WATER QUALITY MANAGEMENT IN AQUACULTURE

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In aquaculture, water quality is one of the prime factors that determines the success of that particular culture. Primarily the water quality parameters are divided into three major categories, physical, chemical and biological. But a slight change in some of the parameters especially pH,temperature,DO will lead to stress in the organism and it may be of physiological or behavioral. Deteriorated or changed water quality will affect growth,reproductive capacity. Susceptibility to diseases is also more in such environment.Water qualitymanagement measures aim at improving water quality. Aquaculture entrepreneurs should know the basics of water quality management measures in aquaculture to reduce the problems related with water quality so as to utilize the of water body with viable profit as well as environmental sustainability.

Water Sampling

It is necessary to make sure that there is no contamination during sampling and all the samples are properly sub-sampled and preserved to avoid/minimize changes in the

How to collect samples?

Niskin bottle sampler is used for collecting water samples from specific depths (Fig. 1). Niskin samplers can be used for sampling surface water also. Samples of surface water can also be collected by merely dipping with open dip samplers. When Niskin bottles are not available, a weighted bottle sampler can be used to collect water atspecific depths (Fig. 2). Surface and bottom water samples are to be collected separately for the near shore and offshore.

Prior to sampling, the sampler and sampling bottles should be acid washed with 1N HCl in the laboratory.

Sample bottles should be rinsed twice with clean water

The desired samples should be collected from the place away from where the sampler and sample bottles were washed.

Care should also be taken to avoid the sewage flush out from the boats/ships at the time of sampling.

Fig. 1 NISKIN BOTTLE SAMPLER

Proper sampling is of utmost importance.

Take adequate number of samples to have representative sampling of the water body

Sampling should be contamination free to avoid erroneous results on analysis

Samples should be appropriately sub-sampled for the different types of analyses needed , such as

- for dissolved gases, alkalinity and pH

- for nutrients and physical parameters
- for trace metals
- for biological - Chlorophylls and plankton
- for bacteria etc.

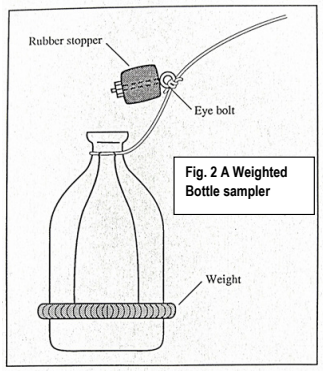


Fig. 2 A Weighted Bottle sampler

Preservation methods (Table 1) are to be adopted to avoid/minimize changes in the water composition during storage. The processing protocol should be meticulously followed for individual samples. For dissolved oxygen, the samples need to be fixed by employing Winkler's reagent on board vessel itself. Collection of samples for measurement of DO, other gases like CO2, pH and alkalinity must avoid atmospheric contamination during sampling and subsampling.

Table 1. Requirements for handling water samples for water quality assessment

Parameter	Preservation	Storage	Sample Holding (duration)	Sample volume	Type of container
Alkalinity		4oC	14 days	100 ml	Plastic / Glass
Ammonia	H2SO4 to pH <2	4oC	28 days	100 ml	Plastic / Glass
Chloride	None		28 days	50 ml	Plastic / Glass
Chlorophyll a		4oC	12 hrs	500 ml	Plastic / Glass
Colour		4oC	48 hrs	50 ml	Plastic / Glass
Conductivity		4oC	28 days	100ml	Plastic / Glass
Dissolved Oxygen	Fix immediately with Winkler A and B reagents	Away from sunlight	8 hrs	125ml	Glass
Nitrate		4oC	48 hrs	100 ml	Plastic / Glass
Nitrate-Nitrite	H2SO4 to pH<2	4oC	28 days	100 ml	Plastic / Glass
Odor		4oC	24 hrs	200ml	Glass
Orthophosphate	Filter immediately	4oC	48hrs	50ml	Plastic / Glass
Particulate organic matter		4oC	24hrs	200ml	Glass
pH	None		In situ	25ml	Plastic / Glass
Silicate		4oC	28 days	50ml	
Total Dissolved Solids (TDS)	None		7 days	100ml	Plastic / Glass
Temperature	None		In situ		Plastic / Glass

WATER QUALITY

Water Temperature

Water temperature is a physical property of water which expresses how hot or cold the water is. Air and water temperature is directly depends upon the solar radiation. Temperature can alter the physical and chemical properties of water (Fig. 3).

