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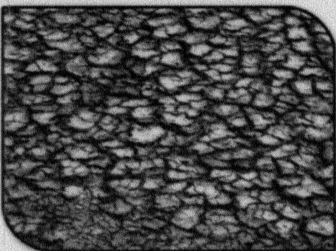
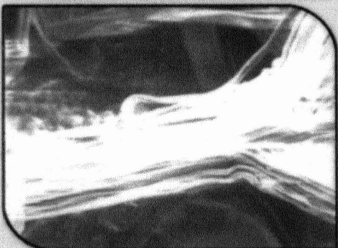
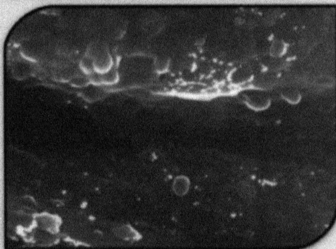
# Advanced Technologies for the Management of Soil and Water Environment in Brackishwater Aquaculture



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National Fisheries Development Board, Hyderabad

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# ADVANCED TECHNOLOGIES FOR THE MANAGEMENT OF SOIL AND WATER ENVIRONMENT IN BRACKISHWATER AQUACULTURE



Compiled by

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September 2009

Sponsored by
National Fisheries Development Board, Hyderabad

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# PREFACE

During the past two decades brackishwater aquaculture has become the fastest growing food-producing sector and is an increasingly important contributor to national economic development, global food supply, food security and nutrition. The water and soil quality management are therefore key factors for regulating success in brackishwater shrimp/fish farming. Interactions between soil and water that influence water quality in ponds must not be ignored, because poor soil condition in ponds can impair survival and growth of aquaculture species. Some soils may have undesirable properties like potential acid sulphate acidity, high organic matter content or excessive porosity. On the other hand, even if the site is good, problems may still crop up by the large quantity of inputs like feed and fertilizers, which lead to excessive phytoplankton production, low dissolved oxygen, high ammonia, poor bottom soil condition and other problems. Out break of disease in shrimp culture system is related to the environmental factors such as deterioration of water and soil quality. Most of these problems can be avoided through adoption of better management practices (BMPs) such as site selection, pond preparation, liming, moderate stocking etc. However, effectiveness of these BMPs depends on taking into consideration the high degree of variability between shrimp farms, their soil types, and source water, ecosystems in which the farms are located and seasonal variations.

The aqua farming sector cannot be considered in isolation and other activities in the coastal areas impact the environment which may in turn affect the culture operations. Its fast growth has invited some of the environmental issues like salinisation of agricultural lands and drinking water resources and conflicts with other users. The aqua farms discharge water is the most significant of all factors that contributes to the degradation of environment and causes 'self pollution' with in the system due to intensification of technology. Conversely the aquatic environment is ultimate sink for all chemicals and pollutants such as heavy metals and pesticides that pose serious environmental hazards because of their persistence and toxicity. Good site selection for shrimp farming operations requires planning for managing entire ecosystem to avoid problems when the numbers of ponds exceed the carrying capacity of the system. All the above issues underline the importance of environmental management in brackishwater aquaculture.

As a part of the transfer of technology programme, the Central Institute of Brackishwater Aquaculture (CIBA) is organizing this training course on 'Advanced Technologies for the Management of Soil and Water Environment in Brackishwater Aquaculture" sponsored by National Fisheries Development Board (NFDB), Hyderabad. The training program covers both the basic and advanced topics such as suitability of soils for brackishwater aquaculture, water and soil quality management during the pre-stocking and culture period, pesticides and heavy metal hazards in source waters, discharge water treatment, aquatic bioremediation, BMPs, environmental impact assessment (EIA) and environmental monitoring programme (EMP) protocols and practicals on analysis of soil and water parameters.

It gives me great pleasure to record my sincere thanks to National Fisheries Development Board, Hyderabad for sponsoring this training programme. My appreciations are to all the faculty members of the training program for their efforts in bringing out this training manual.

Chennai
1st September, 2009

Dr. A.G.Ponniah
Director, Central Institute of Brackishwater Aquaculture

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# 1. SUITABILITY OF SOILS TO BRACKISHWATER AQUACULTURE

**B.P.Gupta and M.Muralidhar**

Aquaculture ponds are normally built of soils. Properties of soils should be considered in selecting a site, designing earthwork, and specifying construction methods to provide a water-tight pond with stable levels and bottom slopes. Interactions between soil and water that influence water quality in ponds must not be ignored, because poor soil condition in ponds can impair survival and growth of aquaculture species. For example, acidic soils can cause low pH and total alkalinity in ponds, and unless lime is applied, ponds may be unsuitable for aquaculture. A large amount of information is needed for proper planning, design and construction of aquaculture ponds. Sometimes lack of attention to soil properties results in aquaculture ponds which can not be used to their full potential.

The productivity of a pond depends upon its soil - water characteristics. Generally, fish/shrimp production is low in ponds located in agriculturally poor productive soils and high in those placed in fertile soils. A satisfactory pond soil is the one in which mineralization of organic matter takes place rapidly and nutrients are absorbed, held and released slowly over a long period. Further, in bottom soil, a series of chemical and biochemical reactions take place resulting in either the release of nutrients from soil to water or absorption of nutrients from water by the soil and microbial population. This process governs the growth and population of the micro and macro food organisms in the fish/shrimp ponds. To understand the complete pond ecosystem, it is essential to study the characteristics of pond soil and water to increase the productivity of the ponds in general and thereby augmenting fish and shrimp production.

Shrimp farms have been constructed on variety of coastal lands – inter-tidal fallow land, dry and saline fallow land, unproductive and marginal agricultural land, and to a lesser extent in wetlands like marshes and mangroves. Coastal areas of the country have vast resources of saline affected fallow lands which cannot be used for any productive purpose. Presently, about 10.0 % of the resources available are being utilized for shrimp aquaculture. Shrimp aquaculture requires natural resources like land, water, and biological resources like seed and feed.

### 1.1 Soils of India

In India aquaculture ponds are located under different agro-climatic conditions. Therefore it is necessary to have a broad knowledge of different types of soils in order to understand the problems of production in relation to the soil conditions. In India, the soils are classified mainly under eight major heads viz., alluvial, black, red, laterite, forest, desert, saline and alkaline and peat. The brackishwater aquaculture is done on salt affected soils or coastal soils and hence the nature and properties of saline and alkaline soils are described:

#### 1.1.1 Saline soil

Saline soils were originally called "white alkali" soils. Saline soils are classified as saline if the solution extracted from a saturated soil paste has an electrical conductivity value of 4 or more mmhos/cm at 25°C, the amount of exchangeable sodium less than 15% and the pH below 8.5. Saline soils usually have a surface crust of white salt, especially in the dry season.

### 1.1.2 Alkali soil

These soils have often been called "black alkali" soils because they are black, owing to the effect of high sodium content which causes the dispersion of the organic matter. In this type of soil, the solution extracted from a saturated soil paste has an electrical conductivity value more than 4 mmhos/cm at 25°C, the amount of exchangeable sodium more than 15% and the soil pH between 8.5 to 10.0.

As the brackishwater aquaculture has expanded enormously in the coastal areas where the above mentioned soils have been observed, the difference between saline and alkali soils should be well understood. The soluble salt which are measured and represented as electrical conductivity consist of cations and anions. The cations are: $Ca^{++}$, $Mg^{++}$, $Na^{+}$, $K^{+}$ and anions: $CO_3^{--}$, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{--}$.

The total area of salt affected soils in India is about 8 million ha, out of which 3.1 million ha are coastal saline soils including 0.5 million ha of mangrove areas. The details of the extent of saline soils in the different states are presented in Table 1. The data shows that most of the coastal areas in India are saline in 1983, much before the development of scientific brackishwater farming practices.

**Table 1. Extent of saline soil in the coastal states of India**

| State | Extent of saline soil (in ha) | Soil salinity (mmhos/cm) |
|---|---|---|
| West Bengal | 8,20,448 | 4 – 35 |
| Gujarat | 7,14,000 | 9-20 |
| Orissa | 4,00,000 | 2-50 |
| Andhra Pradesh | 2,76,000 | 0.5-17 |
| Tamil Nadu | 99,950 | 2 – 10 |
| Karnataka | 86,000 | 3 – 10 |
| Maharashtra | 63,537 | 4-14 |
| Kerala | 26,400 | 1-20 |
| Goa | 18,000 | 4 – 15 |
| A & N islands | 15,000 | - |
| Pondicherry | 1,000 | 1-50 |
| Total | 25,20,335 | |

## 1.2 Soil quality

Before initiating aquaculture operation, one should be well aquainted with the nature of soil as it affects the fish/shrimp production. The properties of soil selected to aquaculture are described below.

### 1.2.1 Soil texture

Soil texture refers to the relative percentage of sand, silt and clay in the soil. It has direct bearing on the productivity of the ponds. In brackishwater ponds, benthic productivity is more important than the production of plankton. A clayey soil rich in organic matter encourages the growth of benthic blue algae which along with the associated micro-organism form the main food of most of the brackishwater animals.

Clayey soils are best suited for constructing bunds and have good water retention properties. Such bunds cannot be easily eroded by wave or tidal action. Sandy soil is porous and very poor material for constructing bunds. Therefore brackishwater soils with moderately heavy textured are ideal for aquaculture. Sandy clay, sandy clay loam and clay loam are some of the textured names suitable for aquaculture. The details of the textured name based on the sand, silt and clay % content are given in Table 2.

### 1.2.2 pH

The pH gives an idea whether the soil is acidic (<7) or alkaline (>7). This is one of the most important soil quality parameters since it affects the pond condition. In general, slightly acid to slightly alkaline soil pH is favourable for higher production. Highly acidic and highly alkaline soil pH are not conducive to higher production. The availability of nutrients, rate of mineralization of organic matter, bacterial activities and fixation of phosphorus are greatly influenced by soil pH. The soil pH ranging between 6.5 and 7.5 are best suited for brackishwater environment. Under this pH range, the availability is maximum for nitrogen, phosphorus and potassium, sulfur, calcium and magnesium. The availability of micro-elements, iron, manganese, boron, copper, chlorine and zinc is more in the acid range than in neutral or alkaline range. Since the requirement of these micro-elements is small, the quantities available at pH 6.5 to 7.5 are usually enough for brackishwater environment.

**Table 2. Percentage of sand, silt and clay in the principal textural classes (based upon U.S. Dept. of Agric. Fraction System)**

| Textural name (Soil class) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|
| Sand | 85-100 | 0-15 | 0-10 |
| Loamy sand | 70-90 | 0-30 | 0-15 |
| Sandy loam | 43-80 | 0-50 | 0-20 |
| Loam | 43-80 | 28-50 | 7-27 |
| Silt loam | 0-50 | 50-88 | 0-27 |
| Sandy clay loam | 45-80 | 0-28 | 20-35 |
| Clay loam | 20-45 | 15-23 | 27-40 |
| Silty clay loam | 0-20 | 40-73 | 27-40 |
| Sandy clay | 45-65 | 0-20 | 35-45 |
| Silty clay | 0-20 | 40-60 | 40-60 |
| Clay | 0-40 | 0-40 | 40-100 |

Size limits of soil separates:

Sand - 0.05 to 2.0 mm ; Silt - 0.05 to 0.002 mm ; Clay - below 0.002 mm

### 1.2.3 Organic matter

Soil organic matter is an important index of soil fertility. Its presence in various proportions influences the productivity of the pond. It also helps in prevention of seepage loss, increases aerability of pond soil bottom and supplies nutrients. Organic matter helps in reducing the turbidity of pond water and acts as anti toxicants. The microbial activity is entirely dependent on the organic matter.

Though excess amount of readily decomposible organic matter may cause problems, but in brackishwater ponds, a high livel of organic matter is always desirable. It is possible to name the soil for productivity based on the organic carbon content. The soil which has organic carbon content less than 0.5% is low productive, 0.5 to 2% medium production and above 2% high production.

**1.2.4 Calcium carbonate ($CaCO_3$)**

This is a parameter which gives a fair idea about the free $CaCO_3$ content of the soil. The soil with no $CaCO_3$ content will show acidic reaction. Such soil can be improved to neutral soil pH or alkaline by the application of lime. By doing so, the harmful action of certain substances like sulpides and acids can be reduced. The soil rich in $CaCO_3$ content promotes biological productivity as it enhances the breakdown of organic substances by bacteria creating a more favourable oxygen and carbon reserves. It precipitates suspended or soluble organic metarials, decreases BOD and enhances nitrification due to the requirement of calcium by nitrifying organisms. The productive soil should have calcium carbonate more than 5%.

**1.2.5 Soil salinity**

Saline soils are usually barren but potentially productive soils. These soils do not support plant growth primarily because of excessive salt in the soil solution. In excess of sodium ions also exert antagonistic effects on the absorption of calcium and magnesium. These saline soils commonly occur in arid and semi-arid regions and areas near to sea. The salinity of soil increases with the increase in water salinity.

Salinity plays an important role in the transformation of nitrogen, both native as well as added in the form of fertilized. The available nitrogen content in water increases with the increase in salinity. However, at higher salinity greater amount of nitrogen is held in the soil complex and nitrification rate become slow. Rate of decomposition of organic manure is also affected under different water salinity levels. Decomposition rate of D.M. is comparatively lower under higher water salinity levels.

**1.2.6 Redox potential**

Oxygen is required for the decomposition of organic waste. In sediments, when inputs of organic matter exceed the supply of oxygen, anaerobic condition develops. This reducing condition can be measured as the redox potential. Redox potential is represented as Eh which indicates whether the water or soil is in reduced condition or oxidized condition. Negative (-) Redox value shows reducing condition and positive (+) value shows aerobic condition of the pond bottom sediments/mud. The optimum range of soil characteristics suitable for shrimp farming with minimum and maximum values are mentioned in Table 3.

**Table 3. Soil characteristics suitable for brackishwater aquaculture**

| Parameters | Minimum | Maximum | Optimum Range |
|---|---|---|---|
| pH | 6.5 | 9.0 | 6.5-7.5 |
| Org. C(%) | 0.5 | 2.5 | 1.5-2.0 |
| $CaCO_3$(%) | NA | NA | >5.0 |
| Av.N(mg/100g) | 25 | 75 | 50-70 |
| Av.P(mg/100g) | 3 | 6 | 4-6 |
| EC(m.mhos/cm) | NA | NA | >4 |

### 1.3 Limitation ratings for aquaculture use

A system of limitation ratings and restrictive features for soil properties was offered for use in aquaculture. Ranges for classes and degree of limitation for each property were based on literature, experience and best judgment. One may alter these ranges if experience and data justify it or add other properties with clay ranges, and still take advantage of this systematic method of evaluating soil for aquaculture.

