4. WATER QUALITY CRITERIA IN AQUACULTURE

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Water is a prime resource which supports all life forms on earth, its quality and quantity vary from place to place. As habitats of aquaculture, there are three categories of waters, viz. fresh, salt and brackish. All these are characterized by a wide difference in their salinities ranging from nil freshwater to nearly 35 ppt in seawater. This variation in salinity influences the fauna and flora. Brackish water is present in the areas influenced by the tidal regime like the estuaries, deltas of rivers, lagoons and backwaters. Depending on the phase of the tide and volume of fresh water discharged through the river into the sea there will be variation in salinity. The capacity of the residents of an estuary to tolerate a wide range of salinity that prevails there is by virtue of a dynamic physiological process of osmoregulation in which the gills, the kidneys, the skin and the buccal cavity lining play significant roles. Salinity tolerance of a species is one of the important parameters for consideration in aquaculture. The success of a fish farming establishment lies greatly on its water quality management programme. Hence, it requires constant monitoring.

The water quality parameters to be monitored are given below.

Temperature

Each species of fish has an optimum temperature range for growth, as well as upper and lower lethal temperatures. Water temperature is critical in growth, reproduction and sometimes survival. Below the optimum temperature feed consumption and feed conversion decline until a temperature is reached at which growth ceases and feed consumption is limited to a maintenance ration. Below this temperature is a lower lethal temperature at which death occurs. Above the optimum temperature feed consumption increases while feed conversion declines.

pH

This parameter shows the concentration of hydrogen ions (H+) in the water. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. At 25 °C, pH of 7.0 will be considered neutral, i.e. neither acidic nor basic, while values below 7.0 are considered acidic, and above 7.0 are basic. Natural waters range between pH 5.0 and pH 10.0 while seawater is near pH 8.3. The pH is interdependent with other water quality parameters, such as carbon dioxide, alkalinity, and hardness. It can be toxic in itself at a certain level, and also known to influence the toxicity as well of hydrogen sulfide, cyanides, heavy metals, and ammonia (Klontz, 1993). For most freshwater species, a pH range between 6.5 - 9.0 is ideal, but most marine animals typically cannot tolerate as wide range pH as freshwater animals, thus the optimum pH is usually between pH 7.5 and 8.5 (Boyd, 1990).

Total Alkalinity

Alkalinity is the measure of the capacity of water to neutralize or buffer acids using carbonate, bicarbonate ions, and in rare cases, by hydroxide, thus protecting the organisms from major fluctuations in pH. Without this, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that may decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbondioxide will be consumed by the phytoplankton and, as a result, drive the pH levels above 10.0. Recommended alkaline level in freshwater is (5-500 mg/l) and seawater 116mg/l (Lawson, 1995).

Dissolved Oxygen (DO)

In a water body, oxygen is available in a dissolved state. It can enter into the system through direct diffusion and as a by-product of photosynthesis. Oxygen concentration maybe reported in terms of milligram per liter (mg/l) or its equivalent,parts per million (ppm). DO is needed by fish to respire and perform metabolic activities. The amount of oxygen consumption varies, depending on the size, feeding rate, activity level and species. Physical condition such as temperature, altitude and salinity can also affect oxygen level as the temperature and salinity increases, the solubility of oxygen in the water decreases. Thus low levels of dissolved oxygen are often linked to fish kill incidents. On the other hand, optimum levels can result to good growth, thus result to high production yield. A saturation level of at least 5 mg/l is required. The level of dissolved oxygen in the water can be increased through mechanical aeration, liquid oxygen injection, wind and wave action, and presence of aquatic plants and algae. However, it can also cause oxygen depletion when the plant population becomes too dense as DO is removed through respiration and decomposition. Food wastage and feed quality should be monitored as both significantly affect the levels of dissolved oxygen in the system.

Nitrogen is one of the limiting nutrients during photosynthesis. It enters into the aquaculture system through rainfall, in-situ Nitrogen fixation, river run-off and diffusion from sediments, uneaten feeds and fish wastes. Nitrogen is largely controlled by redox reactions mediated by phytoplankton and bacteria. The processes include remineralization, ammonification, nitrification, denitrification and fixation.