In water, light energy is absorbed exponentially with depth and so most heat is absorbed within upper layers of water, by dissolved organic matter and particulate matter. Water

temperature influences density of water.

Water temperature affects the metabolism, growth and reproduction in aquatic animals. Many animals use temperature as a signal for when to reproduce and when to migrate. Generally, animals and plants grow faster at warmer temperatures, although all organisms have an upper temperature limit.

Congenial species are to be selected for aquaculture as per temperature preference for maximum growth rate.

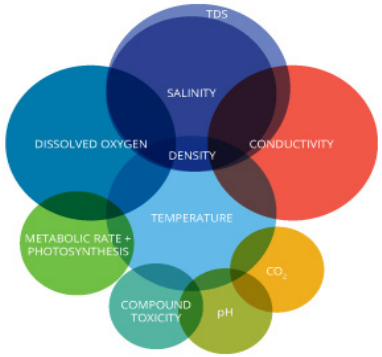


Fig. 3 Water quality paramters being influenced by water temperature

Temperature measurement of water samples collected should be done immediately using mercury / digital thermometer, by immersing the calibrated thermometer into the water

The atmospheric temperature is also measured in a well-ventilated area and in the shade, at 1.2 to 1.5 m above the ground, using a 50oC calibrated (liquid in glass) thermometer.

Turbidity

Turbidity refers to the decreased ability of water to transmit light caused by suspended particulate matter ranging in size from colloidal to coarse dispersions. Light penetration in to the water is measured by using a Secchi disc. The Secchi disk (Fig. 4) is a weighted disk, 20 cm in diameter and painted in alternate black and white quadrants, which easily measures turbidity in pond water. The average of depth at which the disk disappears and reappears is the Secchi disk visibility. Optimum Secchi disk visibility for shrimp ponds is 40 - 60 cm. It must be noted that the Secchi disk visibility isaffected by both types of turbidity ie (1) that resulting from phytoplankton blooms and (2)that caused by suspended soil particles. The individual taking Secchi disk reading

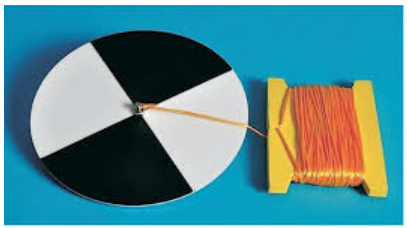


Fig. 4 Secchi Disk

must decide if the turbidity is from phytoplankton or suspended soil particles or both. The following guidelines may be used in evaluating Secchi disk visibilities for ponds (Table 2).

Table 2. Guidelines to evaluate Secchi disk visibilities for pond aquaculture

Secchi disk reading	Remarks
< 20 cm	Pond too turbid. If pond is turbid with phytoplankton, there will be problems with low dissolved oxygen concentrations. When, turbidity is from suspended soil particles productivity will be low.
20 - 30 cm	Turbidity becoming excessive
30-45 cm	If turbidity is from phytoplankton, pond in good condition
45 - 60 cm	Phytoplankton becoming scarce
>60 cm	Water is too clear. Inadequate productivity and danger of aquatic weed problems.

Salinity

Salinity is the concentration of total concentration of all ions in a given volume of water. Salinity is an important characteristic of natural waters. Salinity determines what species of aquatic animals to be present in that water body Salinity is expressed in parts per thousand by weight (ppt, or ‰) or in practical salinity units (PSU). For example, 1 gram of salt in1000 grams of water means its salinity is 1 g/kg, or 1 ppt. Salinity ranges from 0 ppt in fresh water to 35 ppt in the open ocean. For culture ponds of fresh water species the salinity should be in the range of 0.01 to 1 ppt and for brackish water species it is 20-35 ppt for optimum production.

