Winter School on

'RECENT ADVANCES IN DIAGNOSIS AND MANAGEMENT OF DISEASES IN MARICULTURE'

7th to 27th November, 2002

Course Manual

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WATER AND SEDIMENT QUALITY MANAGEMENT IN AQUACULTURE

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1. Water Quality

Water Quality in aquaculture encompasses all physical, chemical and biological variables that affect aquaculture production. The aquatic environment is a complex dynamic system. It is subject to constant physicochemical changes due to natural causes and man's activities. The slightest deviation from the optimal level may result in stress to the cultured organisms. Stress elicits a series of physiological and behavioral responses in the organisms. If prolonged, the stress may lead to poor growth, reproductive failures besides rendering them susceptible to diseases. Most pond management procedures are aimed at improving the water quality.

1.1 Factors affecting water quality

1.1.1 Turbidity

Part of the light (solar radiation) striking pond water does not penetrate the surface. A portion is reflected depending on the roughness of the water surface and the angle of radiation. As light passes through water, scattering and differential absorption by the water takes place. Turbidity refers to the decreased ability of water to transmit light caused by suspended particulate matter ranging in size from colloidal to coarse dispersions. In ponds, turbidity and color may result from colloidal clay particles, from colloidal or dissolved organic matter or from an abundance of plankton.

Photosynthesis cannot proceed at rates exceeding respiration at depths where light intensity is less than 1% of the light striking the water surface. The stratum of water receiving 1% or more of incident radiation is termed as euphotic zone. The depth of Secchi disk visibility multiplied by 2 gives a good estimate of depth of euphotic zone in fish ponds. The Secchi disk 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 depths 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 is affected 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 must decide if the turbidity is from phytoplankton or suspended soil particles or both. The following scheme may be used in evaluating Secchi disk visibilities.

Secchi disk reading (cm)	Comments

< 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.

1.1.2 Temperature

In general, air temperature is related closely to solar radiation. The more the solar radiation, the warmer the atmosphere. Water temperature in ponds is related to solar radiation and air temperature. 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. The density of water is dependent upon water temperature. Ponds and lakes may stratify thermally because the warm upper waters are less dense than cool lower waters. Aquaculture ponds are often relatively small and quite shallow and stratification is not as stable in them as in larger water bodies. Water temperature should be congenial for aquatic organisms as it affects their metabolism. Species, which exhibit maximum growth rates at prevailing water temperature, are to be selected for aquaculture in a particular location.

1.1.3 Salinity

The term salinity refers to the total concentration of all ions in water. The seven major ions that contribute most to salinity are sodium, potassium, calcium, magnesium, chloride, sulfate and bicarbonate. The salinity of pond water in inland areas depends upon geologic and climatic factors. Higher evaporation in arid regions tends to concentrate ions and higher salinities result in pond waters. Ground waters will have higher salinity. In brackish water ponds, the salinity of water varies with the salinity of estuaries which serve as water supplies. 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.

1.1.4 pH

The negative logarithm of hydrogen ion activity in water can affect the water quality. Most natural waters have a pH range between 5 and 10. The pH of natural waters is greatly influenced by the concentration of CO_2, an acidic substance. When CO_2 is removed, water pH is raised and when CO_2 is dissolved, water becomes acidic. Because of photosynthesis by aquatic vegetation including phytoplankton, pH of water body rises during the day and decrease during the night (CO_2 is removed during photosynthesis).

Waters with pH values between 6.5 – 9 at daybreak are considered best for fish production. Ponds which receive drainage from acid soils and swamps are too acidic for fish production. The acid and alkaline death points for pond fish are approximately pH 4 and pH 11 respectively.

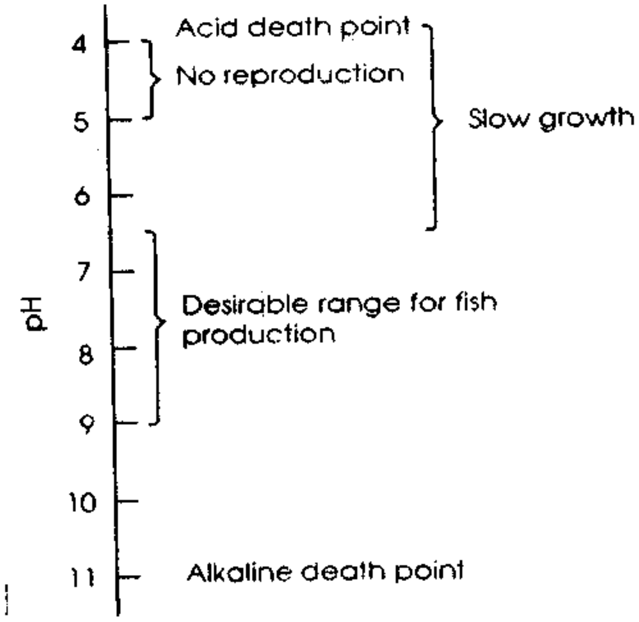

Fig. 1. Effect of pH on fish

Gill tissue is the primary target organ of acid stress. When fish are exposed to low pH, the amount of mucus on gill surfaces increases. Excess mucus interferes with the exchange of respiratory gases and ions across the gill. This results in failure of blood acid – base balance leading to respiratory stress causing osmotic disturbance due to decreased blood concentration of sodium chloride. At low pH in water, aluminum ion concentration increases in water and toxicity due to aluminum is also an after effect of low pH.

1.1.5 Carbon dioxide

Carbon dioxide is highly soluble in water. Greater the CO_2 content, lower the water pH. The CO_2 content of water is usually a function of biological activity. When respiration is proceeding much faster than photosynthesis, CO_2 accumulates. Therefore, pond waters usually are saturated with CO_2 in the early morning.