Ammonia-Nitrogen (NH_3-N)

Ammonia is the initial product of the decomposition of nitrogenous organic wastes and respiration. Nitrogenous organic wastes come from uneaten feeds and excretion of fishes. Thus, the concentration of ammonia-N is positively correlated to the amount of food wastage and the stocking density. Total Ammonia Nitrogen (TAN) is a parameter that measures the un-ionized (NH_3) and ionized (NH_4^+)

forms of ammonia present in the aquaculture system. High concentrations of ammonia causes an increase in pH and ammonia concentration in the blood of the fish which can damage the gills, the red blood cells, affect osmoregulation, reduce the oxygen-carrying capacity of blood and increase the oxygen demand of tissues (Lawson, 1995). Generally, NH_4+ is harmless and can dissipate into the atmosphere easily, however, NH_3 can be extremely toxic. Its toxicity was found out to be directly correlated with temperature and pH, i.e. NH_3 levels increases as the temperature and pH increases. The level of ammonia should not exceed 1mg/l in marine condition.

Nitrite-Nitrogen (NO_2-N)

Nitrite is a byproduct of oxidized NH_3 or NH_4+, an intermediary in the conversion of NH_3 or NH_4+ into NO_3. This process is completed through nitrification which is done by the highly aerobic, gram-negative, chemoautotrophic bacteria found naturally in the system. The conversion is quick, thus high nitrite concentrations are not commonly found. However, if high levels do occur, it can cause hypoxia, due to deactivation of hemoglobin in fish′ blood, a condition known as the "brown blood disease" (Lawson, 1995).The toxicity of nitrite is dependent on chemical factors such as the reduction of calcium-,chloride-, bromide- and bicarbonate ions, and levels of pH, dissolved oxygen and ammonia. Increasing pH, low dissolved oxygen and high ammonia can increase its toxic effect. High nitrite concentrations plus low chloride levels can result to reduced feeding activities, poor feed conversions, lower resistance to diseases and susceptibility to mortality (Lawson, 1995). The nitrite concentration should less than 0.1 mg l^{-1}.

Nitrate-Nitrogen (NO_3-N)

Nitrate is formed through nitrification process, i.e. oxidation of NO_2 into NO_3 by the action of aerobic bacteria. It is highly soluble in water, stable over a wide range and is least toxic. Nitrate not taken up directly by aquatic plants is denitrified in anaerobic sediments. Denitrification occurs in water bodies subject to enhanced nutrient loading from pollution, in water bodies with long residence times and in wetland ecosystems subject to periodic drying, where oxygen inputs during drying periods stimulate coupled mineralization-nitrification-denitrification within organically rich sediments (Furnas, 1992). However, high levels can affect osmoregulation, oxygen transport, eutrophication and algal bloom (Lawson, 1995).

Phosphorous (P)

Phosphorus (P) is found in the form of inorganic and organic phosphates (PO4) in natural waters. Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. Phosphorous is a limiting nutrient needed for the growth of all plants-aquatic plants and algae alike. However, excess concentrations especially in rivers and lakes can result to algal blooms. Phosphates are not toxic to people or animals, unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates. In marine condition below 0.05mg/l phosphorous is ideal for aquaculture.

The sources of phosphorous are wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides.

Total Solids

Total solids refer to any matter either suspended or dissolved in water. Everything that is retained by a filter is considered a suspended solid, while those that passed through are classified as dissolved solids.

Suspended solid (SS) can come from silt, decaying plant and animals, industrial wastes, sewage, etc. High concentrations have several negative effects, such as decreasing the amount of light that can penetrate the water, lower the production of dissolved oxygen, high absorption of heat from sunlight, low visibility which will affect the fish's ability to hunt for food, clog gills, prevent development of egg and larva. It can also be an indicator of higher concentration of bacteria, nutrients and pollutants in the water.