Measurement of salinity

1. Using Refractometer (for in situ measurement)

Open the daylight plate (Fig. 5) and apply one or two drops of the water sample to the surface of the prism, using a glass rod. Hold the prism at an angle close to parallel with the floor so that the sample will not run off. Softly close the daylight plate. The sample should make a thin film over the entire surface of the prism. No bubbles should be there. Look through the eyepiece. Focus the scale until it is sharp to your eyes by gently turning the eyepiece either clockwise or counterclockwise. The upper field of view appears blue and the lower field will be white. The reading is taken at the line where the blue and white fields meet. For salinity, read the scale on the right side. It is marked as a "o/oo". This is read "parts per thousand". After taking a salinity reading, gently wipe the prism with a tissue paper and water. The refractometer needs to be calibrated periodically. To calibrate it, take a reading using distilled water. With distilled water on the prism, turn the calibration screw with the included screwdriver while looking through the eyepiece until the boundary line falls on "0".

2. Titrimetric method(for lab analysis)

In this method the dissolved halogen ions present in water

(chloride, bromide and iodide) are titrated with silver nitrate using potassium chromate as indicator. The halogen ions (other than fluoride) freely react with silver to precipitate silver halides. In this method silver will react with chromate only after all the halide ions, except fluoride, are precipitated and immediatelyas a slight excess of silver ion is present, red silver chromate is formed. A faint red colour of the solution point towards the end point of the titration.

Water pH

Water pH is the measure of hydrogen ion activity or a measure of acidity and alkalinity ranging from 0-14. The natural water pH ranges 5-10. The optimum water pH range in the aquaculture is 6.5-9. A pH of 7 is considered neutral. The lower the pH than 7, the more acidic the water is. The higher the pH than 7, the more basic or alkaline it is. The pH in ponds will rise during the day as phytoplankton and other aquatic plants remove CO2 from the water during photosynthesis. The pH decreases at night because of respiration and production of CO2 by all organisms. If high or low pH extends for a long time, it can cause stress, less survivals, poor growth, susceptibility to diseases and can to low production. Signs of less than optimal pH include increase mucus on the gill surfaces, black gill disease, damage to the eye lens, abnormal swimming behavior, loose shell, soft shell, irregularity in molt, poor phytoplankton and zooplankton growth.

Higher pH can increase the toxicity of ammonia, especially so when the water temperature is high. The acid and alkaline death points for pond fish are approximately pH 4 and pH 11 respectively.

The pH will vary in pond environment depending on a number of factors as follows

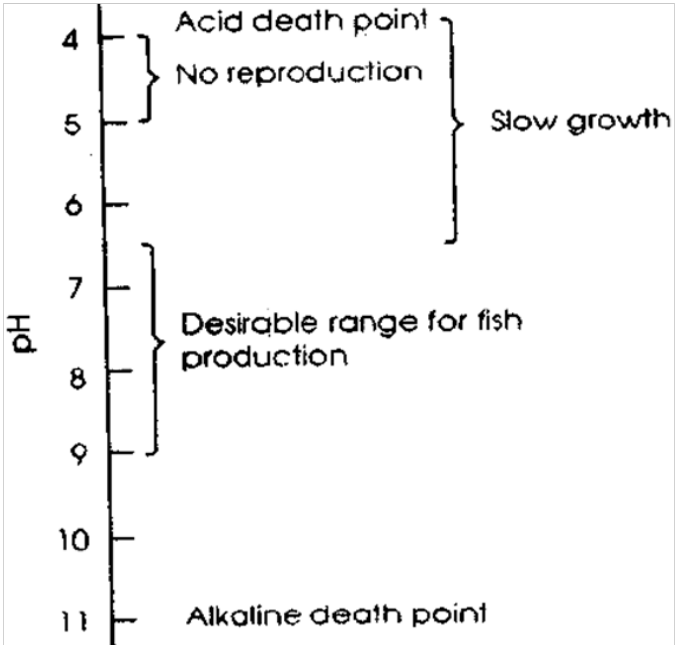
- Acid sulfate soil, acidic source of water
- Rate of rainfalls in pond areas
- Poorly buffered water

- Stocking density of resources
- Feeding and rate of sludge formation in pond bottom.
- Presence of micro/ macro organisms.
- Existence of phytoplankton in pond water.
- Rate of carbon dioxide production in pond water

How to measure pH

pH of water is measured with a pH meter. When the electrodes are dipped in two solutions of different pH levels and connected, a potential difference is set up between the two electrodes, which is measured by the potentiometer. This is directly related to the pH of the solution.

In the laboratory, a bench top pH meter is used to measure pH. For field measurement of water pH, portable pH meters can be used (Fig. 6).



