of 10 ppm provided DO concentrations are high and water supporting good fish populations normally contain less than 5 ppm of free CO_2. According to Ekubo and Abowei (2011) tropical fishes can tolerate CO_2 levels over 100 mg L^{-1} but the ideal level of CO_2 in fishponds is less than 10 mg L^{-1}. Bhatnagar *et al*. (2004) suggested 5-8 ppm is essential for photosynthetic activity; 12-15 ppm is sublethal to fishes and 50-60 ppm is lethal to fishes. The free carbon dioxide in water supporting good fish population should be less than 5 mg L^{-1} (Santhosh and Singh, 2007).

Remedies

1. Proper aeration can "blow" off the excess gas

2. Check organic load and reduce the same by adding more water (no fish) and add Muriatic acid (swimming pool acid) to adjust the pH to about 5 or if possible remove the matter by repeated nettings.

3. Use of lime ($CaCO_3$) or sodium bicarbonate ($NaHCO_3$) (iv) Application of potassium permanganate at the rate 250 g for 0.1 hectare.

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 (Boyd, 1979).

Desirable limits

Fish have an average blood pH of 7.4, a little deviation from this value, generally between 7.0 to 8.5 is more optimum and conducive to fish life. pH between 7 to 8.5 is ideal for biological productivity , fishes can 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 and Abowei, 2011). According to Santhosh and Singh (2007) the suitable pH range for fish culture is between 6.7 and 9.5 and Ideal pH level is between 7.5 and 8.5 and above and below this is stressful to the fishes. Ideally, an aquaculture pond should have a pH between 6.5 and 9 (Wurts and Durborow, 1992: Bhatnagar *et al*., 2004). Bhatnagar *et al*. (2004) also recommended that <4 or >10.5 is lethal to fish/shellfish culture; 7.5-8.5 is highly congenial for *P.monodon*; 7.0-9.0 is acceptable limits; 9.0 -10.5 is sublethal for fish culture.

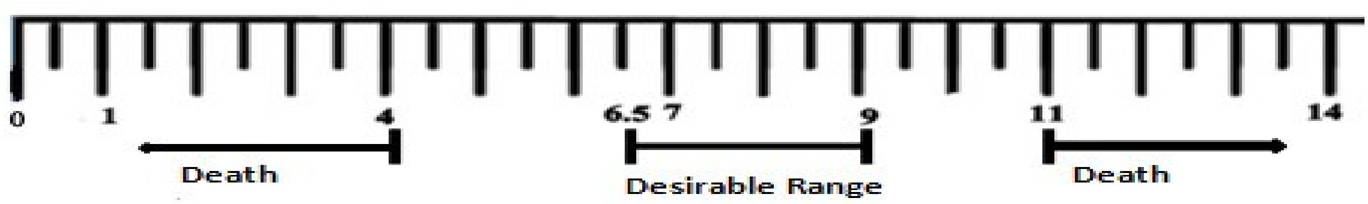

Fig. 3. Suitable pH range for pond fish culture

Remedies

1. Add gypsum ($CaSO_4$) or organic matter (cowdung, poultry droppings etc.) and initial pre-treatment or curing of a new concrete pond to reduce pH levels.

2. Use of quicklime (CaO) to rectify low pH of aquatic body.

Alkalinity

Alkalinity is the water's ability to resist changes in pH and is a measure of the total concentration of bases in pond water including carbonates, bicarbonates, hydroxides, phosphates and borates, dissolved calcium, magnesium, and other compounds in the water. Lime leaching out of concrete ponds or calcareous rocks, photosynthesis, denitrification and sulphate reduction is mainly responsible for increasing alkalinity while respiration, nitrification and sulphide oxidation decrease or consume alkalinity (Stumn and Morgan, 1981: Cook *et al.*, 1986) and to a lesser degree it increases due to evaporation and decomposing organic matter. But if the alkalinity is low, it indicates that even a small amount of acid can cause a large change in our pH.