High concentrations of CO_2 have a narcotic effect on fish and even higher concentrations may cause death. If external concentration of CO_2 is high, there is decrease in rate of loss of CO_2 from gills by diffusion. Thus CO_2 accumulates in the blood and lower blood pH causing detrimental effects. High concentrations of CO_2 interfere with the loading of haemoglobin in fish blood with oxygen.

For good fish population, ponds should contain less than 5 mg/l free CO_2.

1.1.6 Total alkalinity and total hardness

The total concentration of titratable bases in a water expressed as equivalent calcium carbonate is referred to as total alkalinity. Bicarbonate, carbonate, ammonia, hydroxide, phosphate and silicate can react to neutralize hydrogen ions and so these substances are all bases and contribute alkalinity to water. However, in waters used for aquaculture, bicarbonate or carbonate or both usually are responsible for essentially all the measurable alkalinity. Ponds with lower total alkalinity values were in regions with sandy soils, while ponds with the higher alkalinity values were in regions with clay or loam soils which often contained calcium carbonate. High alkalinity values were often seen in waters of arid regions. Most organically stained waters had low alkalinity.

The dissolution of limestone is a major source of alkalinity in natural waters. Limestones are carbonates of calcium and magnesium. Therefore, the milliequivalents per litre of calcium plus magnesium often are similar to the milliequivalents per litre of bicarbonates plus carbonate in natural waters. Concentration of Ca and Mg as equivalent of $CaCO_3$ usually has been taken as a measure of total hardness.

When pH in a culture pond goes below 6.5, liming is done so as to raise the total alkalinity and total hardness of water to 20 mg/litre or more.

1.1.7 Dissolved Oxygen

If air is in contact with water, oxygen will enter the water from the air until the pressure of oxygen in water is equal to the pressure of oxygen in the air. The solubility of oxygen in water decreases as water temperature increases and as salinity increases.

Although, oxygen can diffuse between air and water, biological processes are more important than physical processes in regulating dissolved oxygen concentrations in pond water. In ponds where, photosynthesis is progressing more rapidly than respiration, CO_2 concentrations will be low and dissolved oxygen concentrations will be high. This is the usual situation when light intensity is relatively high and plants are abundant. If respiration exceeds photosynthesis dissolved oxygen concentrations will decline and CO_2 concentrations will increase. This normally occurs during night in pond waters.

Oxygen evolution by phytoplankton is greatest near the surface and decreases with depth because of self shading. Ponds with high densities of phytoplankton have higher rates of oxygen production near the surface than do ponds with less phytoplankton. The depth at which oxygen is produced by photosynthesis just equals oxygen used in respiration is called the compensation point and corresponds to the depth of euphotic zone. If benthic macrophytes are available in the pond, the pond bottom is saturated with oxygen during daylight hours.

During daylight hours, photosynthesis in the euphotic zone usually releases oxygen faster than it is used in respiration. Photosynthesis stops at night, but respiratory processes continue to use oxygen. This pattern of daytime production and continuous use of oxygen during night leads to diel fluctuations of dissolved oxygen in the euphotic zone (Fig.2). Maximum concentrations of dissolved oxygen occur during the afternoon and minimum concentrations at or just after sunrise.

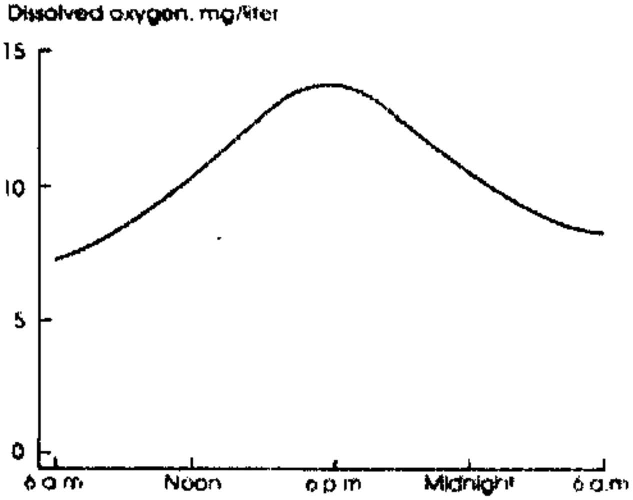

Fig. 2. Diel fluctuation of dissolved oxygen in the surface water of fish pond

In shrimp farming, dissolved oxygen concentrations at the pond bottom are important, because shrimp spend a lot of time on the pond bottom. Studies of dissolved oxygen concentrations in shrimp ponds in Ecuador revealed that dissolved oxygen concentrations in waters of shrimp ponds exhibited a similar diel pattern at both surface and at the bottom (Fig.3). Light intensity at pond bottom is less than that at pond surface, and dissolved oxygen concentrations are higher at surface than at the bottom.

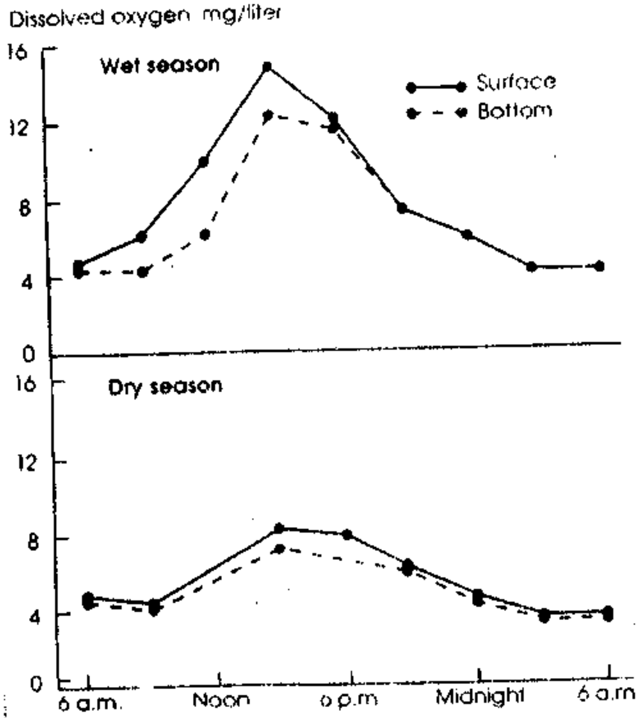

Fig.3. Diel fluctuations of dissolved oxygen in surface and bottom waters during wet and dry seasons of brackish water fish ponds in Ecauador