Dissolved Oxygen (DO)

It is an important parameter in assessing water quality because of its prime impact on the living organisms living in the water. The dissolved oxygen level that is too low or too high can harm aquatic life and affect water quality.Free oxygen (O2), is oxygen that is not bonded to any other element. Dissolved oxygen is this free gaseous oxygen(O2) dissolved in the waterand remain within water.

In a water body, the source of DO is mainly the atmospheric diffusion and photosynthetic activity. When photosynthesis exceeds respiration DO is more. The solubilityof oxygen decreases with increased temperature and salinity. As depth increases DO will decrease. In shrimp farming, dissolved oxygen levels at the bottom is important, since shrimp spend a lot of time at the pond bottom. The desirable concentration of dissolved oxygen in water for fish is >5 mg per litre . As mentioned before, for dissolved oxygen analysis, the samples need to be fixed by adding Winkler's reagent on board vessel /site itself. Surface and bottom water samples are to be collected separately for the near shore and offshore. The processing protocol should be meticulously followed for individual samples.

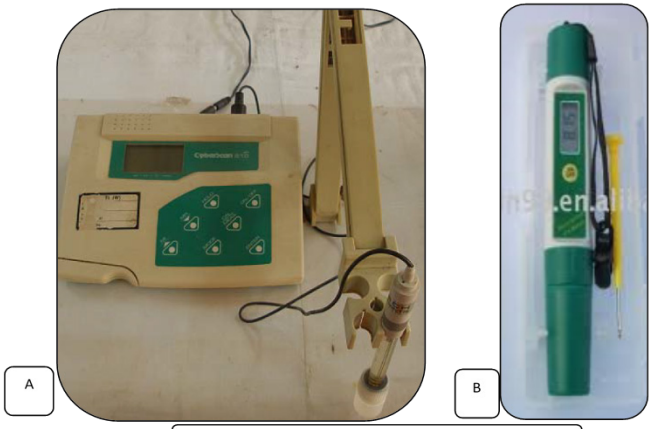
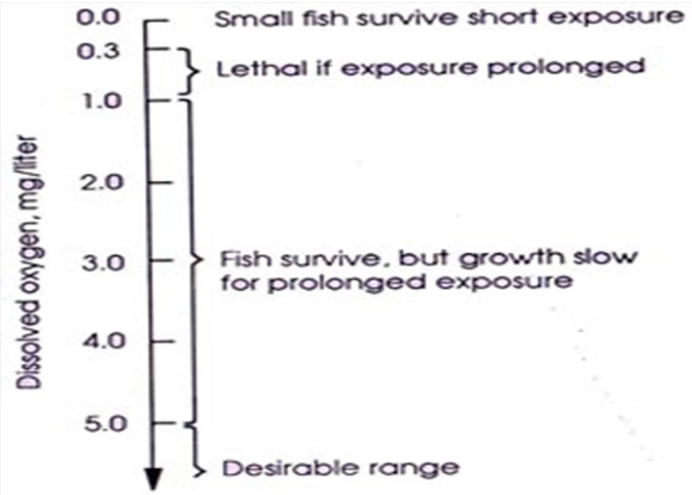


Fig.6 A. Bench top pH meter B. Portable pH meter

The commonly used method of estimation of dissolved oxygen is by Winkler titration method. In this methodology, the oxidation of manganous dioxide (bivalent manganese) by the oxygen dissolved in the sample results in the formation of a tetravalent compound. When the water containing the tetravalent compound is acidified free iodine is liberated from the oxidation of potassium iodide. The free iodine is chemically equivalent to the amount of dissolved oxygen present in the sample and is determined by titration with a standard solution of sodium thiosulphate.

Carbondioxide

The level of CO2 in the water varies with the respiratory and photosynthetic activity of animals and plants in the water body, the level of decomposition of organic material in that water (a significant supplier of CO2 in nutrient-rich waters), and the respiration of the fish themselves. Concentration of CO2 can rise to considerably high levels in systems with large numbers of fish and comparativelyslow water turnover.



How to measure CO2

Free CO2 in natural water is determined by titration with sodium carbonate Na2CO3 to form NaHCO3. Development of pink colour using phenolphthalein indicator in the natural water shows the absence of CO2 in the sample. The water sample is collected without allowance for bubbles.in a DO bottle and is tightly closed. In the laboratory, an amount of 50 ml of this sample water is transferred to a conical flask, carefully, without bubbling and 2-3 drops of phenolphthalein is added. If the water turns to pink then there is no free CO2 in water sample. If the sample remains colourless, it is titrated with standard Na2CO3 solution. The end point is the permanent appearance of the pink colour. Favorable range of CO2 in water is<5mg per litre.