Desirable limits

Moyle (1946) gave the range of total alkalinity as 0.0 - 20.0 ppm for low production, 20.0 -ppm- low to medium, 40.0 - 90.0 ppm- medium to high production and above 90.0 ppm- productive. Boyd and Lichtkoppler (1979) suggested that water with total alkalinities of 20 to 150 mg L^{-1} contain suitable quantities of carbon dioxide to permit plankton production for fish culture. According to Wurts and Durborow (1992) alkalinity between 75 to 200 mg L^{-1}, but not less than 20 mg L^{-1}

is ideal in an aquaculture pond. Swann (1997) recommended total alkalinity values of at least 20 ppm for catfish production and for good pond productivity. Bhatnagar *et al.* (2004) suggested that <20ppm indicates poor status of waterbody, 20-50 ppm shows low to medium, 80-200 ppm is desirable for fish/prawn and >300 ppm is undesirable due to non-availability of CO_2. Stone and Thomforde (2004) suggested 50-150 mg L^{-1} ($CaCO_3$) as desirable range; an acceptable range of above 20 mg L^{-1} and less than 400 mg L^{-1} for ponds and above 10 mg L^{-1} for hatchery water. According to Santhosh and Singh (2007) the ideal value for fish culture is 50-300 mg L^{-1}.

Remedies

1. Fertilize the ponds to check nutrient status of pondwater

2. Alkalinity can be increased by calcium carbonate, concrete blocks, oyster shells, limestone, or even egg shells depending upon soil pH and buffering capacity.

Hardness

Hardness is the measure of alkaline earth elements such as calcium and magnesium in an aquatic body along with other ions such as aluminium, iron, manganese, strontium, zinc, and hydrogen ions. Calcium and magnesium are essential to fish for metabolic reactions such as bone and scale formation.

Desirable limits

The recommended ideal value of hardness for fish culture is at least 20 ppm (Swann, 1997) and a range of 30-180 mg L^{-1} (Santhosh and Singh, 2007). According to Stone and Thomforde (2004) the desirable Range is 50-150 mg L^{-1} as $CaCO_3$ and acceptable Range is above 10 mg L^{-1} as $CaCO_3$. According to Bhatnagar *et al.* (2004) hardness values less than 20ppm causes stress, 75-150 ppm is optimum for fish culture and >300 ppm is lethal to fish life as it increases pH, resulting in non-availability of nutrients. However, some euryhaline species may have high tolerance limits to hardness.

Remedies

1. Add quicklime/alum/both and add zeolite to reduce hardness.

2. During heavy rainfall avoid the runoff water to bring lot of silt into the fish pond.

Calcium

Calcium is generally present in soil as carbonate and most important environmental, divalent salt in fish culture water. Fish can absorb calcium either from the water or from food.

Desirable limits

Wurts and Durborow (1992) recommended range for free calcium in culture waters is 25 to 100 mg L^{-1} (63 to 250 mg L^{-1} $CaCO_3$ hardness) and according to them Channel catfish can tolerate minimum level of mineral calcium in their feed but may grow slowly under such conditions. Water with free calcium concentrations as low as 10 mg L^{-1} if pH is above 6.5 can be tolerated by Rainbow trout, 40 to 100 mg L^{-1} range (100 to 250 mg L^{-1} as $CaCO_3$ hardness) are desirable for striped bass, red drum or crawfish.

Conductivity

Conductivity is an index of the total ionic content of water, and therefore indicates freshness or otherwise of the water (Ogbeibu and Victor, 1995). Conductivity can be used as indicator of primary production (chemical richness) and thus fish production. Conductivity of water depends on its ionic concentration (Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, NO_3^- and PO_4^-), temperature and on variations of dissolved solids. Distilled water has a conductivity of about 1 μ mhos/cm and natural waters have conductivity of 20-1500 μ mhos/cm (Abowei, 2010). Conductivity of freshwater varies between 50 to 1500 hs/cm (Boyd, 1979), but in some polluted waters it may reach 10,000 hs/cm and seawater has conductivity around 35,000 hs/cm and above.

Desirable limits

As fish differ in their ability to maintain osmotic pressure, therefore the optimum conductivity for fish production differs from one species to another. Sikoki and Veen (2004) described a conductivity range of 3.8 -10 hs/cm as extremely poor in chemicals, Stone and Thomforde (2004) recommended the desirable range 100-2,000 mSiemens/cm and acceptable range 30-5,000 mSiemens/cm for pond fish culture.

Salinity

Salinity is defined as the total concentration of electrically charged ions (cations – Ca^{++}, Mg^{++}, K^+, Na^+ ; anions – CO_3^-, HCO_3^-, SO_4^-, Cl^- and other components such as NO_3^-, NH_4^+ and PO_4^-). Salinity is a major driving factor that affects the density and growth of aquatic organism's population (Jamabo, 2008).