Swingle (1969) studied the effect of dissolved oxygen concentration on warm water pond fishes and arrived at the following conclusions

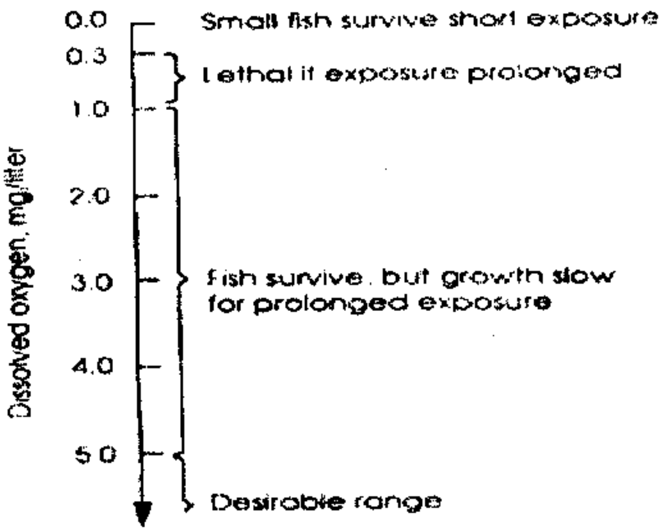

Fig. 4. Effect of dissolved oxygen on pond fish

1.1.8 Decomposition of organic matter

Aerobic decomposition of organic matter is an important drain of oxygen supplies in ponds. 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 species, but rate of decomposition generally increase over the range of 5 to 35°C. A temperature increase of 10°C often doubles the rate of decomposition and oxygen consumption.

The pH preferences of different microorganisms also differ. Bacteria grow best in neutral to slightly alkaline habitats while fungi flourish in 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 when dissolved oxygen concentrations are near saturation. Anaerobic decomposition of organic matter takes place with the help of anaerobic microorganisms. The rate of degradation of organic matter is not as rapid under anaerobic conditions as under aerobic conditions. The end products of anaerobic decomposition are alcohols, organic acids etc. where as CO_2 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.

1.1.8.1 BOD (Biological Oxygen Demand)

BOD is the amount of oxygen taken up by microorganisms that decompose organic waste matter in water. It is used as a measure of certain types of organic pollutants (toxic organic acids and alcohols) in water. For water to be considered as unpolluted, its BOD should be less than 15 mg/l.

1.1.8.2 COD (Chemical Oxygen Demand)

The COD of water represents the amount of oxygen required to oxidize all the organic matter, both biodegradable and non biodegradable by a strong chemical oxidant. If nonbiodegradable organic matter (eg. Coal dust, saw dust etc.) is present, then COD > BOD. Ratio of BOD to COD varies widely and it cannot be predicted for water. Generally for unpolluted water, COD should not exceed 70 mg/l.

1.1.9 Oxidation – Reduction Potential

The oxidation – reduction potential or redox potential is a measure of the proportion of oxidized to reduced substances. In practice, the redox potential is measured with respect to hydrogen electrode and is called Eh. Eh of oxygenated natural waters ranges from 0.45 to 0.52 volt. A change in Eh of 0.059 volt occurs per unit change in pH. This exchange is negative for pH values below 7 and positive for values above 7. As long as dissolved oxygen is present, the redox potential remains at about 0.5 volt but once dissolved oxygen is depleted Eh drops rapidly. Various reduced substances appear in water at specific Eh. Nitrite appears at about 0.34 volts, ferrous iron is detected at about 0.2 volts and H_2S is found at about 0.1 volt. The appearance of Fe^{++} coincides closely with depletion of dissolved oxygen.

1.1.10 Ammonia N

Ammonia is the most toxic form of inorganic N produced in pond water. The major source of ammonia in pond water is the direct excretion of ammonia by fish. It also originates from the mineralization of organic matter by heterotrophic bacteria and as a by-product of nitrogen metabolism by most aquatic animals. Both ammonia (NH_3) and (NH_4^+) are toxic, but NH_3 is much more toxic than NH_4^+. Ammonia toxicity increase as the pH and temperature increase.

The 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/l and below this level, healthy growth of fish is expected. Aquatic autotrophs rapidly utilize ammonium ions , thus naturally preventing it from increasing to toxic levels.

As ammonia concentration increases in water, ammonia excretion by fish decreases and levels of ammonia in blood and other tissues increase. This results in an elevation of blood pH which adversely affects enzyme catalyzed reactions and membrane stability. High ammonia concentrations in water also affect the permeability of fish and reduce internal ion concentrations. Ammonia also increases oxygen consumption by tissues, damages gills and reduces the ability of blood to transport oxygen. Histological changes occur in kidneys, spleen, thyroid and blood of fish exposed to sublethal concentrations of ammonia. Chronic exposure to ammonia increases susceptibility to diseases and reduces growth.

1.1.11 Nitrite

It originates as an intermediary product of nitrification of ammoniacal N by aerobic bacteria. Nitrite N concentration in culture water should not exceed more than 0.5 mg/l as its higher concentration results in methaemoglobin production, which is incapable of transporting oxygen.