Soils were placed into three classes according to their limitations for excavated ponds, pond levels, dikes or embankments. The rate class is given in forms of limitations and restrictive feature(s). Only the most restrictive feature should be listed when a limitation class is given. Other less restrictive features may need to be treated to overcome some soil limitation. If the rating is slight, no restrictive feature is given.

#### 1.3.1 Excavated ponds

Interpretation of soil limitations for excavated ponds (Table 4) considered soil properties to a depth of 150 cm.

**Table 4. Soil limitation ratings for excavated ponds**

| Property | Limitation rating | | | Restrictive feature |
|---|---|---|---|---|
| | Slight | Moderate | Severe | |
| Depth to sulfidic or sulfuric layer (cm) | >100 | 50-100 | <50 | Potential acidity or toxicity |
| Thickness of organic soil material (cm) | <50 | 50-80 | >80 | Seepage; hard to compact |
| Exchangeable acidity (%) | <20 | 20-35 | >35 | Exchangeable acidity |
| Lime requirement (T/ha) | <2 | 2-10 | >10 | Mineral acidity |
| pH of 50-100 cm layer of pond bottom Clay content (%) | >5.5 | 4.5-5.5 | <4.5 | Too acid |
| Clay content (%) | >35 | 18-35 | <18 | Too sandy/ siltry; excessive seepage |
| | Clayey | Loamy | Sandy/ silty | |
| Slope of terrain (%) | <2 | 2-5 | >5 | Slope |
| Depth to water table (cm) | >75 | 25-75 | <25 | Hard to drain; dilution |
| Frequency of flooding[4] | None | Occasional | Frequen t | Flooding |
| Small stones[7] (%) | <50 | 50-75 | >75 | Small stones |
| Large stones[7] (%) | <25 | 25-50 | >50 | Large stones |
| Decomposed OM[8] (%) | | | | |
| Low clay content soil (<60% clay) | <4 | 4-12 | >12 | Excessive humus |
| High clay content soil (>60% clay) | <8 | 8-18 | >18 | Reducing environment |
| Depth to rock (cm) | >150 | 100-150 | <100 | Shallow; seepage |

**1.3.2 Pond embankments, dikes and levees**

Embankments, dikes and levees are raised structures of soil material constructed to impound water. The soil material is considered as being mixed and compacted to medium density. Soil used for these applications must resist seepage and erosion. The final material should not cause toxic leachate to enter ponds. The ratings given in Table 5 for an in-place soil from the surface to the depth of 100 cm, with the assumption that all soil layers will be mixed in dozing, loading, dumping and spreading. The major properties considered are erosion, stability and permeability. These ratings will facilitate use of existing information and indicate the additional data that should be obtained from specific on site evaluations.

**Table 5. Limitation Ratings for pond embankments, dikes and levees**

| Property | Limitation rating | | | Restrictive feature |
|---|---|---|---|---|
| | Slight | Moderate | Severe | |
| Clay content (%) | >35 | 18-35 | <18 | Too sandy |
| | Clayey | Loamy | Sandy | |
| Depth to sulfidic or sulphuric material (cm) | >100 | 50-100 | <50 | Toxicity; potential acidity |
| Engineering classes | | | All'G' and 'S' classes | Too stony<br>Too sandy |
| Slope (%) | <8 | 8-15 | >15 | Slope |
| Thickness of organic material (cm) | <15 | 15-50 | >50 | Subsides; excess humus; difficult to compact |
| Depth to water table (cm) | >100 | 50-100 | <50 | Wetness |
| Fraction >8 cm diameter (%) | <25 | 25-50 | >50 | Large stones |
| Depth to bedrock (cm) | >100 | 50-100 | <50 | Depth to rock |
| Shrink – swell potential | Low | Medium to high | Very high | Shrink – swell |
| Erodibility (K) | <0.1 | 0.1-0.3 | >0.3 | Erosion |

**1.3.3 Definition of limitation ratings**

Soils should be rated in-place. Soils are rated to have a slight, moderate or severe limitation for a particular property. A moderate or severe limitation does not mean that a soil can not be used for aquaculture. Developers can modify soil features, adjust plans and redesign to compensate for many moderate and severe soil limitations. Managers can implement management practices to overcome many severe water limitations. However, the initial cost of pond and dyke construction and cost of maintenance must be considered when on-site soils have a restrictive feature. Limitation ratings are for single properties and the efforts to overcome limitations are different depending on the property and local conditions. The following are limitation rating definitions essentially used;

(1) **Slight** - This rating indicates that on-site soils have properties favourable for use. No unusual construction, design, management or maintenance will be required for the designated use.

(2) **Moderate** - This rating indicates that on-site soils have one or more properties that will require special attention for the designated use. This degree of limitation can be overcome or modified by special planning, design management or maintenance.

(3) **Severe** - The severe rating is given when one or more properties of on-site soils are unfavorable for the rated use. The severe rating usually means, that major reclamation and modifications in design, management or maintenance will be required for the designated use. Sometimes, it may not be economically feasible to use a site with one or more severe limitations.

In our study conducted at Gopalapuram area of Nellore District, Andhra Pradesh some of the properties of farm area such as low pH, high sand content and low organic carbon comes under moderate rating according to the classification mentioned above i.e. these soils have one or more properties that will require special attention for the designated use. This degree of limitation can be overcome or modified by special planning and management such as liming, organic manuring and additional compaction of soils. The soils may be considered suitable for brackishwater aquaculture upon managing these moderate limitation properties.

# 2. IDENTIFICATION AND MANAGEMENT OF ACID SULPHATE SOILS IN SHRIMP FARMS

**M.Muralidhar, B.P.Gupta and R.Saraswathy**

Acid coastal sediments known as acid sulphate soils (ASS) have been identified recently as a major cause of aquaculture production problems in South Asia, South East Asia, East Asia, Africa and Australia. Acid sulphate soils are extensive on coastal plains in the tropics but are less common in temperate regions. Attempts to reclaim tropical mangrove swamps for aquaculture and rice productions often have resulted in the development of unproductive acid sulphate soils. It has been estimated that India has over 2 million ha of ASS that have the potential to cause long-term production problems, if excavated. Oxidised ASSs were located in shrimp farms and along canals that connect shrimp ponds to the estuary.

Acid sulphate soil is the common name given to soil and sediment containing oxidisable, or already oxidised sulphides. The principal form of sulphides is iron pyrite (cubic $FeS_2$) although other forms such as monosulphides exist in smaller concentrations. If the soil remains in a reduced condition so that no oxidation of the sulphide occurs, the soil is referred as a potential acid sulphate soil (PASS) or a sulphudic soil (oxidisable sulphur compounds). Where the sulphides are exposed to air, so that oxidation can take place, the soil is called an actual acid sulphate soil (AASS) or sulphuric soil (field pH of 3.8 and chloride to sulphate ratio in soil solution < 2 mg/L). Oxidising conditions frequently overlie reducing conditions in the same profile so that AASS and PASS apply to different parts of the same profile.

## 2.1 Nature of acid sulphate soils

When the sea level rose and inundate pond, sulphate in the seawater mixed with land sediments containing iron oxides and organic matter. The resulting chemical reactions produced large quantities of iron sulphides in the waterlogged sediments. Under natural conditions iron sulphide layers are covered by water and colonized by native vegetation.

$$\underset{\text{Sediment}}{Fe_2O_3\,(S)} + \underset{\text{Seawater}}{4\,SO_4^{2-}} + \underset{\text{Organic mater}}{8CH_2O} + \tfrac{1}{2}\,O_2 \rightarrow \underset{\text{Pyrite}}{FeS_2\,(S)} + 8HCO_3^- + 4H_2O$$

The five conditions necessary for the formation of sulphides in coastal sediments are

1. Supply of sulphate
2. Supply of easily decomposed organic matter.
3. An adequate source of iron
4. Anaerobic conditions together with chemically reducing microbes flushing to remove soluble reaction products.
5. Tidal action

**Oxidation**

As long as sediments containing pyrites are submerged and anaerobic, they remain reduced and change little. However, if they are rained and exposed to the air, oxidation results and sulphuric acid is formed. The summary reactions for sulphuric acid formation from iron pyrite are:

$$FeS_2 + H_2O + 3.5\ O_2 \rightarrow FeSO_4 + H_2SO_4$$

$$2\ FeSO_4 + 0.5\ O_2 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + H_2O$$

$$FeS_2 + 7\ Fe_2(SO_4)_3 + 8H_2O \rightarrow 15\ FeSO_4 + 8H_2SO_4$$

The production of ferric sulphate from ferrous sulphate is greatly accelerated by the activity of bacteria of the genus *Thiobacillus* and under acidic conditions the oxidation of pyrite by ferric sulphate is very rapid. Ferric sulphate also may react with iron pyrite to form elemental sulphur and the sulphur may be oxidised to sulphuric acid by microorganisms. Soils are termed as acid sulphate soils once oxidation of pyrite occurs.

$$Fe_2(SO_4)_3 + FeS_2 + \rightarrow 3FeSO_4 + 2S$$

$$S + 1.5\ O_2 + H_2O \rightarrow H_2SO_4$$

The $Fe(OH)_3$ crystallizes as a reddish brown material in the sediment. After draining, a sediment containing pyrite is called acid sulphate soil or a "cat's clay" Ferric hydroxide can react with adsorbed bases, such as potassium in acid sulphate soils, to form Jarosite, a basic iron sulfite. Jarosite is relatively stable, but in older acid sulphate soils where acidity has been neutralised, jarosite tends to hydrolyze Sulphuric acid dissolves aluminum, manganese, zinc and copper from soil, and run off from acid sulphate soils or mine spoils not only is highly acidic, but it may contain potentially toxic metallic ions.

$$3\ Fe(OH)_3 + 2\ SO_4^{2-} + K^+ + 3H^+ \rightarrow K\ Fe_3(SO_4)_2(OH)_6.2H_2O + H_2O$$

$$KFe_3(SO_4)_2(OH)_6.2H_2O + 3H_2O \rightarrow 3\ Fe(OH)_3 + K^+ + 2SO_4^{2-} + 3H^+ + 2H_2O$$

When aerobic, acid sulphate soils will have a pH below 4.0. The pH of acid sulphate soils often will decrease as much as 3 units upon drying. The positive test is to measure pH before and after drying.

**Rates of oxidation**

Two important conditions are necessary for the oxidation of sulphudic soils. The first is an adequate supply of oxygen, the second the removal of oxidation products. The rate of oxidation is a critical question and depends on

1 The prevailing hydrology
2. How the soil is drained
3. The climatic conditions
4. The permeability to air of the overlying sediments
5. Soil temperature
6. Amount and particle size of the iron pyrite
7. The presence or absence of exchangeable bases and carbonates within the pyritic bearing material.
8. The exchange of oxygen and solutes with the pyrite
9. The abundance of *Thiobacillus*
10. Grain size and texture
11. Porosity of the soil

**2.2 Check for indicators of ass**

There are several indicators of ASS, that is, where yhe iron sulphide layer has oxidized and produced sulphuric acid.

- Drain water or surface pond water with pH less than 4
- Unusually clear or milky green drain water
- Rust coloured stains and deposits on drain surfaces and in drain water
- Yellow jarosite, sulphur mineral produced in soil generating acid from iron sulphide, usually seen on drain spoil heap, and in holes and cracks in the soil.
- Soil cores with yellow or red mottling
- Corroded, concrete or steel structures

It is less easy to identify the iron sulphide mud, potential ASS which have not acidified, but it is possible to recognize them if you dig them up. They are

- Waterlogged
- mid to dark grey to dark greenish grey in colour
- soft, buttery clay or estuarine silty sands
- pH neutral
- They may also give off a rotten egg smell (hydrogen sulphide)

**Chemical analyses**

**a) Water chemistry as an indicator**

The ratio of soluble chloride to soluble sulphate concentrations ($Cl^-/SO_4^{-2}$) can give a strong indication that regional sulphudic material is or has been oxidized. A ($Cl^-/SO_4^{2-}$) ratio (by mass) of less than four and certainly less than two is a strong indicator of an extra source of sulphate, beyond that normally found in sulphudic sediments. This ratio, coupled with measurements of the pH of the water is a good indicator of the presence of ASS.

**b) *Insitu* field soil pH testing**

A calibrated, double junction, spear-point pH probe inserted directly into moist soil to measure the *insitu* pH of the soil. Where surface soil is unsaturated, distilled water should be added to saturate the soil. The pH probe should be inserted at 0.1 m intervals down the soil profile and the pH and depth were recorded. Below the surface soil, actual AASS show pH less than 4 and increases to mere neutral pH in the unoxidised PASS horizon. It should be noted that an acid pH does not necessarily mean ASS is present. However, *insitu* pH coupled with peroxide test is an excellent field indicator for ASS.

**c) Hydrogen peroxide field test**

1 ml of 30% hydrogen peroxide is added to the soil either in place or in augured samples. It is convenient to add the peroxide to the hole made by insertion of the probe and it is important to do pH and peroxide tests on the same soil sample. The peroxide reaction can take up to 3 minutes to occur. The degree of effervescence may be used as a visual indicator of pyrite concentration and should be noted as *none, weak or vigorous*. The more violent the reaction the higher is the pyrite concentration. Organic matter also reacts with peroxide, but the reaction is much less vigorous.

## 2.3 Impacts of ASS

In ponds, the problem of acid sulphate soils usually originates in levees. The acid produced by oxidation of iron sulphides affects both soil and water and can damage the environment severely. These poor quality waters have the following impacts

1. Ponds constructed in ASSs may contain high levels of acidity resulted in low pH in pond water and thus reduction in aquacultural production.
2. Slow growth of cultured species, low survival and low shrimp yield.
3. Acute shrimp/fish kill because of increased concentration of soluble and toxic aluminum and manganese.
4. Poor response of soil to phosphorus fertilisation.
5. Accumulation of some organic acids
6. Limitation of essential macro and micronutrient elements adversely affects the natural food in the ponds.
7. Accelerated leaching loss and decreased availability of Na, Ca and Mg and enhanced solubility of trace elements like Cu and Zn.
8. Release of heavy metals from contaminated sediments
9. Corrosion and impairment of engineering structures
10. Increased risk of disease outbreak

## 2.4 Management of ASS

In general, there are five options for managing ASS. The particular strategy or mix of strategies adopted will depend on the situation. It is absolutely essential to have in place a rigorous environmental monitoring program.