Desirable limits

Fish are sensitive to the salt concentration of their waters and have evolved a system that maintains a constant salt ionic balance in its bloodstream through the movement of salts and water across their gill membranes. According to Meck (1996) fresh and saltwater fish species generally show poor tolerance to large changes in water salinity. Often salinity limits vary species to species level. Garg and Bhatnagar (1996) have given desirable range 2 ppt for common carp; however, Bhatnagar *et al.* (2004) gave different ideal levels of salinity as 10- 20 ppt for *P. monodon*; 10-25 ppt for euryhaline species and 25-28 ppt for *P. indicus*. Barman *et al.* (2005) gave a level of 10 ppt suitable for *Mugil cephalus* and Garg *et al.* (2003) suggested 25 ppt for *Chanos chanos* (Forsskal)

Remedies

1. Salinity is increased or diluted by replenishment of water.

2. Aeration is essential to equalise the water salinity all over the water column.

Chloride

Chlorine (Cl^-) is a gas which is added in water as a disinfectant to control harmful bacteria and Chloride is the same element found in the form of a salt, both have dramatically different chemical properties. Chloride is a common component of most waters and is useful to fish in maintaining their osmotic balance**.**

Desirable limits

According to Stone and Thomforde (2004) the desirable range of chlorides for commercial catfish production is above 60 mg L^{-1} and acceptable range is 10 times the nitrite concentration. Chloride (in the form of salt) is required at a minimum concentration of 60 mg L^{-1} and a ratio of chloride to nitrite of 10:1 reduces nitrite poisoning as catfish are susceptible to "brown blood" disease (caused by excess nitrite in the water). It becomes a matter of concern if chloride levels become high as above 100 mg L^{-1} in the waters because even in very small concentrations, it burns the edges of the gills with long term after effects and its acceptable range is 0. However, chloride content of water is also dependent on Salinity level.

Ammonia (NH_3)

Ammonia is the by-product from protein metabolism excreted by fish and bacterial decomposition of organic matter (fig- 4) such as wasted food, faeces, dead planktons, sewage etc. The unionized form of ammonia (NH_3) is extremely toxic while the ionized form (NH_4^+) is not and both the forms are grouped together as "total ammonia".

Effect

Ammonia in the range >0.1 mg L^{-1}1tends to cause gill damage, destroy mucous producing membranes, "sub- lethal" effects like reduced growth, poor feed conversion, and reduced disease resistance at concentrations that are lower than lethal concentrations, osmoregulatory imbalance, kidney failure. Fish suffering from ammonia poisoning generally appear sluggish or often at the surface gasping for air.

Desirable limits

The toxic levels for un-ionized ammonia for short-term exposure usually lie between 0.6 and mg L^{-1} for pond fish, and sublethal effects may occur at 0.1 to 0.3 mg L^{-1} (EIFAC, 1973; Robinette, 1976). Maximum limit of ammonia concentration for aquatic organisms is 0.1 mg L^{-1} (Meade, 1985: Santhosh and Singh, 2007). According to Swann (1997) and OATA (2008) the levels below 0.02 ppm were considered safe. Stone and Thomforde (2004) stated the desirable range as Total NH_3-N: 0-2 mg L^{-1} and Un-ionized NH_3-N: 0 mg L^{-1} and acceptable range as Total NH_3-N: Less than 4 mg L^{-1} and Un-ionized NH_3-N: Less than 0.4 mg L^{-1}. Bhatnagar *et al*. (2004) suggested 0.01-0.5 ppm is desirable for shrimp; >0.4 ppm is lethal to many fishes & prawn species; 0.05-0.4 ppm has sublethal effect and <0.05 ppm is safe for many tropical fish species and prawns. Bhatnagar and Singh (2010) recommended the level of ammonia (<0.2 mg L^{-1}) suitable for pond fishery.

Control and treatments

1. Increase pond aeration.

2. Addition of liming agents such as hydrated lime or quick lime decreases ammonia and this technique is effective only in ponds with low alkalinity.

3. Formaldehyde and zeolite treatment. A dosage of 50 ml per 100 gallons to chemically bind up to 1 ppm of ammonia, can be useful and but also check the manufacturer's directions before use.