Brackish water has high concentration of chloride, which tend to reduce nitrite toxicity. Sublethal concentrations of nitrite increase the susceptibility of fish to diseases.

1.1.12 Nitrate

Nitrate is not acutely toxic to aquatic animals even in large concentrations. It is the end product of nitrification 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.

1.1.13 Hydrogen sulfide

Hydrogen sulfide is extremely soluble in water. It is formed in some anaerobic aquatic situations by transformation of sulfate to sulfide.

It inhibits the re-oxidation of cytochrome a3 by molecular oxygen. This blocks the electron transport system and stops oxidative respiration. Blood lactate concentration also increases and anaerobic glycolysis is favored over aerobic respiration.

Hydrogen sulfide toxicity increase with decreasing dissolved oxygen concentrations. Percentage of total sulfide present as H_2S increases as the pH decreases. Hence H_2S toxicity is more in acidic environments.

Un-dissociated forms of H_2S become toxic at concentration above 2 μg/l for fish and other aquatic life, both in fresh and marine water. Concentrations of H_2S of 0.01 to 0.05 mg/l are lethal to fish and any detectable concentration of H_2S in pond water is considered undesirable.

1.1.14 Methane

It is the prominent constituent of some waters. Owes its origin largely to anaerobic decomposition of plant and animal origin. In aquaculture water, it should be absent. It becomes toxic to culturable organisms even at the level of 0.1μg/l.

1.1.15 Chlorine

Both free and combined residual, available chlorine are extremely toxic to fish. If measurable concentrations of chlorine residuals are present in water, the water should not be considered safe for aquaculture.

1.1.16 Heavy metals

Originates from industrial pollution. The toxicity of heavy metals is related to the dissolved ionic form of the metal rather than total concentration of the metal.

Table 1. Toxicity of selected heavy metals to aquatic life

Metal	**96 hr LC 50 (µg/l)**	**Safe level (µg/l)**
Cadmium	80 – 420	10
Chromium	2000 - 20000	100
Copper	300- 1000	25
Lead	1000 - 40000	100
Mercury	10 – 40	0.10
Zinc	1000 - 10000	100

1.1.17 Pesticides

Pesticides from agricultural crops and soils enter run off and reach culture ponds. Acute toxicity values for many commonly used insecticides range from 5 to 100 µg/l. Much lower concentrations may be toxic upon longer exposure. Even if adult fish are not killed outright, long term damage to fish populations may occur in environments contaminated with pesticides. The abundance of food organisms may decrease, fry and eggs may die, and growth rates of fish may decline. Chlorinated hydrocarbons have greatest potential for harming shrimp and fish.

Table 2. Toxicity of selected chlorinated hydrocarbon insecticides to aquatic life

Pesticide	**96 hr LC 50 (µg/l)**	**Safe level (µg/l)**
Aldrin/Dieldrin	0.2 to 16	0.003
BHC	0.17 to 240	4.000
Chlordane	5 to 3000	0.010
DDT	0.24 to 2	0.001
Endrin	0.13 to 12	0.004
Heptachlor	0.10 to 230	0.001
Toxaphene	1 to 6	0.005

Table 3. Water Quality parameters – Problems and Corrective methods

Parameter	***Problem***	***Cause***	***Effect***	***Optimal level***	***Corrective measures***	***Visible indication***
Salinity	Fluctuations	Dilution Evaporation	Stress	0.01–1 ppt for fresh water species and 20 – 35 ppt for euryhaline species	Water exchange	Hyperactivity Mucous on body
Dissolved oxygen	Hypoxia	High organic matter load Plankton blooms Overstocking Overfeeding	Mortality Lethargy	4 –5 mg/l for warm water fishes and 5-6 mg/l for cold water fishes	Aeration Water exchange	Gasping at the surface Mucous accumulation on gills
CO_2	Build up of CO_2 concentration in water	Over stocking Uptake of ground water rich in CO_2 Plankton blooms	Prolonged exposure leads to mortality	<5 mg/l	Water exchange Aeration	Gasping at the surface. Mucous on gills
Ammonia	Build up of NH_3 and NH_4^+ concentration in water	Overstocking Decomposition of excess feed Use of ground water rich in ammonia Agricultural run off rich in ammoniacal fertilizers	Mass mortality	Total ammonia concentration <0.1 mg/l	Practice low density culture Immediate aeration Water exchange Use of biofilters	Gasping at the surface Increased mucous on gills Hyperactivity Gill blisters

Parameter	***Problem***	***Cause***	***Effect***	***Optimal level***	***Corrective measures***	***Visible indication***
Nitrite	Nitrite poisoning	Overstocking Poor nitrification Decomposition of excess feed Algal blooms Faulty biofilters	Methemoglo-binemia	<0.5 mg/l	Aeration Water exchange	Hypoxia Lethargy
Nitrate	Nitrate poisoning	Poor nitrogen recycling Decomposition of organic matter Use of ground water rich in NO_3	Toxic only on prolonged exposure	0.1 to 4.5 mg/l	Water exchange	Reduced movements
Hydrogen sulfide	Hydrogen sulphide toxicosis	Decomposition of excess feed High organic load	Instant mortality	<0.1 µg/l	Aeration Water exchange	Gasping at the surface
pH	Acidosis and alkalosis	Acid sulphate soils Agricultural run off Excessive use of lime	Mass mortality	6.5 – 9.0	Use of lime or gypsum as the case may be	