### 1. Avoidance

If alternate sites containing non-pyritic materials are available it is prudent to avoid the environmental and social problems associated with the drainage of large area AASs.

### 2. Prevention of oxidation

There are a range of techniques which may be used to prevent or to minimise the rate of pyritic oxidation of ASS. Again the technique selected depends on the particular land use required.

### (A) Burial beneath the water table or water surfaces

The production of anaerobic conditions by flooding or immersion of material below the water table can be an effective technique for removing acid from the sediments, provided that sufficient organic matter remains. In the microbial catalysed process, sulphate is reduced to $H_2S$.

$$SO_4^{2-} + 2H^+ + 2CH_2O \rightarrow H_2S + 2H_2O + 2CO_2$$

### (B) Capping

It is a technique which has been used in the treatment of acid mine drainage. In this technique a capping of relatively impermeable material, such as compacted clay or soil or asphalt, is placed over the sulphudic material to lower the rate of both oxygen and water entry. The placement of capping material on the surface of unconsolidated estuarine clays will cause subsidence, particularly if compaction is used. An additional benefit of capping and subsidence is that it places oxidisable material below the water table in a region of lower temperature. This will tend to lower rates of oxidation, because of sensitivity of microbial reactions to temperature.

**(C) Bactericides**

The rate of oxidation of pyritic material is strongly catalysed by microbes. Oxidation rates of pyritic clumps have been reduced temporarily by the use of bactericides to kill catalytic microbes. In natural ecosystems plant growth is heavily dependent on inherent soil microbial processes. Hence, bactericides highly specific to the oxidation of pyrites should be used.

**3. Neutralisation**

Chemical neutralisation of acid by calcite, dolomite, magnesite and slaked lime can be followed. Slaked lime may cause pH to overshoot, which may cause problems. Chemical neutralisation of acid has limited benefits, because acid is regularly transported into the pond there by depleting the neutralising agent. Although the soil can be limed, it will not necessarily lose all its potential acidity. Soil texture and structure may have an influence on liming success. In clayey soil, mixing lime with soil is difficult. The other materials used for neutralisation of acid are filter press muds, fertilisers, rice hull, ash etc. But this is very expensive.

**4. Oxidation and leaching**

As the neutralisation of the ASS is too difficult or expensive, an alternate strategy is to allow the material to oxidise deliberately and to leach out the oxidation products. This is only recommended for coarse textured sands and gravels, which are relatively highly permeable to air and water and which contain relatively small amounts of pyrite. The time required for complete oxidation and leaching cannot be predicted since it depends on prevailing climatic conditions such as rainfall, temperature and wind speed as well as the size and shape of the heap to be oxidised.

**5. Removal of pyritic materials**

It has been proposed that some acid sulphate materials or potential acid sulphate materials can be treated by removal of pyrite from the sediment. This proposal which involves the hydraulic separation and removal of pyrite using hydro clones, relies on the fact that pyrite has a much larger particle density than common soil forming minerals like quartz. Thus the separated pyrite would be placed under anaerobic conditions below the water surface.

## 2.5 Reclamation of acid sulphate pond soils

ASS formation in existing ponds can be avoided by following correct pond preparation. Excessive turning over of pond bottom should be avoided since this will expose sites of potential acid soil to become actual and problem soil. The most beneficial but expensive method of using ASS for aquaculture is to employ plastic liners presently used in SE Asia, particularly in Malaysia and Indonesia. However, the procedure for rapid reclamation of ponds with acid sulphate soils is as follows:

- In the early part of the dry season, dry the pond and harrow thoroughly. Fill with brackishwater. Measure the pH of the water frequently. The pH will drop from that of seawater (7 to 9) to below 4. Once the pH has stabilized, drain the pond. Repeat the process until the pH stabilizes above 5. Often three or more drying and filling cycles may be required.

At the same time when the pond is being reclaimed, acid must be removed from the surrounding levees. To achieve this, level of levee tops and build small bunds along each side of levee tops to produce shallow basins. Fill the basins with backwater. When the pond is drained for drying, also drain the small basins on the levee tops for drying. Repeat if necessary. Finally remove the bunds and broadcast agricultural lime ($CaCO_3$) over the tops and sides of levees at 0.5 to 1.0 kg/m$^2$. Once the last drying refilling cycle is completed, broadcast $CaCO_3$ over the pond bottom at 500 kg/ha.

After 20 - 25 days of liming, fertilization should be done either by broadcasting or spreading all over the pond bottom and mixed thoroughly. To prevent prawn kills by seepage of acid from levees, pH has to be monitored regularly and if necessary $CaCO_3$ may be applied. The traditional practice of rearing 'lab-lab' the natural food for aquatic biota includes admission of 5 – 10 cm deep water into the pond after drying, liming and fertilization. Sudden variation of pH can inhibit the development of the lab-lab population. Acid conditions lead to shortage of food, reduced shelter from predators and death of almost all the fauna, including culture species.

# 3. AQUACULTURE POND SOIL MANAGEMENT

**M.Muralidhar, B.P.Gupta and R.Saraswathy**

Successful shrimp culture depends on good bottom soil condition. Some soils may have undesirable properties like potential acid sulphate acidity, high organic matter content or excessive porosity. On the other hand, even if the site is good, problems may still crop up by the large quantity of inputs like feed and fertilizers, which lead to excessive phytoplankton production, low dissolved oxygen, high ammonia, poor bottom soil condition and other problems. Most of these problems can be avoided by proper management practices such as site selection, pond preparation, liming, moderate stocking etc.

## 3.1 Pond preparation

There are various aspects in the pond preparation, which should be carried out before the pond is used for shrimp culture. By pond preparation, it is meant to prepare the pond to have congenial environment to the shrimp post larvae to live and grow in steady manner so as to attain marketable size within a crop duration of 100 - 120 days. Pond preparation is generally dealt in two categories viz., newly constructed ponds and existing culture ponds. The main objectives of pond preparation are to produce the shrimp with a clean pond base and appropriate stable water quality by ensuring the following

(i) Removal of predatory and unwanted animals from the pond
(ii) Removal of poisonous gases – obnoxious gases such as $H_2S$, $NH_3$, etc.
(iii) Generation of natural productivity in the culture ponds.

### 3.1.1 Newly constructed ponds

In newly dug out ponds, the characteristics of the soil has to be understood first before adopting the various measures to prepare the pond. Soil samples taken from different locations of the pond are thoroughly mixed together and a representative portion is taken for analysis. Understanding of the soil parameters helps to decide the management strategies to be followed in terms of liming, manuring, fertilization, water management etc.

### 3.1.2 Pond preparation after harvest

Before initiating a second crop in a pond, the pond has to be prepared for stocking the shrimp post larvae. In this case, pond preparation is entirely different from that of a newly dug-out pond except for liming, fertilization and raising the water level.

#### 3.1.2.1 Cleaning

During production cycle, considerable quantity of waste accumulates in the ponds depending upon the culture practices. This waste must be removed to ensure sustained production in the pond. Removal of waste by draining and drying of the pond bottom after the production cycle are some of the steps to be followed for keeping pond environment clean.

#### 3.1.2.2 Draining of ponds

The first step in pond preparation is draining the pond after harvest of the previous crop. This could be done either by pumping or draining through sluice. For effective and complete drain, the pond should be designed in such a way that the bottom must have a gradual slope from the inlet gate to drain gate. The effective slope is 1:500. The coastal waters are heavily laden with silt and this gets accumulated in the pond bottom. After draining, pond should be desilted. Often black mud is noticed on the pond bottom. This black colour is caused by an accumulation of iron when the mud is depleted of oxygen. When the mud is oxidised (contains oxygen), the ferrous iron changes to ferric iron and the mud will no longer be black in colour. This accumulated black material can be removed either by wash away the waste before it dries off or to allow the pond to dry out and then remove the waste.

Wet method

In this method, after the final drain harvest, the accumulated black material on the pond bottom is flushed in the form of thin slurry using a pump and a pressure. It is quick and more efficient process than the dry method, reducing the period between production cycles. The advantage of this method is that waste is removed in suspension. This method needs a settling pond where waste is removed from the water and treated repeatedly to avoid polluting the local environment.

Pond mud drying and sediment removal

In this method after the final drain harvest, the pond bottom is allowed to dry and crack, primarily to oxidize the organic components left after the previous culture. The pond bottom is sun dried for at least 7-10 days or until it can support a man's weight without subsiding and the soil should crack to a depth of 25 - 50 mm. After drying, the waste can either be removed manually or with machines.

This method has some advantages, for example, the solid waste can be easily handled and transported away from the ponds. It has also the beneficial effect of making pond bottom harder and it may reduce the levels of some pathogens in the pond. However it needs site for dumping of the removed waste.

Pond drying between crops is a common practice for releasing nutrients to the pond water in brackishwater aquaculture ponds. In aerobic decomposition, the organic matter is oxidized to inorganic substances such as carbon dioxide, water, ammonia, sulphate, phosphate etc. Drying and cracking of pond bottom enhances aeration and favours microbial decomposition of soil organic matter. When ponds are drained and bottom soils exposed to air, which contains 21% oxygen compared to 0.0007% in water, oxygen supply for organic matter decomposition is greatly enhanced. Soil respiration measured in a pond bottom increased drastically during first 3 days after drying. The moisture level of pond muds affects the rate and amount of decomposition. The optimum moisture content for drying is 20%, but it might vary among soils from different ponds. Excessive drying of water-saturated soil may have adverse affect on microbial activity resulting counter productive without any benefit. Pond drying certainly enhances the mineralisation of organic phosphorous but mineralised phosphorus is subjected to available for water column as well as to pond mud. It is always better to allow saturated the mud with mineralised inorganic P rather than existing in organic forms under reducing bottom environment.

Sludge removal obviously took organic material out of the pond before it could mineralise and release inorganic nutrients back to the water column. Both ammonia and reactive ortho phosphate were lower in the sludge removal process. Disposal of sludge on high ground reduces the impact of drain harvest effluent on the receiving stream and in certain situations, may improve high ground soil quality.

Shrimp pond soils consist primarily of mineral soil (95 – 98%) and contain only a little organic carbon (2-5%). In our study in Nellore District of Andhra Pradesh and V.O.C District of Tamil Nadu, it was observed that the organic carbon content of the soil never increased beyond 1.5% during culture/harvest. Hence removal of sediments from pond bottom may not be necessary.

**3.1.2.3 Pond maintenance**

The pond dike is strengthened with soil wherever it has become weak and the inner slope of the dike is consolidated with soil. Tunnels and holes caused by burrowing organisms are to be closed/plugged. Reconditioning of the bottom trench leveling of pond bottom, repairs of sluice structures and sluice screens are also to be attended.

**3.1.3 Tilling**

Tilling or ploughing or raking the bottom soil improves soil quality by exposing subsoil to the atmosphere thereby speeding up oxidation process and release of nutrients that are locked in the soil.

**3.1.4 Eradication of predators and unwanted species**

After the crop is harvested, undesirable species like pests, competitors and predators remain in the ponds, which should be removed. Pests are species that generally do not have direct harmful effects on the cultured stock. Some pests like crabs burrow into the dikes. This can damage the dikes and cause leakage which may allow entry of undesirable species into the pond or the escape of cultured spe.cies. Competitors are species that compete for space, food, oxygen etc. with the stocked species. Predators are the species that prey on the culture stock. These species include finfishes, crustaceans and molluscs. Elimination and control of undesirable species from shrimp culture pond is very important to get good yield. There are two methods to control the undesirable species.

**Physical method**

The most effective method is drying the ponds. Direct sunlight helps to disinfect the pond bottom of light sensitive pathogenic micro organisms (bacteria, fungus, virus) and to desiccate egg, larval and adult stages of predators. It also helps in elimination of undesirable algal mats of filamentous algae. Unwanted organisms are removed from the pond by drying of the pond bottom. Other methods include installation of appropriate screens in the outlet/inlet gates to prevent entrance of undesirable species, proper maintenance of dikes and water gates to prevent leakage and to eradicate boring organisms like crabs and eel. During culture, selective harvesting or the use of cast net can be resorted to minimize the impact of undesirable species.

**Chemical method**

In cases, where complete drying is not possible, organic, biodegradable, piscicides such as Mahua oil cake (100-150 ppm) and tea seed cake (15-20 ppm) can be used. Eradication of undesirable species is very effective, easy, efficient and fast when chemicals are used. This is because chemicals act as contact or systemic poison. After the application of the organic piscicide at least a minimum period of 10 days should be given for its toxic effect to be degraded.

Plant extracted pesticides are recommended since they are biodegradable and also in most cases contribute to the fertility of the soil. The commonly used pesticides are: 1. Mahua oil cake (*Bassia latifolia*): 200 - 250 ppm (2000 - 25000 kg/ha). 2. Saponin : The recommended doses are 12 and 20 g/m$^3$ for salinities above and below 15 ppt, respectively. 3. *Croton tiglium* seed : The seed of *Croton tiglium* @ 3 - 4 g/m$^3$ water is applied. 4. Calcium carbide :It is used to kill crabs. After applying calcium carbide into the crab holes, water is poured to activate it which kills the crabs.5. Ammonium sulphate : This chemical compound, which is also a fertilizer (21 - 0 - 0), is an effective eradicant when used in combination with lime. Ammonia is released from the reaction of ammonium sulphate with lime. It is applied in pond at a dosage of 1 part of ammonium sulphate to 5 parts of lime. Lime must preferably applied first to raise the pH since the rapid release of ammonia from ammonium sulphate is dependent on high pH (above 8.0).