4. Regular water change out.

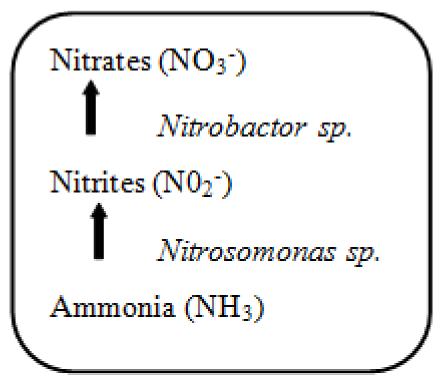

Fig. 4. *Nitrobacter* and *Nitrosomonas* helps in conversion of NH_3 to NO_3.

Nitrite (NO_2^-)

Nitrite is an intermediate product of the aerobic nitrification bacterial process, produced by the autotrophic *Nitrosomonas* bacteria combining oxygen and ammonia (fig.4).

Effects

Nitrite can be termed as an invisible killer of fish because it oxidizes haemoglobin to methemoglobin in the blood, turning the blood and gills brown and hindering respiration also damage for nervous system, liver, spleen and kidneys of the fish.

Desirable limits

The ideal and normal measurement of nitrite is zero in any aquatic system. Stone and Thomforde (2004) suggested that the desirable range 0-1 mg L^{-1} NO_2 and acceptable range less than 4 mg L^{-1} NO_2. According to Bhatnagar *et al*. (2004) 0.02-1.0 ppm is lethal to many fish species, >1.0 ppm is lethal for many warm water fishes and <0.02 ppm is acceptable. Santhosh and Singh (2007) recommended nitrite concentration in water should not exceed 0.5 mg L^{-1}. OATA (2008) recommended that it should not exceed 0.2 mg L^{-1} in freshwater and 0.125 mg L^{-1} in seawater.

Reducing the level of Nitrite

1. Reduction of stocking densities, Improvement of feeding, biological filtration and general husbandry procedures, Increase aeration to maximum, Stop feeding.
2. Addition of small amounts of certain chloride salts, regular water change out.
3. Use of biofertilizers to accelerate nitrification.

Nitrate (NO_3)

Where ammonia and nitrite were toxic to the fish, Nitrate is harmless and is produced by the autotrophic *Nitrobacter* bacteria combining oxygen and nitrite (fig.4). Nitrate levels are normally stabilized in the 50-100 ppm range.

Desirable limits

Meck (1996) recommended that its concentrations from 0 to 200 ppm are acceptable in a fish pond and is generally low toxic for some species whereas especially the marine species are sensitive to its presence. According to Stone and Thomforde (2004) nitrate is relatively nontoxic to fish and not cause any health hazard except at exceedingly high levels (above 90 mg L^{-1}). Santhosh and Singh (2007) described the favourable range of 0.1 mg L^{-1} to 4.0 mg L^{-1} in fish culture water. However, OATA (2008) recommends that nitrate levels in marine systems never exceed 100 mg L^{-1}.

Reducing the level of Nitrate

Dilution by water change (ensure water used for change has a lower nitrate level), Use of ion exchange materials, Increase plant density and by the use of denitrifying biological filtration nitrate concentration can be reduced.

Phosphorus

Almost all of the phosphorus (P) present in water is in the form of phosphate (PO_4) 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.

Desirable limits

Soil phosphorus (unit- mg of P_2O_5 per 100gm of soil) level below 3 might be considered indicative of poor production, between 3 and 6 of average production and ponds having available phosphorus above 6 are productive (Banerjea, 1967). According to Stone and Thomforde (2004) the phosphate level of 0.06 mg L^{-1} is desirable for fish culture. Bhatnagar *et al*. (2004) suggested 0.05-0.07 ppm is optimum and productive; 1.0 ppm is good for plankton / shrimp production.

Remedies

Use inorganic fertilizers to increase phosphorus level (N: P=15:30).

Primary productivity

This is the rate at which photosynthesis takes place. The most commonly used index of productivity is the DO content of the water. Primary productivity may be reported as net or gross. Net primary productivity represents the total amount of new organic matter synthesized by photosynthesis less the amount the organic matter used for respiration. Primary productivity by light and dark bottles is possible methods of measuring phytoplankton abundance.