Table 4 . Water quality sampling frequencies for various aquaculture systems

Type of system	Sampling frequency			Remaks
	Twice daily	Daily	Weekly	
Brackish water 1.Low density	--	DO, salinity, temperature	NH_3, pH, Secchi disc	DO – early morning and next day late evening
2.High density	DO, pH, Temperature	Salinity, NH_3, CO_2, Secchi disc, Alkalinity	NO_2, Hardness, H_2S	DO – early morning and once in the late evening
Fresh water 1.Low density	--	DO, Temperature	NH_3, pH, CO_2	DO – early morning and next day late evening
2.High density	DO, pH, Temperature	CO_2, Secchi disc, Alkalinity	NO_2, Hardness, H_2S	DO – early morning and once in the late evening
Hatchery 1.Brackish water	DO, NH_3, pH, Temperature	NO_2, salinity, Alkalinity, hardness	H_2S	DO,pH – once in the morning and once in the evening
2. Fresh water	DO, pH	NO_2, NH_3, Alkalinity, hardness	H_2S	

2. Sediment Quality

Bottom soils of ponds are called pond soils, muds and sediments. Sediment quality is one of the key factors for the success of aquaculture. The physical and chemical characteristics of pond water are very much influenced by the properties of bottom sediments. The bottom sediments provide food and shelter for the benthic organisms and also act as a reservoir of nutrients for the growth of benthic algae which constitute food for aquatic organisms. The sediment also functions as a buffer and governs the storage and release of nutrients into the water. It serves as a biological filter through the adsorption of organic residues of food, excretory products and algal metabolites. The sediment holds high bacterial load which helps in decomposition and mineralization of organic deposits at the bottom. The nature and decomposition of pond sediment have important role on the balance of coastal aquaculture systems and in determining the fertility of culture ponds and consequently on the growth and survival of fishes and other aquatic organisms.

The sediment quality of brackish water ponds is periodically likely to be altered by tidal influence and consequent churning process. Inorganic and organic nutrients present in the tidal water are in different forms and in varying concentrations and major quantities get deposited at the pond bottom by way of physico-chemical processes of sedimentation. Bio-geochemical processes undergoing in the bottom sediments tend to release nutrients into the water by bacterial action on the sediments. Organic cycling in shallow brackish water ponds is governed by the rate of conversion of living tissues into detritus and secondarily the rate of conversion of detritus into dissolved organic and inorganic forms of nutrients of which the former is faster in the primary and secondary levels resulting in accumulation of organic detritus at the bottom.

2.1 Factors affecting sediment quality

2.1.1 Sediment texture

Sediment texture is the relative proportion of size of the mineral particles (sand, silt and clay). An ideal pond for aquaculture should not be too sandy to allow much leaching of nutrients, nor should it be too clayey to keep all nutrients adsorbed on it. Ponds having sandy loam to silty clay texture are fairly good in productivity on aquaculture point of view.

2.1.2 Sediment colour

Soils exhibit a wide range of color and when covered with water they often develop darker shades of the original colors. A brown crust at the soil-water interface in a pond is a good sign, since it indicates that there is dissolved oxygen at the interface. A jet black color at the soil-water interface is undesirable since it reveals the absence of dissolved oxygen. When dissolved oxygen is depleted in the surface layer, compounds of ferrous iron form to produce black color. In most pond bottoms, a jet black layer will occur a few centimeters below the mud surface. Hydrogen sulfide is produced only in highly reduced black muds, but not all black muds are sufficiently reduced to produce H_2S.

Sometimes reddish precipitates can be seen on the bottom in shallow ponds. This is more common in acidic ponds and ponds with acid sulfate soils. In ponds with acid sulfate soils yellow deposits of mineral jarosite and even of sulfur often may be seen interspersed with the reddish iron deposits.

2.1.3 Sediment pH

Weak alkaline soil reaction (pH 7-8) had been found in most productive fish ponds. Culture systems with acidic soils are generally less productive than with alkaline soils. Banerjea (1967) classified pond muds of various pH into different status of potential for fish production of which pH values between 6.5 and 7.5 were considered as highly productive.

2.1.4 Organic Carbon

Organic carbon is the most important factor determining the fertility status of soil. Organic carbon content originates in sediment due to the presence of organic matter. Organic matter contains 58% carbon. The soil organic matter binds soil particles which help the soil to maintain favorable conditions to facilitate aeration and permeability. It increases the water-holding capacity of soil and serves as a reservoir of the chemical elements that are essential for aquatic productivity. It helps in reducing soil alkalinity and acts as a buffer against rapid changes in pH. It serves as a source of energy for the growth of soil microorganisms and helps in dissolving minerals to be absorbed by the growing plants and animals. Positive correlation between fish production and organic carbon has been reported by Banerjea(1967) and it was found that 1.5% to 2.5% of organic carbon in sediment showed high fish production potential.

2.1.5 Available nitrogen

The available form of nitrogen includes the ammoniacal N, nitrite N and nitrate N. The organic matter on mineralization is converted to ammoniacal N by heterotrophic microorganisms (ammonification), the ammoniacal N is converted to nitrite N by Nitrosomonas and the nitrite N is converted to nitrate N by Nitrobactor (nitrification). Banerjea (1967) found that pond soils having 250-750 ppm of available nitrogen showed high fish production potential.

2.1.6 Available phosphorus

The capacity of sediment to retain or release phosphorus is one of the important factors which influences the concentration of inorganic and organic phosphorus in the overlying water. The available phosphorus in brackish water ponds assumes comparatively higher value over fresh water ponds as reported by Chattopadhyay and Chakraborthy (1986) and Chattopadhyay (1978). It has been shown by Olsen (1964) that exchange of phosphorus is a very rapid process and that as and when the uptake of phosphorus in water by algae takes place, it would be followed by the release of phosphorus from the sediment. According to classification by Banerjea (1967) sediment having >60 ppm available P are highly productive.