Total Alkalinity and Hardness

Total alkalinityrepresents the quantity ofbasic anions present in water bicarbonates, carbonates, phosphates, hydroxides, etc. Alkalinity measures the total amount of base present in water and indicates the ability of a water body to resist large changes in pH. In other words alkalinity shows the buffering capacity of the water body. Alkalinity is expressed as mg per litre CaCO3. The total alkalinity concentration should not be lower than 20 mg per litre CaCO3 in production ponds.

The desired total alkalinity level for most aquaculture species lies between 50-150 mg per litre CaCO3 It can be estimated by titrating the water sample with strong H2SO4, first to pH 8.3 using phenolphthalein as indicator and then further to pH between 4.2 and 5.4 with methyl orange. Hardness is another significant water quality aspect foraquaculture management. Hardness represents the overall concentration of divalent salts (calcium, magnesium etc.). Calcium and magnesium are the most common sources of water hardness. Calcium and magnesium are essential in the biology (bone and scale formation in fish) of aquatic life.

Calcium is the critical component of total hardness is the

calcium concentration, as environmental calcium is crucial for maintaining exact levels of internal salts for normal heart, muscle and nerve function. An appropriate range of hardness is between 75 and 200 mg per litre CaCO3. Alkalinity and hardness are reasonably stable but can change over time, usually during weeks to months, depending upon the pH or mineral content of bottom soils.

Decomposition of Organic matter

In aquaculture, different kinds of organic and inorganic compounds (e.g. formulated food, manures, and fertilizers) are added to the water body to increase fish production. But, a large part of these inputs are not utilized by the fish and are decomposed / disintegrated in the water. The microbiological decomposition of the organic matter is a critical factor for water quality control and nutrient recycle.

Aerobic decomposition of organic matter is an important drain of oxygen supplies in water. Many factors affect this decomposition. Aerobic decomposition of organic matter takes place with the help of aerobic microorganisms.

The temperature optima of microorganisms differ among microbial species, but the rateof decomposition generally increase over the range of 5 to 35°C. A temperature increase of10°C often doubles the rate of decomposition and oxygen consumption.

The pH preferences of different microorganisms also differ. Bacteria grow best inneutral to slightly alkaline habitats while fungi prefer acid environments.

Generally organic matter is degraded faster in neutral to alkaline systems than in acid systems.

Aerobic decomposition requires a continuous supply of oxygen and proceeds more rapidly whendissolved oxygen concentrations are near saturation.

Anaerobic decomposition of organicmatter takes place with the help of anaerobic microorganisms.

The rate of degradation oforganic matter is not as rapid under anaerobic conditions as under aerobic conditions.

The end products of anaerobic decomposition are alcohols, organic acids etc. whereas CO2 is the end product of aerobic decomposition.

The decomposition of organic matter varies with the type of carbonaceous material to be decomposed. Some organic compounds are more resistant to decay than others. For example sugar is decomposed faster than cellulose and cellulose faster than lignin.

The C/N ratio of organic matter has been widely used as an index of the rate at which organic matter will decompose. Organic matter with a wider C/N ratio will decompose much slower than organic matter with a narrow C/N ratio.

Oxidation Reduction Potential

Oxidation reduction potential (ORP) is a measure of the proportion of oxidized to reduced substances in water. It is also known as Eh.

It is measured with respect to Hydrogen electrode, using an ORP meter (Fig 7).

Eh range of natural waters 0.45 – 0.52 V

Appearance of Fe++ ion at 0.2 V coincides with depletion of oxygen

Total Ammonia Nitrogen

In aquatic system the ionized ammonia (ammonium ie., NH4+) is less toxic but unionized ammonia (NH3) is highly toxic to aquatic life. Together, ammonium and ammonia is known as total ammonia nitrogen (TAN).

Toxicity of TAN increases with increased pH and temperature. The sources of TAN are organic mineralization, fish feed and direct

excretion from fishes. The oxidation of ammonia by nitrifying bacteria will provide the bioavailable forms NO2 and NO3 to the aquatic life.