Desirable limits

Bhatnagar *et al*. (2004) recommended 1.60-9.14 mg C L^{-1} D^{-1} (GPP)—as optimum status and <1.6 or >20.3 mg C L^{-1} D^{-1} (GPP)—as poor productivity of a pond culture. Santhosh and Singh (2007) has given the ideal value of primary productivity is 1000-2500 mg C $M^{-3}d^{-1}$ (=1.0-2.0 mg C L^{-1} d^{-1}). A fish pond can be considered good in productivity if it is slight green in colour, with no scum on the surface and having a transparency of about one foot. According to Trifonova (1989) primary productivity can be estimated by measuring the chlorophyll (ch) ‘a’ from the algal biomass. If the productivity value is less than 0.5 g m^{-3} (<1.5 mg ch‘a’m^{-3}) it was considered-oligotrophic, 1-5 g m^{-3} (1.5-10 mg ch‘a’m^{-3}) - mesotrophic, 5-10 gm^{-3} (10-25 mg ch‘a’m^{-3}) - eutrophic and >10 g m^{-3} (>25 mg ch‘a’m^{-3}) as highly eutrophic.

Remedies

1. Productivity can be improved by use of organic/inorganic fertilizers in ponds.
2. In case of plankton bloom / swarm; feed/manure application can be suspended for some time.

Plankton

Those aquatic pelagic organisms, which are carried about by the movement of the water rather than their own ability to swim are called planktons. The plant components are called as phytoplankton and animal components as zooplanktons and they serve as fish food organisms (fig. 5). For enumeration they are collected using plankton net (fig. 6). As plankton is at the base of the food web, there is a close relationship between plankton abundance and fish production (Smith, and Swingle, 1938).

Plankton blooms and fish kill

Fertilization may not be the only reason for eutrophication or excessive growth of planktons in pond water surface. The growth of certain species of blue green algae form dense scums in surface waters, cause shallow thermal stratification, less availability of soluble phosphate in the top layer and prevents the penetration of light for photosynthesis to depths below 1m so leading to anoxic conditions in the deep areas (lack of oxygen and high concentration of free carbon dioxide) resulting in fish kills.

Desirable limits

Bhatnagar and Singh (2010) suggested the optimum plankton population (approximately 3000-4500 Nos. L^{-1}) in pond fish culture.

Significance

1. The main objective to maximise the plankton production in optimum quantity is to maintain the standing crop and optimum fertilisation also reduce the probability of algal crash.

2. Dense phytoplankton helps in producing 10 times more oxygen than it consumes, so have an important role in compensating for respiratory loss without adding further energy expenditure.

3. Exploiting primary production is a cheap method of producing fish. Planktons also prevent the development of macrophytes that are undesirable for fish.