2.1.7 Available potassium

The nature of clay mineral appeared to be main factor for the presence of high amounts of cations like potassium in soil. For productive aquaculture the sediment should contain at least 250 ppm of available potassium.

Table 5. Favorable range of sediment parameters for aquaculture

Soil texture	Sandy clay loam
Soil color	Blackish brown
pH	6.5 – 7.5
Water retention capacity of soil	40% and above
Sand	40%
Silt	40%
Clay	30%
Available N	250 to 750 ppm
Available P	60 ppm and above
Available K	250 ppm and above
Organic carbon	1.5 – 2.5%
Electrical conductivity	<16 mmhos/cm

2.2 Pond mud and fish production

Banerjea (1967) correlated pond muds with their production potential for fish or shrimp.

Variable and range		Potential for fish/shrimp production
pH	< 5.5	Low
	5.5 to 6.5	Average
	6.5 to 7.5	High
	7.5 to 8.5	Average
	> 8.5	Low
Available P	< 30 ppm	Low
	30 to 60 ppm	Average
	> 60 ppm	High
Available nitrogen	< 250 ppm	Low
	250 to 750 ppm	High
Organic carbon	< 0.5%	Low
	0.5 to 1.5%	Average
	1.5 to 2.5%	High
	> 2.5%	Low
C/N ratio	<5	Low
	5 to 10	Average
	10 to 15	High

3. Management

The management practices for proper soil and water quality retention are location specific. The practices vary in culture systems and hatchery systems. Modification of management procedure is needed to fit to a certain set of circumstances. Experimental data from a pond may not suit to another pond. Still there is a set of general management practices which are relevant for aquaculture.

3.1 **Filtration**

Filtration is the removal of impurities by passing water through a thick layer of gravel, sand, activated carbon porous layer etc. Mechanical and airlift filtration reduces the level of particulate and colloidal matter. Biofiltration removes a portion of organics in culture water by mineralization. Mechanical filter is applicable in large scale water demand. Airlift filter is applicable in small scale water demand. Biofiltration is applicable in intensive fish spawn and fry rearing systems.

3.2 **Coagulation**

Raw water with 30 mg/l turbidity can be treated by filtration without any pre-treatment. If turbidity exceeds 30 mg/l, alum can be added as per jar test method observing the optimum dose per litre of sample water. Commercial alum containing combination of $Al_2(SO_4)_3.18H_2O + Al_2(SO_4)_3.9H_2O$ is used as a coagulant. Alum reacts with natural alkalinity and produces a precipitate of $Al(OH)_3$ along with suspended or colloidal impurities due to agglomeration. So by the addition of coagulant alum, suspended impurities can be controlled.

(i) $Al_2(SO_4)_3.9H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 9H_2O + 6CO_2$

(ii) $Al_2(SO_4)_3.9H_2O + 3\ MgCO_3 \rightarrow 2Al(OH)_3 + 3MgSO_4 + 6\ H_2O + 3CO_2$

3.3 **Chlorination**

Sodium hypochlorite solution or bleaching powder ($CaOCl_2$) can be used for chlorination for disinfecting the culture water. For disinfecting, the dosage of chlorine is 1 to 5 ppm. The residual chlorine should be completely removed by aeration.

3.4 **Ozonisation**

If a lot of organic wastes are introduced into the water which cannot be removed by normal filtering or by settling tanks, ozonisation is an effective way of purification of water in hatcheries. Ozonisation not only eliminates organic components by neutralization and oxidation but also kills bacteria in the circulating water. Ozone concentrations should be in the range of 0.6 – 1.0 mg/l and contact time is 1 – 3 minutes.

The merits of ozonisation in aquaculture systems are as follows.

(i) Prevents occurrence of water borne diseases
(ii) Increases survival in packing and transport of fish and prawn seed
(iii) Reduce turbidity created by organic matter
(iv) Maintains optimum pH and dissolved oxygen
(v) Converts toxic nitrite into non toxic nitrate through oxidation
(vi) Neutralizes obnoxious gases like ammonia, H_2S, methane etc.
(vii) Favours increased growth of plankton and
(viii) Reduces BOD and COD loads to trace level

3.5 Oxidation

Low concentration of potassium permanganate (2 to 4 ppm) can be used either as an algicide or as an oxidizing agent to enhance the oxygen levels in the pond.

3.6 **Aeration**

Aeration is a proven technique for improving dissolved oxygen availability in ponds. There are many types of aerators , but propeller – aspirator – pump aerators and small paddle wheel aerators are used widely. Placement of aerator should be taken care of so that eroded sediment does not get accumulated in one place. In heavily aerated ponds where aerators are positioned around the peripheries to create circular water flow. strong water currents cause severe erosion of pond bottom. Mineral soil and organic matter particles eroded from peripheral areas settle in the central part of the pond. where water currents are weaker. Organic matter in sediments which mounds in the center of ponds decomposes and cause anaerobic conditions at the soil surface. with the release of toxic metabolites such as H_2S into the water. A method of aeration that does not erode mineral soil and produces water movement over the entire pond bottom instead of just around the periphery is needed. This method of aeration would produce water currents strong enough to suspend organic particles. it would not suspend heavier mineral soil particles. If the pond is roughly rectangular, the best place to mound the paddle wheel aerator is at the middle of one of the long sides of the pond. The aerator should direct water parallel to the short sides of the pond. Aeration of pond water causes water circulation and paddle wheel aerators are more efficient than other types in circulating pond water. Water circulation prevents thermal and chemical stratification. This makes the entire pond volume habitable and eliminates oxygen depletion at the mud – water interface.