### 3.1.5 Liming

Liming of the pond bottom is one of the most important items in pond preparation to keep the pond environment hygienic for sustainable shrimp production. Liming is an agricultural practice that has been adopted by fish/shrimp culturists and lime materials used in aquaculture are the same that is applied in agriculture. As a practice lime materials such as agricultural limestone ($CaCO_3$), quick lime or unslaked lime ($CaO$), and hydrated lime or slaked lime [$Ca(OH)_2$] are commonly used in agriculture. Besides above lime materials other materials such as dolomite, calcite, sea shell and hydrated granules gained importance recently in shrimp culture. Most of the shrimp/fish farmers use these materials depending on local availability. Application of lime is not for fertilisation but is a remedial procedure necessary in acidic ponds to accomplish one or more of the following tasks:

1 Neutralising acidity
2 Increasing pH of bottom soil and thereby enhancing the availability of phosphorus added in fertiliser
3 Accelerating the microbial activity and thereby diminishing the accumulation of organic matter in pond bottoms and favouring recycling of nutrients
4 Maintaining the alkalinity and other physico-chemical characteristics of soil which in turn helps in enhancing fish/shrimp production
5 Improve the hygiene of the pond bottom
6 Permit normal reproduction and growth
7 Improve survival of aquaculture species
8 Greater availability of carbon dioxide
9 Enhances the nitrification due to the requirement of calcium by nitrifying organisms

**Identification of ponds needing lime**

Generally waters softer than 10 mg/l of total hardness usually need lime applications for inorganic fertilisation to be effective while ponds with water of 20 mg/l or more total hardness seldom responded to liming. Actually total alkalinity is a more reliable indicator of the need for liming than total hardness because some ponds may have a low total hardness and a high alkalinity or vice-versa. But total hardness and total alkalinity rarely should be of concern in brackishwater ponds. Many times the need for lime is first suggested when inorganic fertilisation fails to produce an adequate plankton bottom. In brackishwater soils, where water exchange is not used and soils are acidic or even where water exchange is used but where soils are extremely acidic (acid-sulfate soils), liming may assume more importance.

**Quality evaluation of lime materials**

The commercially available lime materials have to be collected and analysed for their neutralisation value. The term "neutralising value" refers to the relative ability of lime materials to neutralise acidity. Pure calcium carbonate is assigned a neutralisation value (NV) of 100 per cent and is the standard against which various lime materials are compared. The neutralising power is nothing but a statement of its strength with reference to calcium carbonate or its calcium carbonate equivalent (CCE). The lime materials were sieved through 60 mesh sieve (0.25 mm) and analysed for their CCE values. The finer the lime material, quicker is the reaction with the soil. Different lime materials available in the market vary considerably in their particle size. A mechanical analysis is made by the use of different mesh sieves to calculate the fineness factor or efficiency rating (ER).

The calculation of fineness factor rating for a sample of agricultural lime stone that was subjected to sieve analysis is as follows. The particles of lime passing through 60 mesh sieve are rated 100 per cent efficient, those passing through the 8 mesh sieve are rated 50 per cent efficient and those retained on 8 mesh sieve are rated 20 percent efficient. Finally, the per cent effective calcium carbonate (PECC) value was obtained by multiplying the estimated CCE with fineness factor values.

**Calculation of lime requirement for ponds:**

The lime requirement of a soil can be defined as the amount of lime material that must be added to raise the soil pH to 7.0. First, the amount of lime needed as pure calcium carbonate is calculated based on the actual pH of pond soil and the extent of the area to be applied. Values of liming rate as pure $CaCO_3$ (tons/ha) with an efficiency of 100 percent are calculated from the formulae given below.

$$\text{Lime needed} = \frac{\dfrac{\text{Desired pH - Actual pH}}{0.1} \times 0.5}{\text{Efficiency of lime}} \times \text{area}$$

Then, the recommended dose for various lime materials was calculated by dividing the value of lime needed as pure $CaCO_3$ with the PECC value of that particular lime material with the formulae given below.

Recommended rate of application of lime material (tons/ha) :

$$\frac{\text{Liming rate as pure } CaCO_3 \text{ (tons/ha)}}{\dfrac{[\text{PECC}]}{[100]}}$$

where, PECC = Percent effective calcium carbonate or efficiency percent

**Methods of liming**

Liming can be done in two ways.

- By broadcast over dried pond which includes the dike inner walls and
- By mixing with water and spraying over the pond bottom

In using the above methods, the lime should be spread as uniformly as possible over the complete surface of the pond and should be ploughed upto 10-15 cm depth for thorough mixing. This should be done at least 20 –25 days before fertiliser application in minimum water column. This is important because liming materials will precipitate phosphorus if applied at or near the same time in the form of fertiliser. Depending upon the soil pH, the lime is evenly spread over the whole pond bottom and upto the top of the dike and left for 10 - 15 days. During this time, lime will react with mud and will result in greater availability of phosphorus at later stage when phosphatic fertilizers are applied. Ploughing and tilling is recommended only if pond is deeply contaminated. Effective plough depth is 15 cm. A large proportion of the lime should be spread on the feeding areas and any part of the pond that has remained wet. During the crop, lime in smaller dose may be applied to maintain the pH of the pond between 7 - 8. The recommended levels of lime application during pond preparation are given in Table 1.

**3.1.6 Fertilisation**

The usual way of increasing the carrying capacity of the shrimp pond is to improve its natural fertility through the addition of organic and inorganic fertilizers. Pond fertilization is an important and necessary step in extensive and semi-intensive methods of farming operations. Prawns being bottom dwellers, benthic organisms constitute their main food items. Hence fertilization of soil instead of water is more effective. Fertilization of pond should be done after 20-25 days of liming. It should be broadcast/spread all over the pond bottom and mixed thoroughly.

**Table 1. Amount of lime (tons/ha) to raise the soil pH to 7.0.**

| Soil pH | Quantity of lime material (tons/ha) | | |
|---|---|---|---|
| | Dolomite | Agricultural | Quick lime |
| 6 to 6.5 | 5.7 to 2.8 | 5.5 to 2 8 | 4.6 to 2.3 |
| 5.5 to 6.0 | 8.5 to 5.7 | 8.3 to 5.5 | 6.9 to 4 6 |
| 5.0 to 5.5 | 11.3 to 8.5 | 11.1 to 8.3 | 9.2 to 6.9 |
| 4.5 to 5.0 | 14.2 to 11.3 | 13.9 to 11.1 | 11.5 to 9.2 |
| 4.0 to 4.5 | 17.0 to 14.2 | 16.6 to 13.9 | 13.8 to 11.5 |

**Organic fertilizers**

Organic fertilizers or manures are animal wastes or agricultural by-products which when applied to ponds, decompose slowly to release nutrients. The most common organic fertilizers are animal manures, rice bran, compost and sewage. Application of organic fertilizers especially in newly developed ponds is advisable because it serves as soil conditioner. Different forms of organic manures and percentage composition of available major nutrients are shown in Table 2. The rate of application of organic manure in shrimp ponds ranges from 500 to 2000 kg/ha as a basal dose. In saline/brackishwater conditions decomposition of cattle dung is slow and hence application of chicken manure, if available, is advisable. The rate of chicken manure is 1/3 of cattle dung.

**Chemical fertilizers**

Enhancement of nutrients using inorganic fertilisers is required in ponds to increase the phytoplankton production. Inorganic fertilizers are synthetic fertilizers that generally contain an amount of at least one of the major plant nutrients like nitrogen, phosphorus and potassium. These major nutrients are expressed on a percentage by weight basis. Nitrogen is expressed as % N and phosphorus as % phosphorus oxide ($P_2O_5$). Different forms of nitrogen fertilizers are available in the market and some of them, which are commonly used in brackishwater aquaculture are shown in the Table 3.

**Table 2. Percentage composition of available major nutrients in organic manures**

| Manure | N (%) | P (%) | K (%) |
|---|---|---|---|
| Raw cowdung | 0.3-0.4 | 0.1-0.2 | 0.1-0.3 |
| Raw poultry droppings | 1.0-1.8 | 1.4-1.8 | 0.8-0.9 |
| Sewage sludge (dry) | 2.0-3.5 | 1.0-5.0 | 0.2-0.5 |
| Village compost (dry) | 0.5-1.0 | 0.4-0.8 | 0.8-1.2 |
| Agri.farm waste (dry) | 0.4-1.5 | 0.3-0.9 | 0.3-1.9 |

Nitrates ($NO_3$) form of fertilizers are highly soluble in water. On application in ponds, a portion of $NO_3$ leaches down to the reducing zone of the pond soil and gets reduced to nitrite from ($NO_2$) and ultimately lost to elemental nitrogen by the denitrifying bacterial present in the environment. On the other hand, ammonium ($NH_4$) carriers are better fertilizers as they are absorbed by the exchange complex in the bottom soil and loss due to leaching is thus avoided. Urea is the widely used nitrogen fertilizer in shrimp ponds. Application of urea in split doses at regular intervals yield optimum result. It is concentrated in granular form and completely soluble in water. The conversion of urea into ammoniacal and nitrate forms requires 7 - 14 days. Urea is liable to be lost in leaching only for 3 - 4 days after application. Once urea is converted to ammonial form, it is absorbed by soil colloids and slowly released and nitrified to nitrates.

**Table 3. Some of the nitrogenous fertilizers commonly used in brackishwater aquaculture**

| Fertiliser | Availability |
|---|---|
| Ammonium sulfate $(NH_4)_2 SO_4$ | 20-21 % as $NH_3$ |
| Ammonium nitrate ($NH_4NO_3$) | 17-18 % as $NH_3$<br>17-18 % as $NO_3$ |
| Urea ($NH_2 CONH_2$) | 46 % N |

**Phosphate fertilizers**

Single super phosphate [Ca $(H_2PO_4)_2$ ] and ammonium phosphate ($NH_4H_2PO_4$)are the two main forms of inorganic phosphate fertilizers with available phosphate as P being 16-18 % and 48-56 % respectively, are under great use in aquaculture. In ammonium phosphate, 11 % nitrogen is also available. The rate of application of these fertilizers ranges from 25 to 100 kg/ha as a basal dose during pond preparation.

**Rate of application of inorganic fertilizers**

The rate of application of inorganic fertilizers ranges from 25 - 100 kg/ha as a basal dose during pond preparation with minimum water depth of 10 - 15 cm. When the shrimp culture progresses, depending upon the phyloplankton density as exemplified by turbidity of the pond water, the required quantity of the fertilizers may be applied in split doses at short intervals for sustained plankton production. Based on the content of available nitrogen and phosphorus, the requirement of inorganic fertilizers can be understood as shown below:

| Available nitrogen in soil (mg/100 g soil) | Quantity of urea (kg/ha) |
|---|---|
| 12.5 | 100.00 |
| 25.0 | 50.00 |
| 50.0 | 25.00 |

| Available phosphate in soil (mg/100 g soil) | Quantity of single superphosphate (kg/ha) |
|---|---|
| 1.5 | 100.00 |
| 3.0 | 50.00 |
| 6.0 | 25.00 |

The main nutrient limitting phytoplankton production in brackishwater ponds is phosphorus. Hence both phosphorus and nitrogen should be applied in the ratio of 1 : 1. Application of fertilisers in pond should be regulated depending on the phytoplankton density. Excessive application of urea and ammonium fertilizers may cause ammonia toxicity to shrimps and also may lead to algal blooms reducing of dissolved oxygen. In shrimp farming, both organic manures and inorganic fertilizers are supplementary to each other and one cannot be exchanged for the other. It is always better to apply both organic and inorganic fertilizers together as a basal dose during pond preparation for optimum result.

**3.1.7 Raising of water level**

The pond is then filled with brackish or seawater by pumping or by opening the sluice with proper screens to prevent entry of unwanted organisms into the pond. The water level is maintained to 30 - 40 cm and allowd to remain for 10 - 15 days. By this time, the colour of water may turn dark green with algal bloom and a layer of benthic algae alongwith associated food organisms will form at the bottom.

Subsequently small doses of organic and inorganic fertilizers are applied based on the observations (transparency with secchi disc 30 - 40 cm) of algal production. The water level is then raised to 100-125cm. Now the pond is ready for stocking postlarvae of shrimps.

Once the pond is filled, nutrients will release to water column resulting higher nutrient concentrations. High dissolved inorganic nitrogen (DIN) concentration might contain considerable amount of ammonia and nitrite which may harm cultured animals and thus it is always safer not to stock fish/ shrimp right after filling pond. Perhaps one-week time may be sufficient to decrease DIN concentration allowing plankton to absorb.

**3.2 Management of pond bottom during culture**

During culture, inputs like high energy protein feed, fertilizers etc are added. The feed not eaten by the shrimps sinks to pond bottom. The carbonaceous matter, suspended solids, faecal matter and dead plankton etc. also settle at the pond bottom. These materials have combined effect on the environment of the pond bottom. To understand the condition of the pond bottom, the following parameters are to be monitored regularly;

**pH of soil**

This is one of the most important soil quality parameters since it affects the pond condition. Generally, soil pH ranging between 6.5 and 7.5 is the best suited where availability of nitrogen, phosphorus, potassium, calcium and magnesium is maximum. The micronutrient whose requirements are very small is also available in this pH range. The low pH of bottom sediment indicates unhygienic condition needs regular check up.

**Organic matter**

Unutilized feed, carbonaceous matter, dissolved solids, faecal matter, dead plankton etc. settle at the pond bottom and results in the accumulation of organic loads. The change in the bottom in terms of increasing organic load should be recorded regularly for the management of the pond bottom.

**Redox-potential**

Reduced or anaerobic sediments may occur at the pond bottom of heavily stocked pond with heavy organic load and poor water circulation. Under anaerobic condition of the pond bottom, reduced substances such as $H_2S$, $NH_3$, $CH_4$ etc. are formed which are toxic to benthic organisms.

Water circulation by water exchange, wind or aeration helps to move water across mud surface and prevent the development of reduced condition. Bottom should be smoothened and sloped to facilitate draining of organic waste and toxic substances. Central drainage canal in the pond may also help in the removal of organic waste periodically. The redox potential (Eh) of mud should not exceed -200 mV.

### 3.2.1 Application of pond conditioners and chemicals to improve water and soil quality

A variety of chemicals both indigenous and imported are available in the market with high claims of efficiency. But the efficiency of most of them have not been scientifically proved. For example, bacterial and enzyme preparations are used to enhance nutrient removal, organic matter oxidation and removal of ammonia. Such bacteria and enzymes are present in the ponds and further addition is unnecessary. Similarly, Zeolite is used for the absorption of ammonia but for the efficient absorption the quantity required will be very high. Application of 350 - 500 kg / ha health stone after fertilization of the pond is recommended for optimum production of phytoplankton due to mineral ions present in it.

In shrimp ponds bottom pollution is a major problem caused by the unconsumed feed, dead plant and animal matter, exuviae of shrimps, fecal matter of shrimps etc. The very slow rate of microbial degradation naturally occurring in the pond bottom is not enough to cope up with the rate and bulk of waste accumulation. The pond bottom, thereby, becomes unhygienic and leads to a host of problems like formation of $NH_3$, $H_2S$, nitrites, nitrates, acidity, and depletion of DO. External fouling is usually associated with deterioration in the pond bottom or the water quality. The shrimps are under tremendous stress and diseases set in causing heavy mortality. The first priority, therefore, should be to ensure a clean environment for the shrimp. Chemical treatment should be resorted only if the environment has been improved but the shrimp have not moulted.

