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Water Quality Challenges in Fish Farms and Solution in The South Western Region Of Nigeria

Abstract
Fish and fish products are known worldwide as very important diets because of their high nutritive values and significance in improving human health. Fish plays a vital role in feeding the world's population and contributing significantly to the dietary protein intake of hundreds of millions of the populace (Amao et al., 2006).
Fish farming or culture is an integral component of the overall agricultural production system in Nigeria. The major species cultured in Nigeria include tilapias, catfish and carp. However the African catfish Clarias gariepinus is the most farmed (Agbede et al., 2003). Water is a finite resource that is very essential for the human existence, agriculture, industry etc. Without any doubt, inadequate quantity and quality of water have serious impact on sustainable development. In developing countries, most of which have huge debt burdens, population explosion and moderate to rapid urbanization, people have little or no option but to accept water sources of doubtful quality, due to lack of better alternative sources or due to economic and technological constraints to treat the available water adequately before use (Calamari and Naeve, 2004; Aina and Adedipe, 2006). The scarcity of clean water and pollution of fresh water have therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three quarters of their rural dwelling population do not have access to reasonably safe water supplies (Lloyd and Helmer, 2002).
Assessment of water is not only for suitability for human consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life. Water quality monitoring is therefore a fundamental tool in the management of freshwater resources.

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I. Prospect Of Fish Farming

The fish industry remains about the most unexplored investment sector in Nigeria compared with the importation of frozen fish in the domestic market (Kudi *et al.*, 2008). A sure means of substantially solving the demand-supply gap is by embarking on widespread small scale fish production. The potential of fish farming in developing countries is great, as it offers economical source of protein rich food. According to UN survey, the fish production from aquaculture in 1985 stood at 1million metric ton, close behind beef, pork and poultry (FAO, 2005), declining to 0.8million metric ton in 2020 (CBN, 2020) Comparatively, fish does not use much energy to maintain body heat or for locomotion and has a food to flesh conversion rate of 1.5 to 1.0 as against beef's 7.0 to 1.0 and chicken's 2.3 to 1.0 (Nazri, 2001).

II. Problems Of Fish Farming

Unlike the developed World, Africa is mesmerized by underdevelopment in governance, education, technology, etc., being responsible for African countries inability to address a number of problems militating against adequate production in the aquacultural sub-sector. The main constraints facing aqua cultural activities in Nigeria are:-

- ***Climatic Factors***: Climatic factors are mainly physical forces of nature that arise due to extreme manifestations of climatic elements and meteorological conditions (Agbabi and Fagbenro, 2006). These factors include excessive rainfall and flooding, excessive heat and drought (Moyle *et al*., 2000; Enabulele 2009; Plumb, 2009-

Financial Factors: These are due to unstable government financial policies. Fish farmers require repeated loans, in addition to loans for capital investment and start-up operational cost. Short term loans are meant for annual supplies of seed, feed, new equipment and expansion (Odoye *et al*., 2005) – these are lacking in our system, hindering growth of aquaculture.

Institutional Factors: This refers to macro and micro institutional programmes, like training, extension services as well as political stability, which are all lacking to the detriment of growth of aquaculture.

Social Factors: This refers to the influences of living {human within the employment (positive and negative activities)}{human outside the employment (sabotage, pilfering, etc)}, as well as social acceptability of aquaculture (Odoye *et al.,* 2005).

- *Disease Factors**:* Fish being a poikilothermic animal tend to react quickly to environmental changes and this increases susceptibility of fish to infectious agent due to compromised immune response (Plumb, 2009). Myole (2000) also stated that stressed fish are more susceptible to diseases and parasites than fish which are held under optimum condition. Ahmed and Ambali (2005) reported that parasitic infections were found to be a common feature in fish population with nematode being significantly prominent.