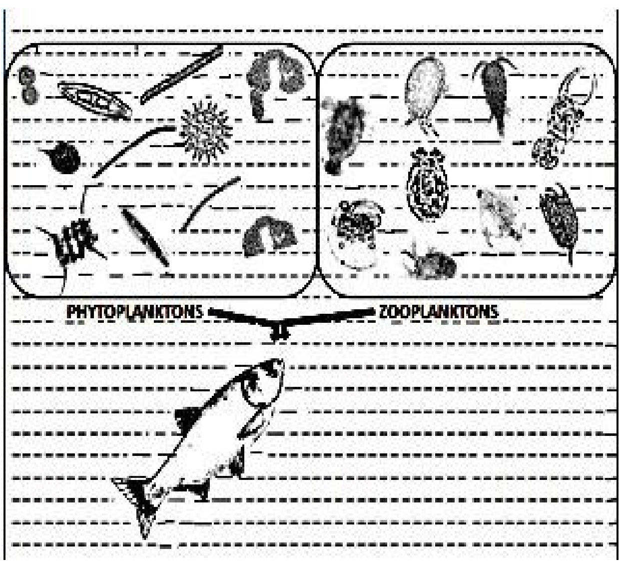

Fig. 5. Planktons as fish food organisms

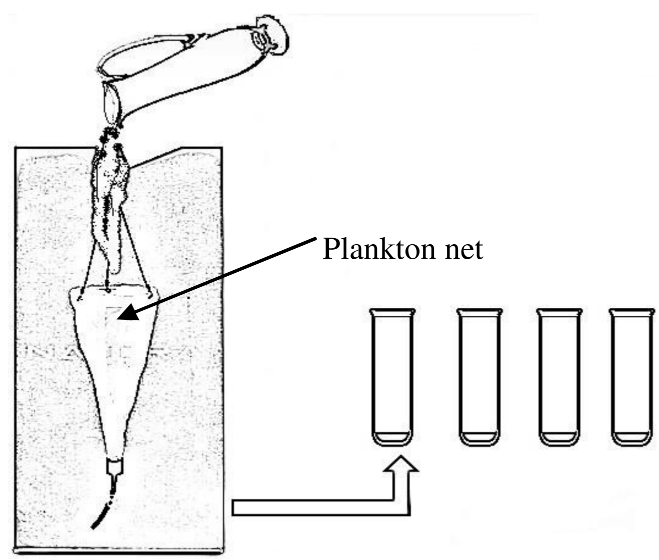

Fig. 6. Method of plankton collection

Control and treatment

1. Water circulation should be proper to avoid the appearance of anaerobic microzones and large sized inedible phytoplankton species.

2. Biological control of phytoplankton scum using herbivores (plankton feeding fishes such as silver carp) that reduces the blue green algae and total phytoplankton biomass appear more promising.

3. When plankton scums appear, DO should be measured daily to ensure that oxygen is present in depths below 1.3 m. Light penetration and distribution of DO in ponds can be facilitated with copper tetraoxosulphate ($CuSO_4$) in one or two applications, a week. The quantity of $CuSO_4$ in waters with 25ppm hardness is 800 g/ha surface area.

   Disadvantage is that, it adds to the total Biochemical Oxygen Demand (BOD) in the water. Nutrients may later recycle and may cause heavy scum.

How to detect pond water of poor quality

The following guidelines are given to a fish farmer to know when pond water is deteriorating in quality and therefore not suitable for fish growth.

1. Clear water indicates very low or absence of biological production- not fertile enough and fish will not grow well in it.

2. Muddy water (that is a lot of clay particles are present), fish can have their gills blocked by the soil particles and this can result in death - not good for fish culture.

3. Deep green water indicates over-production of planktons that serve as food for fish but occur as a result of application of more than enough fertilizers, manure or nutrient rich feeds to a pond.

4. When a fish pond gives an offensive odour, it indicates pollution of pond water. Sources of pollution include application of excess food stuff to the pond, or inflow of water from polluted rivers. Pollution can also result from application of chemicals to arable crops around the pond site.

5. In an already stocked fishpond, if a farmer noticed the fish always struggling at the pond water surface to get oxygen, then there is low DO content in the water (fig. 2).

The optimum range of various water quality parameters are summarised in Table-1.

TABLE 1: Suggested water-quality criteria for pond water fishery for getting high yield via applying minimum input.

Sr. No	Parameter	Acceptable range	Desirable range	Stress
1.	Temperature (^{0}C)	15-35	20-30	<12, >35
2.	Turbidity (cm)		30-80	<12,>80
3.	Water colour	Pale to light green	Light green to light brown	Clear water, Dark green &Brown
4.	Dissolved oxygen (mg L^{-1})	3-5	5	<5, >8
5.	BOD (mg L^{-1})	3-6	1-2	>10
6.	CO_2 (mg L^{-1})	0-10	<5, 5-8	>12
7.	pH	7-9.5	6.5-9	<4, >11
8.	Alkalinity (mg L^{-1})	50-200	25-100	<20, >300
9.	Hardness (mg L^{-1})	>20	75-150	<20,>300
10.	Calcium (mg L^{-1})	4-160	25-100	<10, >250
11.	Ammonia (mg L^{-1})	0-0.05	0- <0.025	>0.3
12.	Nitrite (mg L^{-1})	0.02-2	<0.02	>0.2
13.	Nitrate (mg L^{-1})	0-100	0.1-4.5	>100, <0.01
14.	Phosphorus (mg L^{-1})	0.03-2	0.01-3	>3
15.	H_2S (mg L^{-1})	0-0.02	0.002	Any detectable level
16.	Primary productivity (C L^{-1} D^{-1})	1-15	1.6-9.14	<1.6, >20.3
17.	Plankton (No. L^{-1})	2000-6000	3000-4500	<3000, >7000

These precautions and above mentioned guidelines if taken will not only raise productivity and economic benefits but will also help the farmers in maintaining ecofriendly ponds environment required for sustainable fish culture / aquaculture.

REFERENCES

[1] Abowei, J. F. N., (2010), Salinity, Dissolved Oxygen, pH and surface water temperature conditions in Nkoro River, Niger

Delta, Nigeria, Advance journal of food science and technology, 2(1), pp 16-21.