The most commonly used compound for this purpose is formalin (37 to 40% formaldehyde). The dose of formalin used to treat external fouling in shrimp a pond is much lower than that used for finfish or shrimp hatcheries. The recommended dose of formalin is 25 to 30 ppm. The diluted formalin should be applied widely over the surface of the pond. Five to six hours after adding the formalin the pond should be filled upto its normal level. If possible 5 to 10% of the water should be exchanged the following level. Formalin is a reducing agent, which removes dissolved oxygen from the water, therefore if it is applied at night the DO levels must be very carefully monitored. The above problems can also be minimised by the application of BN 10. Application of 3 kg/ha BN 10 and 100 kg/ha of health stone as supplementary dose reduce the harmful effect of bacterial load and help to keep the pond environment hygienic.

**Chlorination**

Shrimp farmers practice chlorination as a means to sterilise pond bottoms and water. To achieve this enough chlorine should be applied so as to overcome the chlorine demand of orgnic matter and other substances that react with and convert it into harmless chloride. Toxicity level of chlorine for the shrimps and the microbial population is practically same and if the shrimps are not killed then the microorganisms also will not be killed and the purpose of application will be defeated.

**Probiotics**

Now, researchers are trying to use probiotic bacteria in aquaculture to improve water quality by balancing bacterial population in water and reducing pathogenic bacterial load. Researchers are increasingly paying more attention to this new approach (ecological aquaculture), and have made considerable headway. Probiotics generally includes bacteria, cyanobacteria, micro algae fungi, etc. Some Chinese researchers translate it into English as "Normal micro biota" or "Effective micro biota"; it includes Photosynthetic bacteria, *Lactobacillus*, *Actinomycetes*, *Nitrobacteria*, *Denitrifying* bacteria, Bifidobacterium, yeast, etc. Usually, it does not include micro algae. In English literature, probiotic bacteria are generally called the bacteria which can improve the water quality of aquaculture, and (or) inhibit the pathogens in water there by increasing production. "Probiotics", "Probiont", "Probiotic bacteria" or "Beneficial bacteria" are the terms synonymously used for probiotic bacteria.

Recently, the biocontrolling theory has been applied to aquaculture. Many researchers attempt to use some kind of probiotics in aquaculture water to regulate the micro flora of aquaculture water, control pathogenic microorganisms, to enhance decomposition of the undesirable organic substances in aquaculture water, and improve ecological environment of aquaculture. In addition, the use of probiotics can increase the population of food organisms, improve the nutrition level of aquacultural animals and improve immunity of cultured animals to pathogenic microorganisms. In addition, the use of antibiotics and chemicals can be reduced and frequent outbreaks of diseases can be prevented.

# 4. WATER QUALITY MANAGEMENT IN BRACKISHWATER AQUACULTURE

**K.K.Krishnani, B.P.Gupta and R.Saraswathy**

Shrimp farming in brackishwater ponds is an economically attractive and a rapidly growing industry in many tropical nations. Shrimp farming promised quick and high returns with little investment. However, production of shrimp in ponds is often limited by the water quality degradation. Poor environmental conditions bring in a state of stress that is unfavourable for the cultured animals but favourable for the disease causing agents. Out break of disease in shrimp culture system is related to the environment factors such as deterioration of water quality and sedimentation. The water management and control of water quality are therefore key factors for regulating success in brackishwater shrimp/fish farming. Basic aspects that can lead to serious problems are

| S.NO. | FACTORS |
|---|---|
| A. | Lack of proper monitoring of water characteristics |
| B. | Excess of phytoplankton growth. |
| C. | Use of chlorine in grow out ponds. |
| D | Excessive Liming |
| E. | High alkalinity/excessive phosphorous |
| F. | High suspended solids/High organic load. |
| G. | High toxic nitrogenous and sulfurous compounds |
| H. | Lack of proper aeration and water exchange |
| I. | Over Feeding |

### 4.1 Monitoring of water characteristics

The physical variables such as pH, Salinity, Turbidity and Total Suspended Solids (TSS) and chemical variables such as Oxygen level (DO), Alkalinity, Hardness, $NH_3$, $NO_2$, Chemical oxygen demand (COD), Biochemical oxygen demand(BOD), residual chlorine and $H_2S$ are the most important parameters for the management of the pond water. The best growth performance of animals can be achieved only in optimum condition of these environmental factors. The discharge water quality is directly related to the source water characteristics. Their comparison is very useful to define standards for regulation of aqua farm discharges.

#### 4.1.1 Physical characteristics

Physical water quality parameters required for brackishwater shrimp culture are presented in the Table 1.

**Water temperature**

Water temperature plays a very important role in regulating the activities of cultured animals. The optimum level of temperature for most of the brackishwater penaeid shrimp is 28-32°C. The rate of chemical and biological reactions is said to double at every 10°C increase in temperature. This means that aquatic organisms will use twice as much dissolved oxygen and chemical reactions will progress twice as fast at 30°C than 20°C. Thus the dissolved oxygen requirement of aquatic species is higher in warmer than in cooler water.

In brackishwater shallow ponds, where regular exchange between the tidal water and the pond water is not maintained during the hot dry months, the temperature of pond water may shoot up beyond the tolerance limit causing mortality of reared prawns. The high rate of evaporation may also occur with the result of increase in salinity beyond the tolerance level. Similarly, during the winter season, the low temperature will have a chilling effect reducing metabolic and growth rates of cultured prawns.

**Table 1. Normal, optimum and critical ranges of physical characteristics of shrimp farm water**

| Physical Parameters | Shrimp farm pond water | | |
|---|---|---|---|
| | Normal | Optimum | Critical |
| Temperature (°C) | 18-32 | 28-32 | <14 |
| pH | 7.0-9.0 | 7.5 - 8.5 | <6.0 (Daily fluctuation 0.5) |
| Salinity (ppt) | 10-35 | 15-25 | < 5 and > 40 (Daily fluctuation 5 ppt) |
| Transparency (cm) | 25-40 | 30-40 | < 20 and > 60 |
| TSS (ppm) | < 100 | <100 | — |

On account of unequal distribution of temperature with higher temperature near the surface layer and decreasing temperature with depth, thermal stratification can occur in deeper ponds. This can result in reduced heat budget for the pond and formation of methane, hydrogen sulphide and ammonia can occur causing degradation of water quality. The planting of trees on pond dikes to give shade will reduce stratification but at the same time reduce the beneficial effects of wind mixing and restricts solar energy for photosynthesis. Operation of aerators during warm and calm afternoons help to break thermal stratification by mixing warm surface water with cool sub surface water.

## pH

The pH indicates acidic or basic nature of water. It is an index of the presence of metabolites, photosynthetic activity and the fertility of the pond water.. Low pH is reported to be harmful to crustaceans and higher pH can lead the alkaline death. Effects of pH on the growth of shrimp is shown below:

| pH | EFFECT |
|---|---|
| 4 | Acid death point |
| 4-6 | Slow growth |
| 6-9 | Best for growth |
| 9-11 | Slow growth |
| 11 | Alkaline death point |

The normal range for the growth of penaeid prawn is 7.0 to 9.0. Above or below this range, the water should immediately be changed. It is at maximum when photosynthetic activity is vigorous. High pH value means water is too fertile, therefore, there is the possibility of plankton bloom, which remove carbon dioxide for use in photosynthesis and more oxygen is formed. This result in an increase in carbonates concentration (Ca and Mg hardness), which react with water to form hydroxyl ions which in turns increase the pH. High pH can dramatically reduce the ammonia ionisation constant increasing % of the toxic unionized portion.

As a medium for shrimp culture, brackishwater has many advantages. It contains a high concentration of nutrient salts and is perfectly buffered medium against abrupt changes in pH. Nonetheless, It can fluctuates between 7.5-9.5 with the accumulation of residual feed, dead algae and excreta over a 24 hour period with lowest pH occurring near dawn and the highest pH occurring in the afternoon. Low variation in pH values will indicate stable phytoplankton blooms. The pH should be in optimum level of 7.5 to 8.5. It should not vary more than 0.5 in a day.

**Salinity**

The term salinity refers to the total concentration of all dissolved ions in grams contained in 1 kg of sea water. Following major ions contribute to the saline nature of water. Salinity as a single factor plays an important role in prawn farming as it is responsible for many functions such as metabolism, growth, osmotic behaviour, reproduction etc. Prawns have an optimal range of salinity for better growth and survival, depending on the species. If the salinity is allowed to go beyond the optimal limit, the prawns refrain from taking normal food and hence are emaciated and become susceptible to disease.

In pond condition, the tiger prawn *Penaeus monodon* can tolerate wide range of salinity from as low as 5 ppt to a high of 40 ppt, but white prawn *P. indicus* and banana prawn *P. merguiensis* generally prefer brackishwater (Salinity : 5 to 25 ppt). Salinity above 45 to 60 ppt can be lethal. Most species will grow best at salinities of 15 to 30 ppt.

| Ion (mg/l) | Sea water | Brackishwater | Freshwater |
|---|---|---|---|
| Chlorides | 19000 | 12090 | 6 |
| Sodium | 10500 | 7745 | 8 |
| Sulphate | 2700 | 995 | 16 |
| Mangnassium | 1350 | 125 | 11 |
| Calcium | 400 | 308 | 42 |
| Pottassium | 380 | 75 | 2 |
| Bicarbonate | 142 | 156 | 174 |
| Other | 86 | 35 | 4 |
| Total | 34558 | 21529 | 263 |

Due to high evaporation rate in summer, salt concentration in ponds gradually increases. Salinity may increase to beyond 40 ppt which can affect the growth of prawns. Water should be exchanged frequently either by pumps or through tidal exchange. The groundwater with low salinity (2-5 ppt) can be utilized for reducing the salinity. Seawater (35 ppt) mixed with groundwater can be used for preparing water with required salinity for use or exchange. Sudden fluctuations in the salinity associated with the heavy rains result in heavy mortality.

Prawn larvae are produced in waters with salinities of 28-35 ppt but advanced post larval stages often are stocked in ponds where salinity is much lower. At the time of stocking they should be acclimated gradually to the salinity of pond water so as to reduce stress and mortality. The acclimatization rate should not exceed 1 or 2 ppt per hour.

**Total Solids**

Organic and inorganic, settleable, suspended (TSS) and dissolved matter are termed as total solids. Portion of organic and inorganic solids that settles in 1h in an Imhoff cone is known as settleable solids and dissolved solids are portion of organic and inorganic solids which is not filterable. Settleable solids more than 20 ml/l result in rapid silting of the pond and decreasing of water depth. Portion of inorganic and organic solids that are not dissolved are suspended solids(TSS). Deforestation, poor soil management practices in agriculture and erosion in drainage basins of rivers are major causes for heavy load of suspended solids (silt and clay) in intake water. Optimum level of TSS for most of the shrimp is < 100 ppm. Excessive TSS lead to increased sedimentation of eco-system.

**Turbidity**

Turbidity can be caused either by planktonic organisms or by suspended soil particles. The turbidity due to silt and clay particles is also known as inorganic turbidity and can interfere with the penetration of light and by absorbing nutrients present in the water and in turns affects the growth of benthos. This can cause uneasiness and stress to the shrimp leading to disease. Suspended clay particles (>4% by volume) damage the gills of prawns by clogging it. In certain cases, oxygen deficiency has also been reported as a result of sudden increase in turbidity.

Turbidity due to both plankton density and suspended silt and clay particles can be measured in terms of transparency using Secchi disc. High value of transparency (>60 cm) is indicative of poor plankton density and therefore water should be fertilized with right kind of fertilisers. Low value indicates high density of plankton and hence fertilization rate and frequency should be reduced. The optimum range of transparency is 25-35 cm. Transparency less than 20 indicates that the water is unsuitable for shrimp culture and should be changed immediately to flush out excess bloom.

**4.1.2 Chemical characteristics**

Chemical water quality parameters required for shrimp farming are given in the Table below:

| Chemical Parameters | Shrimp farm pond water | | |
|---|---|---|---|
| | Normal | Optimum | Critical |
| DO (ppm) | 3.0-9.0 | 4.0 - 7.0 | < 3.0 |
| Total ammonia-N (ppm) | <4 | <3.7 | ---- |
| Free Ammonia (ppm) | < 0.1 | <0.1 | >1.0 |
| Nitrite-N (ppm) | 0.25 | <0.25 | >1.5 |
| Nitrate-N (ppm) | ----- | 0.2-0.5 | ---- |
| Dissolved-P (ppm) | 0.008-0.20 | 0.10-0.20 | ---- |
| COD(ppm) | <75 | <70 | >200 |
| $BOD_5$(ppm) | <20 | <10 | >30 |
| $H_2S$(ppm) | < 0.003 | Nil | >0.03 |
| Free chlorine (ppm) | < 0.001 | Nil | >0.001 |

**Dissolved Oxygen**

DO is the most important and critical water quality parameter because of its direct effect on the feed consumption and metabolism of shrimp as well as indirect influence on the water quality. DO should be maintained in the range of 3-10 mg/l. For penaeid prawns optimum concentration of water DO reported for maximum growth rate is 6 ppm. Prolonged exposure to low oxygen content causes low feed consumption which leads to slow growth and the culture organisms become inactive and they are susceptible to disease. Furthermore, many or even all organisms may die from lack of oxygen. DO in the waters comes from two sources: 1. As a by product of photosynthesis and 2. Diffusion of atmospheric air. Photosynthesis is the primary source of DO in brackishwaters. As photosynthesis occurs most rapidly in the surface layer of water and DO concentration decline with depth, in deeper ponds, DO may fall to o ppm at depth of 1.5 m or 2 m. Hence it is advantageous to have fairly shallow ponds (75 cm to 150 cm deep) for prawn, because they dwell mainly on the bottom and low DO at the pond bottom would be harmful

DO can be affected by many factors particularly water temperature, respiration of plants and animals and the level of organic matter. In tropical waters the DO level is normally low because of higher temperature. The concentration of toxic substance such as unionized/reduced form($NH_3$), sulphur ($H_2S$) and carbon metabolites(methane) increases when low DO level exists. However, in the presence of optimum level of oxygen the toxic substances are converted into their oxidized and less harmful farms. Phytoplankton mainly blue green algae in ponds may suddenly die and decompose, causing DO depletion. Hence, scum formed by phytoplankton bloom must be removed periodically in order to prevent DO depletion.