3.7 **Liming**

Lime is frequently applied in aquaculture practices to improve water quality and ameliorate acidity of soils. Boyd (1982) found a close relationship between the base saturation of bottom soils and total hardness of water. Total hardness of water exceeded 20 mg/l when bottom mud was 80% or more saturated. Fertilization of ponds seldom produces good plankton growth if either the total hardness or total alkalinity is lesser than 20 mg/l. Some pond waters which contain >20 mg/l total hardness or total alkalinity, but are dark colored because of the presence of humic substances, may also need lime to clean the water, permit better light penetration for photosynthesis. The other beneficial effects of lime are as follows.

1. Lime creates a buffer system to prevent marked diurnal changes of the water from acidic to alkaline conditions.
2. It neutralizes the soil acidity.
3. It precipitates colloidal matters such as clay suspended in water.
4. It kills pathogens and promotes bacterial breakdown of organic matter.
5. It helps phosphorus fixation in the pond soil.
6. It supplies calcium needed for bone formation in fish and for plankton growth.

3.7.1 Kinds of lime

Lime stone ($CaCO_3$) under prolonged heating in calcining process gets converted into quick lime or calcium oxide which in turn on hydrolysis gets converted into slaked lime ($Ca(OH)_2$).

$$CaCO_3 \xrightarrow{\text{calcined process}} CaO + CO_2$$

$$CaO + H_2O \xrightarrow{\text{hydrolysis}} Ca(OH)_2$$

3.7.2 Application of lime

Based on the pH of soil and type of lime, the quantity of lime to be applied varies. To raise the pH of soil to 7 and the time of pond preparation, the quantity of lime (tonnes/ha) to be applied are as follows.

Soil pH	$CaCO_3$ (Limestone)	$Ca(OH)_2$ (Slaked lime)	CaO (Quick Lime)
6.1 to 6.5	2.5	1.9	1.4
5.6 to 6.0	5.0	3.7	2.9
5.1 to 5.5	10.0	7.4	5.8
4.6 to 5.0	12.5	9.3	7.2
4.0 to 4.5	15.0	11.1	8.7

For application within the culture period, a rate of 2000 Kg Limestone per hectare can be taken as the general dose.

3.8 Fertilization

Fertilizers are applied to ponds to increase inorganic nutrient concentrations, favour greater phytoplankton growth and ultimately enhance production of fish or crustaceans. Phosphorus and nitrogen are the most important nutrients. Nitrogen is more limiting in brackish and marine water whereas P is more limiting in fresh water. The following points are to be taken into consideration about fertilization.

1. Waters with high concentration of nitrogen and phosphorus do not require as much fertilizer as with low concentrations of these nutrients
2. Fertilization becomes less important as feeding rate increases
3. High feeding and fertilization rates cause heavy phytoplankton blooms and decrease dissolved oxygen concentrations
4. Fertilization and feeding creates turbidity which helps control the growth of under water weeds
5. The development of a suitable fertilization schedule for a particular farm must be done by trial and error, because research findings are inconclusive.
6. Water exchange flushes out fertilizer nutrients

Rate of fertilization though vary from pond to pond, a general dose of 20 Kg N/ha and 1 Kg P/ha once in a week can be adopted for brackish and marine water shrimp culture when water is comparatively infertile. When water is more fertile, the amount of N and P may be reduced to 50%, but the ratio should be maintained at 20:1. In fresh water, quantities of primary nutrients per application for the fertilization programme for fish culture suggested by Boyd and Snow (1975) is 9 Kg/ha of N, 4 Kg/ha of P and 2 Kg/ha of K. The application may be repeated 9 – 12 times within a growing season as necessary when plankton blooms diminished, so that under water objects are visible to a depth of 30cm.

Fertilizers should be dissolved in water and then splashed in the pond. Otherwise, they settle to bottom before dissolving completely and the mixing will not be efficient. The water in which the fertilizer was dissolved should not be poured directly into pond water because they are heavier than water and will settle to the bottom.

Nitrogen, phosphorus and potassium are termed as the primary nutrients and when a fertilizer contains all these three elements it is a complete fertilizer. The N, P, K in fertilizer is traditionally expressed as N, P_2O_5 and K_2O respectively.

Table 5 Approximate grades of common commercial fertilizers

Substance	Percentage		
	N	P_2O_5	K_2O
Urea	46	0	0
Calcium nitrate	15	0	0
Ammonium nitrate	16	0	0
Ammonium sulfate	21	0	0
Super phosphate	0	20	0
Triple super phosphate	0	46	0
Mono ammonium phosphate	11	48	0
Di ammonium phosphate	18	48	0
Ammonium polyphosphate	10-13	34-39	0
Muriate of potash	0	0	60

To supply the required amount of nutrients (N, P_2O_5, K_2O) the amount of fertilizer can be calculated as follows.

$$\text{Fertilizer quantity (Kg)} = \frac{\text{Required quantity of nutrient (Kg)} \times 100}{\text{Content of nutrient (\%)}}$$

Organic fertilizers or manures are animal wastes or agricultural by products which will decompose slowly and release nutrients to the water. Because of their low nutrient content, their quantity needed will be much higher than the chemical fertilizers. The decomposition of organic manures depend on their C/N ratio and the presence of microorganisms which require oxygen. The quantity of application should not increase the BOD beyond the limit. Application of a chemical fertilizer with manures that contain a wide C/N ratio is beneficial because the nitrogen from the chemical fertilizer stimulates microbial degradation of the manure. Thus phosphorus and other nutrients in the manure are released more rapidly to the water and the rate of accumulation of organic residue in the pond bottom is reduced (Chakraborthy, 1975). When organic manures are applied to the pond, at least three weeks time should be given for the next application to give room for proper decomposition. At the time of pond preparation, 200 to 2000 Kg organic manure per hectare can be used.