Increased TAN will affect fish health and the major symptoms includeincreased oxygen consumption, damage of gills, histological changes, susceptibility to disease, reduced growth and the toxicity may lead to death.

Aquatic autotrophs rapidly utilize ammonium ions, thus naturally preventing it from increasing to toxic levels. The total ammoniacal N content of water is an index of the degree of pollution. Its concentration in unpolluted water should never be more than 0.1 mg per litre.

The TAN in water is measured making use of a spectrophotometer, using phenol hypochlorite method.

In this method phenol and hypochlorite react in an alkaline solution to form phenyl quinone-monoimine, which in turn, react with ammonia to form indophenol.

Indophenol gives the solution a blue colour, the intensity of which is proportional to the concentration of ammonia present in the sample.

Sodium nitroprusside is added to intensify the blue colour. Both ammonia and ammonium are measured, because in a strong alkaline solution all the ammonium is converted to ammonia. This procedure gives an estimate of total ammonia nitrogen.

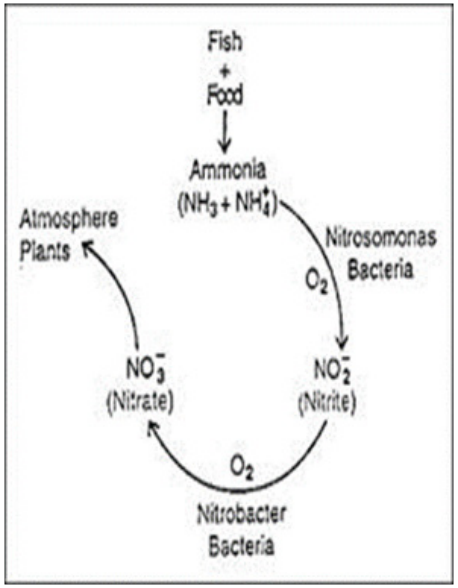
Fig. 7 Portable ORP meter

Nitrite N

Nitrite N originates as intermediary product of nitrification of ammoniacal N

The concentration of nitrite N in water should not exceed 0.5 mg per litre.

Nitrite N is toxic to fish and shrimp because it forms methemoglobin, affects immune and circulation systems, and reduces the transfer of oxygen to cells.



High chloride concentration reduces nitrite toxicity and so nitrite toxicity is less in brackish water.

To measure nitrite, the nitrite in water is allowed to react with sulphanilamide in an acid solution.

The resulting diazo compound further reacts with NNED and forms a highly colored azo dye, the absorbance of which is measured spectrophotometrically.

Nitrate N

It is the end product of nitritication of ammoniacal nitrogen by aerobic autotrophs. The favorable range of nitrate in culture waters is 0.1 mg/l to 4.5 mg/l. Its higher concentrations may lead to inability to swim and reduced movement.

The estimation of nitrate N in water is based on a method of reduction of nitrate to nitrite and then estimating the nitrite through spectrophotometrically.

Nitrate in water is reduced almost quantitatively to nitrite when the sample is passed through a column containing cadmium filings coated with metallic copper (Fig. 8).

Dissolved inorganic phosphorus

Phosphorous is a limiting nutrient needed for the growth of aquatic plants and algae alike. Excess concentrations of P can result in algal blooms.

An algal bloom is a rapid increase in the population of algae in an aquatic system. It can occur in green, yellow- brown or red in colour (Fig. 9).

Algal bloom is caused by an imbalance of nutrients in an aquatic system (P and N mainly)

For coastal waters the dissolved inorganic phosphorus (DIP) should not exceed 0.05 mg per litre and dissolved inorganic nitrogen (DIN) should not exceed 0.5 mg per litre.

Harmful Algal Blooms(HAB) causes negative impacts to aquatic organisms via production of natural toxins, mechanical damage etc.

Dissolved Orthophosphate can be determined by Ascorbic acid method. Ammonium molybdate and potassium antimony tartrate react in an acid medium with dilute solutions of orthophosphate to form phosphomolybdic acid that is reduced to the intensely coloured molybdenum blue by ascorbic acid.

The intensity of the blue colour increases in proportion

to the amount of phosphorous present and can be measured spectrophotometrically.

Hydrogen sulfide (H2S)

Hydrogen sulfideis a toxic, colorless gas with the distinctive foul smell of rotten eggs. It is formed in anaerobic situations (by transformation of sulfate to sulfide).