The uses of aerators result in mixing of water at surface and bottom and breakdowns DO stratification and also can eliminate black mud formed at interface of pond water and bottom mud. Water exchange is the best solution to prevent low DO problem in the pond where aeration is not practiced. In semi-intensive culture, rate of water exchange depends on the period of culture as indicated below

Intensive feeding systems require an average exchange rate of 10% per day which can be reduced to 5% in semi-intensive system. However daily water exchange usually does not improve water quality in brackishwater ponds, because routine water exchange can discharge carbon, nitrogen and phosphorous substances from ponds before they can be assimilated. Thus water exchange rates should be reduced in brackishwater ponds and this should only be used when necessary

Over feeding should be avoided in order to maintain the DO level One of the effects of overfeeding is to decease the feed conversion efficiency. Uneaten feed get decomposed, releasing nutrients into the water. Consequently, phytoplankton abundance increases as a function of increasing feeding rate. DO concentration decline more rapidly with depth as phytoplankton abundance increases in response to higher feeding rates. Besides, the likelihood of phytoplankton die-off are greater in ponds with high feeding rate and abundant phytoplankton.

**Alkalinity and Hardness**

Total alkalinity is a measure of the concentration of carbonates, bicarbonates and hydroxide ions present in the water and is usually expressed as mg/l equivalent calcium carbonate. It indicates the buffering capacity of the water. Alkalinity primarily determines the magnitude of diel fluctuation of pH of water. Waters with low alkalinity (20 mg/l) has low buffering capacity against pH changes. This results in wide fluctuations in pH value from 6 or 7.5 at dawn to 10 or even higher in the afternoon. Very high alkalinity (200-250 mg/l) coupled with low hardness (<20 mg/l) results in rise in the afternoon pH beyond 11 and cause alkaline death. Very high alkalinity water may also suffer from poor productivity due to a limitation of carbon dioxide for photosynthesis. pH of water with moderate to high alkalinity values(20-150 mg/l), normally fluctuates between 7.5 or 8 at dawn and 9 or 10 in the afternoon.

Total hardness is defined as the total concentration of divalent cations such as $Ca^{++}$ and $Mg^{++}$ ions in waters, also expressed as mg/l of calcium carbonate. The importance of hardness is closely related to alkalinity. However, low hardness water contains insufficient calcium ions. Hardness and alkalinity are more important for the exo-skeleton of prawns. Alkalinity and hardness can be increased by addition of agricultural lime (calcite or dolomite). In brackishwater, alkalinity and hardness are usually high, so these variables are seldom important in management of prawn farms.

Agricultural gypsum (ppm) = (Total alkalinity-total hardness) x 2.2

**Carbon Dioxide**

Free carbon dioxide refers to the concentration of $CO_2$+$H_2CO_3$. Concentration of $CO_2$ below 20 mg/l probably is not harmful to prawns, provided DO is high. DO concentrations declines when photosynthesis is not proceeding as rapidly as respiration, thus $CO_2$ accumulates because it is not removed for use in photosynthesis. $CO_2$ concentrations are normally high when DO concentrations are low. Because of the necessity of light for photosynthesis, $CO_2$ concentrations increase at night and decrease during the day. High concentrations of $CO_2$ also occur in ponds during cloudy weather.

It is seldom practical to remove $CO_2$ from pond waters. However, it sometimes is necessary to remove $CO_2$ from tanks/containers in which prawn are fish are reared are held using calcium hydroxide or calcium oxide. 0.84 mg/l $Ca(OH)_2$ or 0.64 mg/l CaO may reduce 1 mg/l $CO_2$

**Residual Chlorine**

Chlorine in various forms is commonly used in prawn hatcheries to disinfect sea water. This may cause toxicity problems. The residual chlorine if allowed to remain in water can form highly toxic chloramines with nitrogenous compound present in hatchery water. Permissible level of chlorine residuals in treated water for use in shrimp grow-out ponds is less than 0.001 ppm and for hatcheries, it is nil or traces.

**Nutrients- Nitrogen, Phosphorus, Nitrates and Phosphates**

Total N includes organic nitrogen, ammonia, nitrite and nitrate. Organic nitrogen is bound nitrogen into protein, amino acid and urea. Nitrate is the final product of nitrification of ammonia and is a major phytoplankton nutrient in marine environments. It is the least toxic of inorganic nitrogen compounds. Total P exists in organic and inorganic form. Organic P is bound in organic matter and inorganic form of P exists as orthophosphate and polyphosphate.

Nitrogen and phosphorous along with carbon and other trace elements serve as nutrients thus accelerate the growth of phytoplankton, which is the base of the food web in culture system. Optimum nutrient concentrations are undefined. Since coastal waters are polluted slowly, there is a possibility that prawn farms are supplied waters that are contaminated with domestic sewage. This water contains moderate to high concentrations of nitrates, ammonia and phosphate. When held in ponds, this water will usually produce phytoplankton blooms. If ponds are constructed in areas where waters are not polluted with sewage, it will be necessary to apply inorganic fertilizers or manures to foster phytoplankton growth.

**Toxic metabolites in brackishwater culture system**

**Ammonia**

Ammonia is the most common toxicant in intensive and semi-intensive culture system. Ammonia is the principal excretory product of crustaceans. Ammonia exists in aqueous solution as highly toxic unionized ammonia and non toxic ionized form($NH_4^+$). The toxicity of ammonia is known to be affected by water pH, its toxicity increases with increasing pH. Obviously ammonia toxicity will be a greater problem of high pH. However, ponds seldom contain more than 2 or 3 mg/l of total ammonia-N. Ammonia increases oxygen consumption by tissues, damages gills and reduces the ability of blood to transport oxygen. Hence, it is very harmful to aquatic organisms and should be below 0 1 mg/l. Concentration of unionized ammonia above 1 mg/l are potentially lethal, concentrations greater than 0 1 mg/l may adversely affect growth of prawn.

**Nitrite**

Nitrite is also one of the common toxicants in semi-intensive and intensive culture system. It is an intermediate product in the bacterial nitrification of ammonia to nitrate, a process called nitrification. It is toxic to fish and crustaceans and therefore is important for aquaculturists. The toxicity of nitrite is known to be affected by water pH and the presence of chloride and calcium ions. Nitrite toxicity increases with increasing pH. It decreases with increasing calcium and chloride concentrations. Hence nitrite is more toxic in freshwater than in seawater

In semi-intensive and intensive shrimp culture systems, ammonia and nitrite increases exponentially over time in both hatchery and grow-out ponds even with frequent water exchange. high concentration of ammonia and nitrite reduce shrimp growth and in extreme cases cause mortality.

Nitrite in prawn ponds is seldom at concentrations great enough to kill prawn, but the growth may be adversely affected by concentrations above 4 mg/l. The desired level is less than 0.20 mg/l for maximum production in brackishwater culture system.

**Hydrogen Sulphide**

$H_2S$ is a by product of decomposition of dead plants, animals and organic residues in the ponds. This accumulates on the pond bottom and turns the soil black. The pH regulates the distribution of total sulphides among its forms ($H_2S$, $HS^-$, $S^{--}$).

Unionized $H_2S$ is toxic to aquatic organisms: the ionic form, however, has no appreciable toxicity. The percentage of hydrogen sulphide decreases as the pH increases. Therefore, presence of sulphides is considered as indicator of organic pollution under reducing conditions. Heavy accumulation of $H_2S$ results in oxygen depletion leading to mortality of prawns. The concentrations of 0.01 to 0.05 mg/l of hydrogen sulphide may be lethal to aquatic organisms. The safe levels of $H_2S$ is less than 0.003 mg/l for prawns.

## 4.2 Eefect of abiotic factors on shrimp farming and remedial measures

Effects of various abiotic factors on shrimp farming and their remedial measures are discussed in the Table below:

### 4.2.1 Physical factors

| | FACTORS | | EFFECT | REMEDY |
|---|---|---|---|---|
| PHYSICAL | i. TEMPERATURE Excessive :-→ | | Cramped body, DO depletion, respiratory trouble, | Thermal stratification. Use of Aerators & Planting of trees on Pond Dikes |
| | ii. TURBIDITY Excessive :→ | | Asphyxiation & Osmo-regulatory Stress | Use of Sedimentation tanks following use of sand filters Application of manure /gypsum / alum |
| | iii. TSS Excessive :-→ | | Sedimentation & damage the gills by clogging & DO Depletion | Use of Sedimentation tanks following use of sand filters Application of manure, gypsum, alum |
| | iv. TRANSPARENCY | Excessive→ | Poor Plankton density | Fertilisation |
| | | Low value → | High Plankton Density | Reduction of Fertilisation, water exchange to remove excessive blooms |
| | v. SALINITY : Excessive :-→ | | Metabolism/Growth Emaciation/Stress | Water/Tidal Exchange |

### 4.2.2 Chemical factors

| | FACTORS | | EFFECT | REMEDY |
|---|---|---|---|---|
| CHEMICAL | i. pH | Low pH (<4) | Acidic Death Point | Application of Lime |
| | | High pH (>11) | Alkaline Death Point | Reduce fertilization / Water Exchange |
| | ii. DO Depletion | | Slow Growth, Increase in $NH_3$, $S^{-}$ & C metabolites->Stress → Disease/Mortality | Aeration/Water Exchange Shallow Ponds (75-100 cm deep)/ Remove scum/Avoid Overfeeding |
| | iii. ALKALINITY High (200-250ppm)→ | | Poor Productivity & Alkaline death | |

| | | | |
|---|---|---|---|
| | iv. ACCUMULATION OF ORGANIC MATTER | $NH_3$ :→ Increase $O_2$ Consumption & Damage the gills | Use of Zeolites/Bio-augmentors (Health stone @ 500 kg/ha, BN-10 @ 10-20 kg/ha) Periodic Removal of Bloom Exchange |
| | | $NO_2$ | Adequate Aeration, Removal of Org. Wast |
| | | COD/BOD Destroy gills/Inhibit normal respiration | Water Exchange |
| | v. EXCESSIVE N & P | High Algal bloom→ DO Depletion | Reduce Fertilisation. |
| | vi. INDISCRIMINATE USE OF CHEMICALS | Mutation, Resistant pathogens & Bioaccumulation | Avoid the use of such chemicals |

**4.2.3 Gaseous factors**

| | | | |
|---|---|---|---|
| GASEOUS | $H_2S$ | Poor Water Quality DO Depletion | Use of Iron Oxide(@ 1kg/m$^2$/D Bioaugmentors Central Drainage System, **Water Exchange.** Remove Org. Waste. |
| | $CO_2$ | Less important parameter In brackishwater | $Ca(OH)_2$ @ 0.84 ppm & CaO @ 0.64 ppm to remove 1 ppm $CO_2$ |
| | $Cl_2$ | Chlorination -→ | **5-10 ppm Bleaching Powder** |
| | | Excessive Chloramines | Use of Aerators |
| | | Dechlorination → | Use of $SO_2$/Activated C Hypo @ 0.5-2 ppm to reduce 1 ppm residual $Cl_2$ |

**4.3 Excessive phytoplankton growth**

Pond preparation play significant role in shrimp farming. Natural productivity is not sufficient and ponds treatments are indispensable to enhance the growth of phytoplanktons and to bring the water and soil parameters under optimum level. Application of inorganic fertilizers ($N:P_2O_5::1:1$) or manures is necessary to foster phytoplankton growth, when water is low in nutrient contents. Sometimes, ponds which develop clear water condition are repeatedly fertilised with high doses of inorganic fertilisers with the hope to produce bloom. Once the benthic algae develop, it is useless to fertilise the ponds. Badly prepared ponds can pose problems of maintaining plankton blooms, stable water conditions and eventually lead to disease syndromes. The disadvantages of various types of algae in shrimp ponds are known. Some species of benthic algae are highly toxic and hinder movement of shrimp and compete for oxygen and algae aid sedimentation and pond bottom degradation. These are all potential factors contributing to stress on the shrimp and invites disease outbreak. Dense phytoplankton blooms as net consumers of oxygen should be of greater concern than their role as oxygen producers. Hence, it is advisable to check the inherent organic load, plankton and possible contamination in the water source. Plankton density, suspended silt and clay particles can be measured in terms of transparency using Secchi disc. High value of transparency is indicative of poor plankton density and therefore water should be fertilised. Low value indicates that the plankton density is high or the water is turbid due to suspended particles and hence fertilisation rate should be reduced. The optimum range of transparency is 25-35 cm. Transparency less than 20 cm. indicates that the water is unsuitable for shrimp culture and should be changed immediately. It is wrong notion that intake of plankton rich water is good for initial tilling. Clear water is best suited.

**4.4 Chlorination**

Chlorination should be done before tilling the pond and applying fertiliser. It is safer to manipulate water quality in reservoir before release to grow-out ponds. The water should be treated with 5.0-10 ppm of chlorine.

Sufficient number of paddle wheel aerators must be placed to ensure sufficient aeration for complete dechlorination. However, this may not be cost effective for low production targets and hence, this practice is not recommended for extensive farming system because chlorine can not be easily eliminated from ponds as the use of aerators that help to oxidize chlorine is rare. This practice is generally recommended for the semi-intensive and intensive systems only. Physical aeration is the cheapest and the best available method of dechlorination available to shrimp farmers. Some substances like sulfur dioxide and activated carbon can also be used for dechlorination but these are expensive. Excess chlorine may be immediately neutralized by the addition of reducing agents such as sodium thiosulphate pentahydrate (hypo). For every 1 ppm of residual chlorine detected, 0.5-2.0 ppm hypo is suffice for neutralization. Hypo is also toxic to penaeid shrimps at concentrations above 0.5 mg/l. Without effective dechlorination and monitoring, chlorination of source water for hatchery purpose should be avoided.

**4.5 Liming**

The problem of low alkalinity (<20 ppm as $CaCO_3$) can be abated through application of liming materials. The use of agricultural lime such as dolomite and limestone for pond preparation is strongly recommended over the use of hydrated or quick lime. Use of latter two limes can destroy the initial inoculum of decompsing bacteria, which will slow down the mineralisation processes during culture operations and will increase nutrient/organic load on pond bottom which in turn will favour the growth of fouling bacteria. Hydrated or quick lime should be used only to rectify pH in high acidic ponds and in cases where disinfection is required. Excessive liming should be avoided, because it can be harmful by removing $CO_2$, precipitating dissolved phosphate and raising pH which, in turn, favours ammonia toxicity to shrimp. As a medium for shrimp culture, brackishwater has many advantages. It contains a high concentration of nutrient salts and have alkalinities of 50-75 ppm or higher. Hence, it is a perfectly buffered medium against abrupt changes in pH and liming normally is unnecessary.