- *Physical Factors:* Lack of adequate technology or technical information and expertise as regards hatchery, propagation and husbandry management affect fish production. Fish farmers should be provided with effective machinery and comprehensive information on the availability of tools that will enhance productivity of fish in Nigeria. Processing and preservation of fish are of utmost importance since it deteriorates immediately after harvesting. Therefore, processing of fish after capture using high quality machines and preservation is imperative to prevent serious economic losses (Davies and Davies, 2009).

- *Business Factors**:* Fish farmers also face market and consumer related risks. Such risks are due to loss of quality products, lack of market information, and health regulations.

Water quality guidelines for the management of fish farm
Water and pollution

This is one of the most important resource used in fish farming. Without assured, adequate and good quality water supply, fish production would be made impossible. Water is one of the most critical factors besides good feed/feeding, in fish production. Water quality and quantity are critical factors to successful fish production.

The water should be void of any chemical harmful to fish and be within acceptable pH range of 6.5 – 8.5. To a large extent, water temperature will determine what species of fish can be grown successfully. The amount of water available will limit the size of the fish farm. At a minimum you want enough water to drain and fill a fish production pond at least once a year, as well as the capability of replacing any water lost through leakage or evaporation. The major source of water for fish farmers in Nigeria includes: tap water from domestic water supply, water from streams/ rivers, well and borehole. The greatest challenges encountered by fish farmers in Nigeria have to do with pollution from industrial activities, mining and the petroleum industries. Water pollution has become a great issue especially in the oil-rich areas. Pollution of surface water has had severe impacts on fisheries production. Olowosegun *et al.* (2005) reported that in Nigeria, most of the fishing grounds have been rendered unproductive by oil exploration, dredging of some water bodies and dumping of toxic industrial effluents. Massive fish kills have been reported to occur in the aquaculture industry. Also the level of yield in the industry has been reported to be affected by pollution (Akanni and Akinwumi, 2007).

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.

Remedies

1. By water exchange, planting shady trees or making artificial shades during summer's thermal stratification can be prevented.
2.

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 (2009) suggested that the clay turbidity in water to 30cm or less may prevent development of plankton blooms, 30 to 60cm and as below 30cm - generally adequate for good fish production and there is an increase in the frequency of dissolved oxygen problems when values above 60cm, 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 < 12cm 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

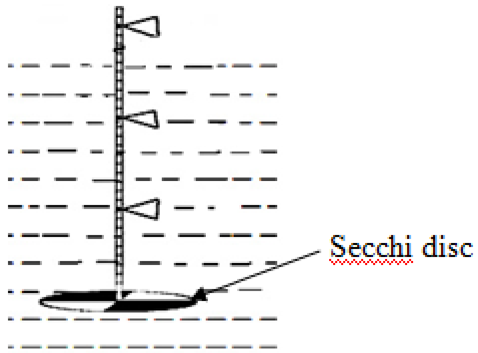

Figure 1: Measurement of turbidity using Secchi disc.

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 (2002) 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 fish, shrimps and other aquatic organisms (Solis, 2008). 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.

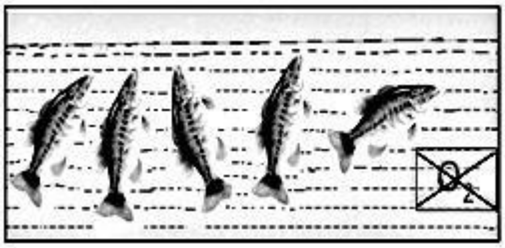

Figure 2: Stressed fishes due to low DO levels at surface of water

Desirable limits
According to Banerjea (2007) 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
(ii) Physical control of aquatic plants and also management of phytoplankton biomass
(ii) Recycling of water and use of aerators.
(iii) Artificially or manually beating of water.
(iv) Avoid over stocking of fishes.
(v) Natural/Artificial creation of shade over fish ponds to enhance
Aeration/ventilation, cooling the water and enhancing oxygen solubility.

Biochemical oxygen demand (BOD)
BOD is the measure of oxygen consumption rate resulting from metabolic activities. It is an indicator of the stress level the fish population is subjected to.