[2] Alikunhi, K. H., Ramachandra, V. and Chaudhuri, H., (1952), Mortality of carp fry under supersaturation of dissolved oxygen in water, Proceedings of the national institute of sciences of India, 17 (4), pp 261-264.

[3] Banerjea, S. M., (1967), Water quality and soil condition of fishponds in some states of India in relation to fish production, Indian journal of fisheries, 14, pp 115-144.

[4] Barman, U. K., Jana, S.N., Garg, S. K., Bhatnagar, A. and Arasu, A.R.T., (2005), Effect of inland water salinity on growth feed conversion efficiency and intestinal enzyme activity in growing grey mullet, *Mugil cephalus* (Lin.): Field and laboratory studies, Aquaculture international, 13(3), pp 241-256.

[5] Bhatnagar, A. and Garg, S.K., (2000), Causative factors of fish mortality in still water fish ponds under sub-tropical conditions, Aquaculture, 1(2), pp 91-96.

[6] Bhatnagar, A. and Singh, G., (2010), Culture fisheries in village ponds: a multi- location study in Haryana, India. Agriculture and Biology Journal of North America, 1(5), pp 961-968.

[7] Bhatnagar, A., (2008), Productivity and fish biodiversity of selected ponds of Haryana, Project Report submitted to Department of fisheries Government of Haryana.

[8] Bhatnagar, A., Jana, S.N., Garg, S.K. Patra, B.C., Singh, G. and Barman, U.K., (2004), Water quality management in aquaculture, In: Course Manual of summerschool on development of sustainable aquaculture technology in fresh and saline waters, CCS Haryana Agricultural, Hisar (India), pp 203- 210.

[9] Boyd, C. E., (1979), Water Quality in Warmwater Fish Ponds, Agriculture Experiment Station, Auburn, Alabama, pp 359.

[10] Boyd, C.E and Lichtkoppler, F., (1979), Water Quality Management in Fish Ponds. Research and Development Series No. 22, International Centre for Aquaculture (J.C.A.A) Experimental Station Auburn University, Alabama, pp 45-47.

[11] Bronmark, C. and Hansson, L. A., (2005), The biology of lakes and ponds, Oxford University Press, Oxford, pp 285.

[12] Clerk, R.B., (1986), Marine Pollution. Clarandon Press, Oxford, pp 256.

[13] Cook, R.B., Kelly, C.A., Schindler, D. W. and Turner, M. A., (1986), Mechanisma of hydrogen ion neutralization in an experimentally acidified lake, Limnology and Oceanography, 31, pp 134-148.

[14] Davenport, Y., (1993), Responses of the *Blennius pholis* to fluctuating salinities, Marine Ecology Progress Series, 1, pp 101 – 107.

[15] Delince, G., (1992), The ecology of the fish pond ecosystem, Kluwer Acadmic Publisers London, pp 230.

[16] Ekubo, A. A. and Abowei, J. F. N., (2011), Review of some water quality management principles in culture fisheries, Research Journal of Applied Sciences, Engineering and Technology, 3(2), pp 1342-1357.

[17] European Inland Fisheries Advisory Commission (EIFAC) , (1973), Water Quality Criteria for European Freshwater Fish, Report on Ammonia and Inland Fisheries, Water Resources., 7, pp1011-1022.

[18] Garg, S. K. and Bhatnagar, A., (1996). Effect of varying doses of organic and inorganic fertilizers on plankton production and fish biomass in brackish water ponds, Aquaculture Research (The Netherlands), 27, pp 157-166.

[19] Garg, S. K. and Bhatnagar, A., (1999), Effect of different doses of organic fertilizer (cowdung) on pond productivity and fish biomass in still water ponds. Journal of Applied Ichthyology, 15, pp 10-18.

[20] Garg, S.K., Jana, S.N. and Bhatnagar, A., (2003), Effect of inland groundwater salinity on digestibility and other aspects of nutrition physiology in *Mugil cephalus* and *Chanos chanos* (Forsskal), In: Fish production using brackish water in arid ecosystem (eds. Garg, S.K. and Arasu, A.R.T.), Ankush Printers, Hisar, pp 53-59.

[21] Jamabo, N.A., (2008), Ecology of *Tympanotonus fuscatus* (Linnaeus, 1758) in the Mangrove Swamps of the Upper Bonny River, Niger Delta, Nigeria. Ph.D. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, pp 231.