#### 4.6 Excessive alkalinity & phosphorus

High pH in ponds result from high rates of photosynthesis. Ammonium sulphate lowers the pH of water but its excessive application can cause ammonia toxicity in animals in waters of high pH. Alum has been found to be very effective to lower the pH and excessive phosphorus. 1 ppm of alum is needed to remove 1 ppm of phenophthaliene alkalinity. But alum treatment does nothing to alter the conditions responsible for execessive high pH so if phytoplanktons growth continues at a rapid rate following alum treatment, the pH will rise again to dangerous levels. In such cases, treatment with agricultural gypsum (good source of $Ca^{++}$) decreases the likelyhood of dangerous high pH during periods of rapid photosynthesis, because the increase in $Ca^{++}$ ions will cause precipitation of calcium carbonate and inorganic P, both events favour lower the pH. Algicide such as copper sulphate can be used to reduce the pH and phytoplankton abundance in intensive culture system but care must be taken to avoid oxygen depletion. The usual recommendation is to apply a dose of copper sulphate equal to 1/100 of the total alkalinity.

#### 4.7 Excessive suspended solids

Inorganic turbidity should be removed at intake point, if not, sedimentation tanks/canals or basins have to be used before water can be taken into production ponds. Following sedimentation, water should be passed through sand filters as sedimentation is not adequate to rid the water to remove fine suspended particles. Source water turbid with suspended soil particles can also be cleared by applications of manure, gypsum or alum. Unless the source of turbidity is eliminated, no lasting benefit can be expected. Generally saline water facilitates the flocculation and sedimentation of suspended soil particles, and water retention times 1 to 2 hrs are adequate. The major factor favouring rapid sedimentation is reduction of velocity and turbulence of water. Baffle levies can be used to reduce velocity and turbulence where only a small area is available for sedimentation.

#### 4.8 Water exchange

Regulation of environmental factors is mainly achieved by controlling water exchange either by the use of tidal flow or pumping depending on the system. In semi-intensive culture, rate of water exchange depends on the period of culture as indicated below.

| | |
|---|---|
| 0-30 days | Daily addition of 2-3 cm + 5% every 6th day |
| 30-60 days | 10% every 5th day |
| 61-90 days | 20% every 5th day |
| 91-till harvest | 30% every 3rd day |
| | **Average 5% per day** |

Intensive feeding systems require an average exchange rate of 10% per day which can be reduced to 5% in semi-intensive system. However, daily water exchange usually does not improve water quality in brackishwater ponds, because routine water exchange can discharge carbon, nitrogen and phosphorus substances from ponds before they can be assimilated. Thus, water exchange rates should be reduced in brackishwater ponds and this should only be used when necessary.

### 4.9 Toxic nitrogenous and sulfurous compounds

**Ammonia**

Various techniques for reducing total ammonia nitrogen (TAN) concentration may be implemented. Some common procedures are water exchange, aeration and application of zeolites and bacterial products. Water exchange can dilute ammonia concentration and it can be effective if enough water is available to rapidly exchange a large volume of the pond with water of much low TAN concentration.

Zeolites are ion exchange media which removes ammonia from water but there is no evidence that zeolite can effectively reduce ammonia concentration in ponds. While, this is technically true, a very large amount of of zeolite would be required to significantly lower ammonia concentration. Besides, bioaugmentation materials such as health stone powder (500kg/ha) and BN10(10-20 kg/ha) are claimed to improve soil and water quality by reducing ammonia and hydrogen sulphide concentration Since, bacteria in these products already occur naturally in ponds, application of these commercial preparations of bacteria are unnecessary. In addition, research has failed to demonstrate benefits, they don't effect much on reduction of TAN concentration Farmers can save their money and use it for better purpose. The toxic effect of ammonia may be minimised in following ways:

i. Maintaining sufficient level of DO facilitates oxidation of ammonia to harmless nitrates by nitrifying bacteria.
ii Periodic partial removal of algal blooms by flushing or scooping out the scum which facilitates optimum density and prevents sudden die-off of the bloom.
iii. Water exchange

**Nitrite**

In ponds effective removal of organic waste, adequate aeration and correct application of fertilizers are the methods to prevent the accumulation of nitrite to toxic levels In hatcheries, control of nitrite may be accomplished by installing biological filters.

**Sulphide**

Toxic $H_2S$ levels can be controlled either by adopting central drainage system, higher rate of water exchange and other management practices like effective removal of organic waste from the pond bottom. The use of iron oxide(70% of ferrous oxide) at the rate of 1 kg/m$^2$ of pond bottom per day is also recommended but it would not be economical if bottom soil contains high levels of $H_2S$. 6.19 mg/l Potassium permanganate can also be used to remove 1 mg/l $H_2S$. Some bio-augmentations materials such as health stone powder (500kg/ha) and BN10(10-20 kg/ha) are said to remove $H_2S$, $NH_3$ and methane and speed up organic decomposition.

### 4.10 Feed management

**Proper feed management is indispensable for successful and profitable shrimp** culture. The most important difference between aquatic animal feeds and land animal feeds is the durability of aquatic feeds. As shrimps are slow feeders, feeds require good water stability, which can be increased by supplementation of phospho-lipid Improved diet water stability which should retain shape of feed at least for two hours enhances shrimp growth. Feeds which are not water stable will cause water pollution in the pond. Nutritionally balanced feeds should always be used. A typical prawn feed may contain crude protein-38%, lipids-8%, carbohydrates- 22%, crude fibre- 3 5%, Moisture- 8.6% and ash- 15% Feeds containing moisture more than 10% develops fungus and reduces shelf life Shrimp feed is an organic input into the pond Overfeeding is more dangerous than under feeding as over feeding rate can degrade the pond bottom and can lead to excessive phytoplankton, DO depletion and toxic concentration of metabolites Well prepared ponds with low stocking juveniles will not require initial feeding for a few days, as naturally generated food organism form nutritious foods for post larvae Feed may be given @ 10% of weight of shrimp in the pond during the first month, 8% during the second month, 5% during the third month and 3% during the fourth month Changes in feed brands in a given culture cycle could lead to under feeding Shrimp that are trained to accept a particular feed will find it difficult to adapt to a change Thus there are chances of the feed being leftover Shrimps prefer to feed and swim in clean shade areas of a pond As aerators are not used in extensive system to keep feeding areas clean, it is advisable to broadcast feed evenly in all areas of the pond to avoid bottom degradation in specific areas

**Conclusion**

The prawn farmers should try to maintain the water quality variables within the optimum range as far as possible by suitable management techniques It is high time to adopt the old Chinese proverb "To culture fish, one has to culture water Thus, by aiming good all round water quality management practices towards reduction of stressors, the occurrence of disease and mortality can be efficiently prevented and the magnificent industry can be made sustainable

# 5. FEED MANAGEMENT FOR SUSTAINABLE AQUACULTURE

S. Ahamad Ali

### 5.1 What is feed management?

Feed management means control and use of feed for aquaculture operation in such a manner that the utilization of feed is optimum with minimum wastage, negligible impact on environment, achieving best feed conversion ratio (FCR) and maximum growth of fish and shrimp and production. Such feed management practice if adopted, aquaculture production will be not only economical and profitable but also sustainable and eco-friendly. A best can produce poor results if the feed management is poor. On the other hand a moderate feed can produce best results under good feed management.

Most of the feed suppliers provide feeding charts for feeding fish and shrimp during the period of culture operation. These tables may be prepared based either some experiences or based on theoretical models. Since most of the feeding charts are based on size of fish and biomass in the culture pond still errors occur because accurate estimation of biomass in a pond is very often not possible correctly. In many farms excess feeding may occur due to this error. In some cases farmers may be over enthusiastic in achieving faster growth may over feed the stock leading to poor feed management.

### 5.2 Rate of feeding

Even though there are some investigations on the quantities requirements of feed in relation size and stage of the growing fish/shrimp still research on these aspects is needed for making the feeding tables more accurate. Generally the method of calculating the daily ration is based on the body weight of fish. The quantity of ration varies from 100% of body weight for larvae and fry and gradually reduced to 50%, 20%, 10%, 5% and 2-3% as the fish/shrimp grow marketable size. Suppose if W grams is the average weight of the stoked animal and if there are A number of animals in the pond then the total biomass in the pond is W x A grams which is equal to W x A/1000 kg. If feed is to be given at 10% of body weight then the quantity feed required per day is

$$\frac{W \times A}{1000} \times \frac{10}{100} \text{ kg}$$

In pond to estimate the biomass accurately is not possible. Generally periodically (once a week or 10 days) using a suitable net, sampling of the fish/shrimp and the average weight of the animal is calculated. Total biomass is calculated by multiplying the average weight by the number of animals surviving at that time. This is mainly by done by counting the numbers of animals caught per each netting and estimating the total number of animals taking into account the area covered by each netting and the total area of the pond. Some times the number of animals surviving in the pond is approximately estimated by giving a margin of 5 –10% mortality per month on the total number of animals initially stocked.

The alternative method of feeding is not by calculating the daily ration but by leaving the fish on self-demand feeding conditions. When the fish is hungry it will approach the demand feeder for its food requirements. It was observed that fish quickly learn how to obtain feed. The growth of fish also is good with best FCR and minimum wastage of feed. This method works best with finfish farming. Mechanical demand feeders and feed bags suspended at different places in pond are used in this method feeding.

Floating pellet feeds for finfish have the advantage in controlled feeding Since the feed floats on the surface of water, the active feeding by fish can be directly observed and the consumption of feed can be monitored. Based on the observations the quantity of feed to be broadcast can be regulated.

**5.3 Schedule and frequency of feeding**

The total quantity of feed required in a day should not be fed at time. Scheduling and frequency of feeding greatly help in successful feed management. Time schedules for feeding the fish may be fixed such that larger ration may be given when the fish is expected to be most hungry. If night feeding is limited the morning feeding should have larger ration. There should be a minimum of three time schedules of feeding in a day – morning, noon and evening. Some species are more active during night and should receive comparatively larger portion of the ration. Observations and experiences show that frequent feeding of small portions of the ration seems to help in better utilization of the feed and there by lead to efficient FCR. The daily ration can be offered at every 2- 4-hour interval in divided doses. There must also a mechanism in each case to monitor the feed consumption and offering of the next scheduled dose should be regulated according to the consumption from the previous feed offered. Regular observations and experience help in mastering the management of feeding in a culture farm

**5.4 Feeding shrimp in grow-out ponds**

The quantity of feed required in a day for feeding shrimp is estimated based on biomass in the culture pond. To start with feed is offered at 15 – 20% of body weight. As the shrimps grow, it is gradually reduced and brought down to 2-3% towards the end of the culture period. A model chart for feeding is given in Table 1 The entire quantity of feed required for a day in a pond should not be put at one time The shrimps should be offered feed at every 3 - 4 hours in small doses. This helps in better utilization of feed and reduces wastage. Shrimps are active feeders during night, hence large doses may be offered in the evening and during night. Keeping the feed in bamboo or velon screen trays kept inside the pond at different locations is a good practice (Fig. 1). These are known as check trays Periodically these check trays can be lifted up to check the feed consumption. A part of the feed may also be broadcasted for proper distribution. Instructions of the feed supplier with regard to feeding may be followed. Excess feeding leads to uneaten feed at the pond bottom This will cause pollution of pond water and stimulates algal blooms, which may cause stress to shrimp. Under these conditions mass mortality of shrimp may occur. Feeding a little less does not do any harm, but feeding a little excess may be harmful and can cause heavy loss. Feed management needs experience and skill to obtain best results. Water quality in culture pond is also linked to feed management. If the water quality (such as dissolved oxygen, ammonia, nitrite, nitrate, hydrogen sulphide) in the pond is poor, even the best feed may give poor performance.

Shrimp feeds should be stored properly. Absorption of moisture during storage leads to mould growth and lowers the quality Certain kinds of fungi

(*Aspergillus* sp) produce aflatoxin, which is very toxic to shrimps. Feedstocks required for use of one month may be purchased at a time and stored in a cool and well-ventilated place. For longer shelf-life, the feed may be stored at lower temperature of $10^0$ C.

Farmers should look for feeds that are as fresh as possible. Fresh feeds generally give good fishy smell. Stale smell indicates that the feed is not fresh. Water stability of feed also affects the performance of the feed. It will not disintegrate fast but also causes water pollution leading to economic loss. The feed should be stable under water at least for 2 hours. Feed should not be too hard also as it not properly assimilated the animal. Feed with poor water stability leads to poor FCR and higher cost of production

Table 1: Rate of feeding of shrimp and quantity of feed to be given in culture pond

| Week after stocking | Weight of shrimp(g) | Survival expected% | Rate of feeding of body weight % | | Quantity of feed to be given per day (kg) | |
|---|---|---|---|---|---|---|
| | | | $5/m^2$ * | $10/m^2$ * | $5/m^2$ * | $10/m^2$ * |
| 1 | 0.5 | 90 | nil | - | nil | 2 .0 |
| 2 | 1.0 | 89 | nil | - | nil | 4.0 |
| 3 | 2.0 | 88 | 4.0 | 6.0 | 3.5 | 10.5 |
| 4 | 2.9 | 87 | 3.8 | 5.5 | 4.8 | 13.9 |
| 5 | 3.9 | 85 | 3.6 | 5.0 | 5.9 | 16.6 |
| 6 | 5.0 | 84 | 3.4 | 4.8 | 7.1 | 20.2 |
| 7 | 6.2 | 84 | 3.2 | 4.6 | 8.3 | 23.9 |
| 8 | 7.5 | 83 | 3.0 | 4.4 | 9.3 | 27.4 |
| 9 | 9.0 | 82 | 3.0 | 4.0 | 11.0 | 29.5 |
| 10 | 11.0 | 80 | 3.0 | 3.8 | 13.2 | 33.4 |
| 11 | 14.0 | 78 | 2.8 | 3.4 | 15.2 | 37.1 |
| 12 | 16.0 | 76 | 2.5 | 3.2 | 15.2 | 38.9 |
| 13 | 18.5 | 75 | 2.4 | 2.8 | 16.2 | 38.9 |
| 14 | 20.0 | 74 | 2.3 | 2.7 | 17.0 | 40.0 |
| 15 | 22.5 | 73 | 2.2 | 2.5 | 18.0 | 41.0 |
| 16 | 25.0 | 72 | 2.0 | 2.3 | 18.0 | 41.4 |
| 17 | 28.0 | 71 | 2.0 | 2.1 | 19.8 | 41.7 |
| 18 | 31.0 | 70 | 2.0 | 2.0 | 21.7 | 43.4 |
| 19 | 33.0 | 70 | 1.9 | 2.0 | 22.0 | 46.2 |
| 20 | 35.0 | 70 | 1.8 | 1.9 | 22.0 | 46.2 |

The above figures are only a guideline. The actual figures should be calculated by periodic sampling and recording the average weight and estimated survival.