3.9 Sediment removal

Mounds of sediment in heavily aerated ponds usually do not contain large amounts of organic matter. They consist primarily of mineral soil and contain little organic matter (2-5%). In brackish water ponds, sediment has a high salt content and its removal for disposal on land constitutes an environmental hazard. Salts leach from sediment piles and contaminate fresh water sources. Sediment mounds should be prevented by better aeration techniques. If mounds are allowed to form, they should be dried between crops and spread back over eroded areas in ponds. Bottoms should be compacted to minimize erosion by aerator induced currents during the next crop. High external sediment loads can rapidly fill ponds and reduce water volumes. This problem can be solved with sedimentation ponds for removing solids before they enter ponds. Sedimentation ponds must be dredged occasionally, as otherwise, they will fill in and shorten the water retention time.

3.10 Water exchange

Water exchange flushes nutrients and phytoplankton from ponds to prevent excessive phytoplankton blooms ; it removes toxic metabolic wastes such as ammonia, it dilutes pond water so that salinity does not become excessive during the dry season and it improves the aeration of the pond.

Water pumped into ponds should be applied at the pond surface. Water should be drained from near the pond bottom and at opposite side from which it is introduced. The most beneficial means of exchanging water in a pond is to first drain out the volume to be exchanged and then pump an equal volume of replacement water.

If water quality in ponds is good, there is no reason to exchange water. Daily water exchange usually does not improve water quality in ponds, and pumping costs are a liability. Ponds are highly efficient in assimilating C, N and P inputs not covered by fish or shrimp flesh, but if water exchange is great, these substances are discharged from ponds before they can be assimilated. Thus, the pollution potential of aquaculture increases as a function of increasing water exchange. From both economic and environmental perspectives, water exchange should only be used whenever necessary.

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DETERMINATION OF ORGANIC CARBON AND ORGANIC MATTER IN SOIL

(Walkely and Black Method / Wet digestion method)

Principle

A known weight of soil is treated with an excess volume of standard $K_2Cr_2O_7$ solution in the presence of conc. H_2SO_4. The soil is slowly digested at a low temperature by the heat of dilution of H_2SO_4 and organic carbon in the soil is oxidized to CO_2. The excess of $K_2Cr_2O_7$, unused in oxidation, is titrated back against a standard solution of ferrous ammonium sulfate in the presence of H_3PO_4 with diphenyl amine as indicator. The color is dull green at the beginning, then shifts to turbid blue as the titration proceeds. At the endpoint, this color sharply shifts to a brilliant green, giving one-drop endpoint.

a) Oxidation of carbon

$$K_2Cr_2O_7 + 4\,H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3O \quad (\text{ i })$$

$$C + 2O \longrightarrow CO_2 \quad (\text{ii})$$

$$2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2\,K_2SO_4 + 2Cr_2(SO_4)_3 + 8H_2O + 3CO_2$$

b) The excess nascent oxygen is titrated against ferrous ammonium sulfate.

$$FeSO_4\,(NH4)_2SO_4.6H_2O \longrightarrow FeSO_4 + (NH_4)_2SO_4 + 6\,H_2O \quad (\text{ i })$$

$$FeSO_4 + H_2SO_4 + O \longrightarrow Fe_2(SO_4)_3 + H_2O \quad (\text{ii})$$

$$2(FeSO_4(NH_4)_2SO_4.6H_2O) \longrightarrow 2(NH_4)_2SO_4 + Fe_2(SO_4)3 + 13H_2O$$

Reagents

1.1*N* $K_2Cr_2O_7$ solution: Dissolve 49.04g of $K_2Cr_2O_7$ in distilled water and make up the volume to 1000 ml.

2.Ferrous ammonium sulfate (approx. 0.5*N*): Dissolve 392g of $FeSO_4(NH_4)_2SO_4.6H_2O$ in distilled water. Add 15 ml of H_2SO_4 and make up the volume to 2 litres with distilled water.

3.Diphenyl amine indicator: Dissolve 0.5g of diphenyl amine indicator in a mixture of 100 ml of conc. H_2SO_4 and 20 ml distilled water.

4. Conc. H_2SO_4

5. Orthophosphoric acid. 85%.

Procedure

1.Take accurately weighed 0.5g portion of the soil (passed through 0.2 mm sieve) in a 500 ml conical flask.

2.Pipette out 10 ml of 1*N* $K_2Cr_2O_7$ solution, shake and mix.

3.Add 20 ml of conc. H_2SO_4 and swirl the flask during addition (in case of soil containing high chloride add 20 ml of Ag_2SO_4 solution prepared by dissolving 25 g Ag_2SO_4 in 1000 ml of conc. H_2SO_4).

4. Keep the flask for 30 minutes to complete the reaction.

5. Add 150 ml of distilled water followed by 10 ml of H_3PO_4 and shake vigorously and mix.

6. Add 1 ml of diphenyl amine indicator.

7.Titrate the content of the flask against ferrous ammonium sulfate till the color changes from blue to bright green.

8.Note the volume of ferrous ammonium sulfate.

9. Carry out a blank in a similar manner. (This titration is also useful for determining the exact normality of ferrous ammonium sulfate solution.)

Calculation

Volume of 1*N* $K_2Cr_2O_7$ pipetted out	: 10 ml
Volume of Ferrous ammonium sulfate used for blank titration	: X ml
Normality of Ferrous ammonium sulfate (n)	: 10/x
Volume of Ferrous ammonium sulfate used for titrating the excess dichromate sample	: Y ml

1 ml of 1 *N* $K_2Cr_2O_7$ = 0.003g organic C

Percentage of organic carbon in soil (O.C) = (X-Y)n*0.003*100/w

Percentage of organic matter (O.M) = % OC*1.724

More precisely, % O.M = %O.C * 1.724*100/77 (77% is the recovery factor)