[22] Kiran, B. R., (2010), Physico-chemical characteristics of fish ponds of Bhadra project at Karnataka, RASĀYAN Journal of Chemistry, 3(4), pp 671-676.

[23] Lucinda, C. and Martin, N., (1999), Oxford English Mini-Dictionary Oxford University Press Inc, New York, pp 200-535.

[24] Meade, J.W., (1985), Allowable ammonia for fish culture, Progressive Fish culture, 47, pp 135-145.

[25] Meck Norm., (1996), Pond water chemistry, San Diego, Koi Club, Http://users.vcnet.com/rrenshaw/h2oquality.html Revised on July 31, 1996.

[26] Moses, B.S., (1983), Introduction to Tropical Fisheries, Ibadan University Press, UNESCO/ICSU, Part, pp: 102-105.

[27] Moyle, J.B., (1946), Some indices of lake productivity, Transactions of the American Fisheries Society, 76, pp 322-334.

[28] Mumtazuddin, M., Rahman, M. S. and Mostafa, G., (1982), Limnological studies of four selected rearing ponds at the aquaculture experiment station, Mymenshingh. Bangladesh Journal of Fisheries Research, 2-5 (1-2), pp 83-90.

[29] National Agricultural Extension and Research, 1996, Water Quality Management in Fish Culture, Extension Bulletin No. 98 Fisheries Series No 3 Published by Liaison Services Ahmadu Bello University, Zaria.

[30] Ogbeibu, A. E. and Victor, R., (1995), Hydrological studies of water bodies in the okomu forest reserves (sanctuary) in Southern Nigeria, physico-chemical hydrology, Tropical Freshwater Biology, 4, pp 83-100.

[31] Ornamental Aquatic Trade Association (OATA), (2008), Water Quality Criteria- ornamental fish. Company Limited by Guarantee and Registered in England No 2738119 Registered Office Wessex House, 40 Station Road, Westbury, Wiltshire, BA13 3JN, UK, info@ornamentalfish.org www.ornamentalfish.org. Version 2.0 March 2008

[32] Pruthi, H.S., (1932), Investigations regarding a recent epidemic of fish mortality in the tank in the Indian museum compound with remarks on the causation of such epidemics in general. Review of Hydrobiology Hydrographic, 26, pp 242-257.

[33] Robinette, H. R., (1976), Effect of Selected Sublethal Levels of Ammonia on the Growth of Channel Catfish (*Ictalurus punctatus*), Progressive Fish Culturist, 38, pp 26-29.

[34] Santhosh, B. and Singh, N.P., (2007), Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, Publication no.29

[35] Sewell, R.B.S., (1927), On mortality of fishes, Journal of the Asiatic Society of Bengal, 22, pp 177-204.

[36] Sikoki, F.D. and J.V. Veen, (2004), Aspects of Water Quality and the Potential for Fish Production of Shiroro Reservoir Nigeria, Living System Sustainable development, 2, pp 7.

[37] Smith, E. V. and Swingle. H. S., (1938), The Relationship Between Plankton Production and Fish Production in Ponds. Transactions of the American Fisheries Society, 68, pp 309-315.

[38] Solis, N.B., (1988), The Biology and Culture of *Penaeus Monodon*, Department Papers. SEAFDEC Aquaculture Department, Tigbouan, Boilo Philippines, pp 3-36.

[39] Stone, N. M. and Thomforde H. K., (2004), Understanding Your Fish Pond Water Analysis Report. Cooperative Extension Program, University of Arkansas at Pine Bluff Aquaculture / Fisheries.

[40] Stumn, W. and Morgan, J.J., (1981), An introduction imphasizing chemical equlibria in natural waters, Aquatic chemistry. 2ND Ed., John Wiley and Sons, New York, pp 780.

[41] Swann, L.D., (1997), A Fish Farmer's Guide to Understanding Water Quality, Aquaculture Extension Illinois, Purdue University, Indiana Sea Grant Program Fact Sheet AS-503.

[42] Trifonova, I. S., (1989), Change in community structure and productivity of phytoplankton as indicator of lake reservoir eutrophication, Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie, 33, pp 363- 371.

[43] Upadhyaya, M.P., (1964), Seminar on inland fisheries development in U. P., pp 127- 135.

[44] Wurts, W.A. and Durborow, R. M., (1992), Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds Southern Regional Aquaculture Center, SRAC Publication No. 464.