Desirable limits
Clerk (2006) 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 sub lethal 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 1.0 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 non-biodegradable / floating organic matter from the pond surface, aeration, screening or skimming to reduce BOD level.
2. Before stocking, pond water 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.
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 (2009) 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 (2007) 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 sub lethal 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 in water. 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 ldeal 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 sub lethal for fish culture.

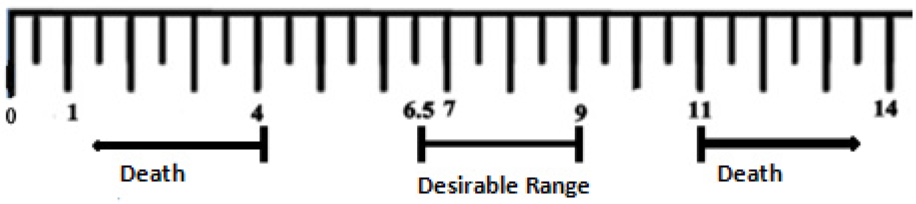

Figure 3: Suitable pH range for pond fish culture.

Remedies
1. Add gypsum ($CaSO_4$) or organic matter (cow-dung, 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, de-nitrification and sulphate reduction is mainly responsible for increasing alkalinity while

respiration, nitrification and sulphide oxidation decrease or consume alkalinity (Stumn and Morgan, 2001: Cook *et al.*, 2006) 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 (2006) gave the range of total alkalinity as 0.0 - 20.0 ppm for low production, 20.0 - 40.0 ppm- low to medium, 40.0 - 90.0 ppm- medium to high production and above 90.0 ppm- productive. Boyd and Lichtkoppler (2009) 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 (2002) alkalinity between 75 to 200 mg L^{-1}, and not less than 20 mg L^{-1} is ideal in an aquaculture pond. Swann (2007) 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 water body, 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 CO2. 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 pond water
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 aluminum, 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, 2007) 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 (2002) 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, 2005). Conductivity can be used as indicator of primary production (chemical richness) and thus fish production. Conductivity of water depends on its ionic concentration (Ca2+, Mg2+, HCO3-, CO3-, NO3- and PO4-), 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, 2009), 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 (cautions – 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 (2006) fresh and saltwater fish species generally show poor tolerance to large changes in water salinity.

Remedies
1. Salinity is decreased or diluted by replenishment of water.
2. Aeration is essential to equalize 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 2.0 mg L^{-1} for pond fish, and sub lethal effects may occur at 0.1 to 0.3 mg L^{-1}. Maximum limit of ammonia concentration for aquatic organisms is 0.1 mg L-1 (Santhosh and Singh, 2007). According to OATA (2008) the levels below 0.02 ppm were considered safe. Stone and Thomforde (2004) stated the desirable range as Total NH3-N: 0-2 mg L-1 and Un-ionized NH3-N: 0 mg L-1 and acceptable range as Total NH3-N: Less than 4 mg L-1 and Un-ionized NH3-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.

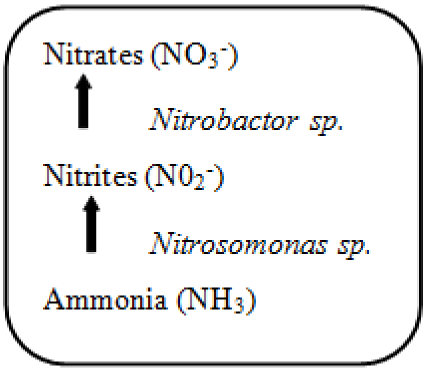

Figure 4: *Nitrobacter* and *Nitrosomonas* helps in conversion of NH_3 to NO_3.

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.
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 (0C)	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.	CO2 (mg L-1)	0-10	<5, 5-8	>12
	pH	7-9.5	6.5-9	<4, >11

7.				
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.	H2S (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.

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