Its toxicity increases with decreasing dissolved oxygen and decrease in pH.

It is toxic above 0.1 µg per litre,that means detectable concentrations of hydrogen sulfide is undesirable for aquaculture.

H2S can be eliminated from ponds by the use of aeration or KMnO4 (potassium permanganate) to oxidizethe hydrogen sulfide into non-toxic sulfur compounds.

The occurrence of hydrogen sulfide can be identified by its stinking odor of rotten eggs.

For verification of presence of hydrogen sulfide, add 0.5 ml of

Fig. 9 Algal blooms

saturated solution of potassium antimony tartrate and 0.5 ml of 6N hydrochloric acid to 200 ml of water sample and shake well. The yellow colour of antimony sulfide is a positive test for sulfide.

Water quality sampling frequencies for various aquaculture systems

Sampling for water quality assessment in different aquaculture systems can be done at frequent intervals as shown in Table 2.

Table 2. Water quality sampling frequencies for various aquaculture systems

Type of system	Sampling frequency			Remaks
	Twice daily	Daily	Weekly	
Brackish water				
Low density		DO, salinity. Temperature	NH3, pH, Secchi disc	DO - early morning and next day late evening
High density	DO, pH, Temperature	Salinity, NH3, CO2, Secchi disc, Alkalinity	NO2, Hardness, H2S	DO - early morning and once in the late evening
Fresh water				
Low density		DO, Temperature	NH3, pH, CO2	DO - early morning and next day late evening
High density	DO, pH, Temperature	CO2, Secchi disc. Alkalinity	NO2, Hardness, H2S	DO - early morning and once in the late evening
Hatchery				
Brackish water	DO, NH3, pH, Temperature	NO2, Salinity, Alkalinity, Hardness	H2S	DO,pH - once in the morning and once in the evening
Fresh water	DO ,pH	NO2, NH3, Alkalinity, hardness	H2S	

Water Quality Parameters - Problems and Corrective Methods

Frequently encountered water quality problems and their corrective measures are given in Table 3.

Table 3 Water Quality Parameters - Problems and Corrective Methods

Parameter	Problem	Cause	Effect	Optimal level	Corrective measure	Visible indication
Salinity	Fluctuations	Dilution & Evaporation	Stress	0.01-1 ppt for fresh water species and 20 - 35 ppt for euryhaline species	Water exchange	Hyper activity Mucous on body
Dissolved oxygen	Hypoxia	High organic matter load Plankton blooms Overstocking Overfeeding	Mortality Lethargy	4 -5 mg/1 for warm water fishes and 5-6 mg/1 for cold water fishes	Aeration Water exchange	Gasping at the surface Mucous accumulation on gills
CO2	Buildup of CO2 concentration in water	Over stocking Uptake of ground water rich in CO2 Plankton blooms	Prolonged exposure leads to mortality	<5 mgL-1	Water exchange/ Aeration	Gasping at the surface. Mucous on gills
Ammonia	Buildup of NH3 and NH4+- concentration in water	Overstocking Decomposition of excess feed Use of ground water rich in ammonia Agricultural runoff rich in ammoniacal fertilizers	Mass mortality			

Nitrite	Nitrite poison-ing	Over-stocking Poor nitri-fication Decom-position of excess feed Algal blooms Faulty biofilters	Methe-mo-glo-bine-mia	Methemo-glo-bine-mia	Aeration Water exchange	Hypoxia Lethargy
Nitrate	Nitrate poison-ing	Poor nitrogen recycling Decom-position of organic matter Use of ground water rich in NO3	Toxic only on pro-longed exposure	0.1 to 4.5 mg/l	Water exchange	Reduced move-ments
Hy-drogen sulfide	Hy-drogen sulphide toxicity	Decom-position of excess feed High organic load	Instant mortality	<0.1 µg/l	<0.1 µg/l	Gasping at the surface
pH	Acidosis and alka-losis	Acid sulphate soils Agricul-tural run off Excessive use of lime	Mass mortality	6.5 – 9.0	Use of lime or gypsum as the case may	

Water quality monitoring and management is essential for the smooth functioning of the aquaculture enterprises and a basic knowledge about all the above mentioned water quality parameters isa necessary pre requisite for its effective,

sustainable and profitable implementation.

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