Dissolved solid (DS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life. However, high concentrations can result to damage in organism's cell , reduce photosynthetic activity and increase the water temperature. The acceptable TSS value is based on the previous sampling, wherein it should not be increased by more than 10% and 30%, respectively. It is because TSS levels in marine waters are highly variable and depend on many factors, thus, setting an absolute numerical value is not possible.

Heavy Metals

Heavy metals bioaccumulate and results in lower product quality and human health risk. The anthropogenic sources include ore mining and processing, plating industries, smelters, tanneries and textile industries. The concentration of these substances can be determined through chemical analysis of the water, sediments and fish tissue.

Mercury (Hg)

Mercury is toxic to both aquatic life and humans. Inorganic form occurs naturally in rocks and soils. It is being transported to the surface water through erosion and weathering.

However, higher concentrations can be found in areas near the industries and agriculture. The sources are caustic soda, fossil fuel combustion, paint, pulp and paper, batteries, dental amalgam and bactericides.

Lead

(Pb) comes from deposition of exhaust from vehicles in the atmosphere, batteries, waste from lead ore mines, lead smelters and sewage discharge. Its toxicity is dependent on pH level, hardness and alkalinity of the water. The toxic effects on fish are increased at lower pH level, low alkalinity and low solubility in hard water.

Chronic lead toxicity in fish leads to nervous damage which can be determined by the blackening of the fins. Acute toxicity, on the other hand causes gill damage and suffocation (Svobodova *et al.*, 1993).

Cadmium

Cadmium (Cd) is a highly toxic metal and is exceptionally persistent in humans. Low levels of exposure may also result to accumulation in kidneys (WHO, 1989). The most common sources are electroplating, nickel plating, smeltling, engraving, batteries, sewage sludge, fertilizers and zinc mines. In fishes, acute toxic exposure results to damage of the central nervous system. Chronic exposure have adverse effects on the reproductive organs, maturation, hatchability and larval development as well as mortality (Svobodova *et al.*, 1993; Lloyd,1992).

Nickel

Nickel (Ni) is only moderately toxic to fish and has little capacity for bioaccumulation. The dominant form in water is Ni2+. It enters the aquatic environment through the disposal of batteries and effluents from metal plating and ore processing industries. In humans, nickel can be carcinogenic and teratogenic.

Among the four metals, generally, cadium has the most stringent criteria, ranging from less than 0.2-5.0 µg/L, followed by mercury, lead and then lastly by nickel. Under marine condition the level of Hg, Pb, Cd and Ni should be less than 1 µg/L.

Coliform bacteria

Coliform bacteria consist of several genera belonging to Family *Enterobacteriaceae. Fecal* coliform which belongs to this group is found mostly in feces and intestinal tracts of humans and other warm blooded animals. It is not pathogenic per se, however, it is a good indicator of the presence of pathogenic bacteria. High levels of fecal coliform in the water may cause typhoid fever, hepatitis, gastroenteritis and dysentery. Factors which affect the concentration of this bacteria are the presence of wastewater and septic system, animal wastes, run-off, high temperature and nutrient-rich water. Around 30 counts per ml for fresh and marine water is permissible.

Pesticides

Pesticide refers to any chemical used to control unwanted non-pathogenic organisms, including insecticides, herbicides, fungicides, algicides and rotenone (used in killing unwanted fish) (Svobodova, 1993). These chemicals are designed to be toxic and persistent, thus it is also of concern in aquaculture. It can affect the quality of the aquaculture product as well as the health of the fish and humans.

The safe level of some of the pesticides are given below

Pesticide	Safe level (ppb)
Aldrin	0.003
BHC	4.0
Chlordane	0.0043 (freshwater) 0.004 (marine)
DDT	0.001
Heptachlor	0.0038 (freshwater) 0.0036 (marine)
Dieldrin	0.003 0.0019

Source: Boyd (1990)

Aquaculture increasingly plays a more significant role in fisheries sector. Increasing nutrient output from domestic, industrial, agriculture, deforestation and livestock production also adds to the water nutrient load and these have an effect on aquaculture and carrying capacity of the water body. Some water body may have a short residence time, i.e. time for the water to flushed out all the nutrients, while some have long residence time. Thus, the pollution level and its effect to the organisms will not be uniform.