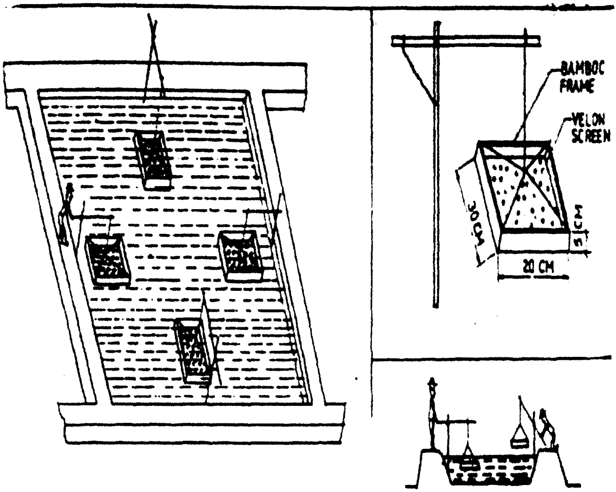



**Fig.1 Arrangement of feed check trays in a shrimp farm for monitoring the feed consumption**

# 6. ENVIRONMENT PERSPECTIVES OF SHRIMP HEALTH MANAGEMENT

T.C. Santiago, M.Poornima, S.V. Alavandi and N. Kalaimani

Aquaculture has become the fastest growing activity contributing significantly to national economic development through export of fish and fishery produce and providing food security to the country. Indian aquaculture sector has achieved remarkable growth during the past 15 years, especially with respect to shrimp production through aquaculture. Disease problems in culture systems have become a significant constraint to production from aquaculture sector affecting economic development of the farming communities in many countries around the world including India. It has been estimated that economic losses due to disease and environment-related problems account to annual losses to aquaculture production to the tune of more than US$3 thousand million per year in the Asian countries alone according to the estimates made in the year 1995 (Subasinghe, 1996). Despite good management practices adopted by aquaculturists, disease and mortality problems continue to confront shrimp aquaculture sector including emergence of new disease problems. In this context, it is essential to understand aspects of disease management in aquaculture systems both at macro-level, *i.e.*, global level, regional level, including national levels, and also at micro-level, i.e., on farm / in hatcheries, and explore possibility of available avenues for disease prevention and control.

Attention to disease problems was paid only when widespread outbreak of disease alarmingly reduced the profit from shrimp farming projects. It has become essential for shrimp farmers to understand the biological and environmental factors that lead to disease development, the maladies that can cause considerable loss to cultured shrimp, the early detection of incidence of diseases and drawing up farming strategy that would minimise or prevent the onset of diseases.

## 6.1 What is disease and how diseases develop?

As any other living organisms, shrimp also have specific physiological functions for growth and development, which is greatly influenced by various factors of the environment in which they are living. Any impairment in the physiological functioning may lead to abnormal condition of an organism, and this phenomenon is known as disease. However, many experts consider that there are 3 factors viz., host (shrimp), the environment and disease-causing organism (pathogen) which interact with each other and result in the occurrence of disease. A decline in host's immunity is the main cause of disease. A lot of factors will impair shrimp health and the most important pre-disposing factors leading to diseases in shrimp culture are:

I. Adverse environment
II. High stocking density with limited water exchange facilities
III. Nutritional deficiency/poor nourishment
IV. Accumulation of unused feed
V. Inadequate aeration
VI. Sub-optimal or heavy algal blooms in the pond
VII. Physical injury and
VIII. Presence of virulent pathogens in high count.

In these, changes in the physical or chemical factors will be obvious, but the biological factors will be subtle and complicated. This can be explained by micro ecology. This refers to the interaction of biological factors and it explains the interaction between normal microorganisms and its environment.

**Host**

Like any other crustaceans, shrimp host's body is covered by exoskeleton, which is regularly replaced by a new one during moulting. The moulting process exerts energy requirement on the shrimp and renders the shrimp susceptible to disease agents or cannibalism. In addition, the shrimp's nutritional well being, size and immune response determine its degree of resistance to disease agents. Behavioural characteristic such as burrowing at the pond bottom also exposes the shrimp condition prevailing in the pond.

**Environment**

The term environment in aquaculture comprises the pond soil, rearing water and the various living organisms in it. The living organisms include not only shrimp but also other aquatic fauna and flora including pathogenic organisms. The survival and growth of the organisms is largely influenced by various physico-chemical parameters such pH, dissolved oxygen, temperature, light etc. Any abnormal change in these factors will adversely affect shrimp in the culture system. For example, high ammonia level, low dissolved oxygen etc. are stressful and may affect the survival of shrimp.

**Pathogen**

Various pathogenic organisms may be present in the aquaculture system. They may be the part of the natural flora and fauna of the rearing water or pond soil. Various disease causing organism of shrimp have been reported. Mere presence of these organisms may not cause any disease condition. However, when present in large numbers these may readily invade the injured tissues get established and multiply resulting in disease and death. Nevertheless, the quantitative level of pathogen is influenced largely by prevailing culture condition such as availability of food source, temperature, dissolved oxygen, pH etc.

## 6.2 Interactions of pond environment in shrimp culture

Disease prevalence in populations and ecosystems is influenced by numerous environmental factors, including infectious organisms such as fungi and viruses, pollutants such as chemical and biological wastes, and shortage of food and nutrients. This complex of factors and their interactions make tracking and assessing the causes and effects of individual diseases extremely difficult. The disease problems in penaeid shrimp aquaculture have escalated since the late1990s. The diseases of cultured penaeid shrimp include syndromes with infectious viral, rickettsial, bacterial, fungal, etiologies, as well as noninfectious diseases, caused by environmental extremes, nutritional imbalances, toxicants and other factors.The two significant components of the pond environment are the pond water and sediments which interact continuously to influence the culture environment. Pond management activities which influence the culture environment include feeding, use of aerators, water exchange and liming. The production system evolved from extensive toward intensive with increasing inputs of high quality feed and water supply. Consequently, waste loads from culture ponds as uneaten feed and metabolic wastes also increase. A major concern shrimp farming industry is the discharge of nutrients from shrimp farms, with the potential to contribute to increased algal blooms, oxygen depletion of bottom waters and reduced biodiversity. Most of the nutrients discharged from intensive shrimp farms originate from the formulated feed. Therefore, efforts to improve feeding strategies must focus on both optimizing production and minimizing waste. Feeding strategies also influence water quality and shrimp health. The time of feeding was very important to ensure rapid consumption of the feed by shrimp, thereby minimizing the loss of nutrients and resulting in an improvement in growth rate. The organic component of the accumulated sediment is a mixture of pond soil organic content and detrital material. This detrital material is composed of sedimented organic material from plankton, shrimp faeces and uneaten feed. The character of the accumulated sediment is therefore dependent upon culture intensity, pond soil organic content, and water exchange practices. Problems associated with the pond bottom and accumulated sediment occur when excessive organic material builds up causing release of ammonia, organic sulphur compounds. As accumulated sediment is known to be undesirable, need to be removed. Frequent water exchanges are advocated. The development of acid sulfate soils, and associated release of toxic levels of aluminum, precipitation of iron, and alterations of water chemistry e.g. calcium and magnesium. may indirectly cause production failure by increasing physiological stresses and lowering the immune response. Inadequate sediment removal would cause water quality problems in the subsequent crop. In areas with high pond density, the emitted chemical and biological pollutants are recirculated among farms, and consequently, the degree of self-pollution increases. In order to reduce disease risk, the grow-out period in shrimp farming is often shortened, resulting in harvesting of smaller shrimp. Sometimes, cultivation continues until first signs of disease appear when the crop is immediately harvested and can still be marketed, but at lower quality.

**6.3 The role of pond environmental factors in disease outbreak**

Viral and bacterial diseases, together with poor soil and water quality and deficient environmental management of shrimp farms are the main causes of shrimp mortality. Chemical and biological pollution by farms includes disposal of pond effluents and sludge in coastal waters, salinization of soil and water, misuse of chemicals, including antibiotics and pesticides and under some conditions, the host and its pathogen may be co-existing with little or no adverse effect. In penaeid shrimp, there are examples of normally innocuous epicommensal organisms on shrimp gills causing disease when host populations are crowded and environmental conditions are stressful such as high BOD combined with low dissolved oxygen conditions. Instances are common in which bacteria that may be part of the shrimp's normal microflora are found causing disease in stressed shrimp, and there are viruses which seem to cause little or no disease in some shrimp species, genetic strain, or life stage of the same species. Thus, apparently healthy shrimp have constant low levels of bacteria, especially *Vibrio* spp., present in the hemolymph, although their mechanisms of defence seem capable of controlling these bacteria under normal circumstances. Common problems in the open water exchange system include phytoplankton crashes, deteriorated pond bottoms and bacterial diseases. A phytoplankton crash causes a significant increase in ammonia in the water, a decrease in dissolved oxygen and a rise in organic material. This stressful situation, together with increased bacterial concentrations, often leads to outbreaks of vibriosis, *Zoothamnion* infections, and luminescent *Vibrio* in the ponds. Fluctuations in normal environmental conditions e.g. oxygen, temperature, salinity have a significant effect on the virulence of *Vibrio harleyi*, with salinity being more lethal to shrimp than temperature. Low oxygen levels, which are a common problem in ponds with high shrimp stocking density, increase sensitivity to vibriosis in penaeid shrimp.

It is also interesting to note that Baculovirus and White Spot virus can be present in shrimp ponds without causing major losses .The disease occurrence in shrimp ponds in Hainan, China was closely associated with excessive stocking and poor water quality. In the Philippines, the Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV) prevalence in various wild populations of *Penaeus monodon* has been correlated with shrimp culture intensification and mangrove status. White Spot virus disease seems to be triggered or aggravated by changes in sea water quality including, hardness, temperature and dissolved oxygen. Sudden change in pH or low dissolved oxygen levels can precipitate an outbreak of Yellow Head Virus disease, and pollution from outside, such as insecticide residues that have a very high direct toxicity on shrimp may be important at sublethal levels as predisposing factors for disease. Other studies have shown that salinity reductions cause physiological stress in crustaceans and lower their tolerance to pollutants , indicating that toxicants in combination with environmental factors may act synergistically. Clearly, physiological stress seems to be one of the most important factors triggering the disease outbreak.The method for ameliorating this problem is high levels of water exchange. Water quality management was achieved by a combination of flushing the pond with clean seawater and management of the phytoplankton bloom by assessment of pond colour. There appears to be a clear linkage between environmental conditions and disease, although the precise nature of the relationship is complex and has to be established.

**6.4 Antibiotics and chemicals usage in shrimp aquaculture**

An extensive range of chemicals, such as disinfectants, therapeutics, antibiotics, vitamins, immunostimulants, and bioremediation products, have been used to treat pond soil and water .The use of chemicals usually increases with farming intensity, but their environmental impacts are unknown. Disinfection by chlorine is widely used as a disease-preventing measure in intensive shrimp farming. Chlorine kills bacteria and viruses, but also small crustaceans and other invertebrates that could act as vectors for the disease-causing organisms, besides controlling phytoplankton and macroalgae abundance. The impacts of chlorination have received limited investigation. Another issue is the use of antibiotics in shrimp farming. This includes misapplication of some chemicals e.g. the excessive prophylactic use of antibacterials and insufficient understanding of mode of action and efficacy under tropical aquaculture conditions, as well as uncertainties with regard to legal and institutional frameworks to govern chemical use in aquaculture as there are many potential side-effects from excessive use of antibiotics. The majority of administered antibiotics will ultimately end up in the environment as a result of uneaten treated food and contaminated excrement. The appearance of drug residues in non-target organisms, human health issues and ecological impacts associated with antibiotic uses raise concern. The continued use of antibiotics and their persistence in sediments tends to lead to the proliferation of antibiotic-resistant pathogens, which may complicate disease treatment. The presence of antibiotics in bottom sediments may also affect bacterial decomposition of wastes and hence, influence the ecological structure of the benthic microbial communities. Antibiotic use reduces natural microbial activity, which leads to waste accumulation and reduced degradation and nutrient recycling.

Consequently, the pond system will increasingly become a throughput system where natural feedback controls and regulators are cut off. This results in loss of buffer capacity and ecological resilience

**6.5 Environment management strategies for disease prevention and control in shrimp farming**

An understanding about the environment, biota and biology of the target species along with the in depth knowledge of the disease, pathogen, disease development, diagnostics, epidemiology and control measures are essential factors in management of a disease problem. Hence, Shrimp health management requires a holistic approach, addressing all aspects that contribute to the development of disease. Disease out break is an end result of negative interaction between pathogen, host and the environment. Hence, management of disease problems must be aimed towards broader ecosystem management with a view to control farm-level environmental deterioration and to take preventative measures against the introduction of pathogens into the aquaculture system. The emphasis should be on better management for prevention, which is likely to be more cost effective than treatment, involving both on-farm management and the management of the environment. Steps must include reducing the use of chemicals and drugs. Regulations with respect to land and water usage, environmental protective measures, inputs that go into the aquaculture systems, farm-wise and region-wise must be put in place by the Government for disease management of aquatic animals and sustainable development of aquaculture at large. In addition, research and development, training programs, extension. and information exchange would help achieve the objective of disease prevention and control in aquaculture effective.

The ultimate goal of most aquaculture operations is to produce maximum possible biomass per culture unit area in a sustainable manner, regardless of the type of operation and the species cultured. However, the production depends upon a number of factors including environmental conditions, availability of good quality water, nutrition and disease and mortality of cultured stock. Incidence and severity of infectious disease outbreaks very often depend on the quality of environment. Hence the foremost important step in aquaculture health management is to provide the best quality environment within the culture unit.

**6.6 Approaches to reduce disease problems in shrimp farming**

Several factors may be involved in the occurrence of epizootics of cultured stock and are often complex and difficult to pinpoint. Therefore, disease management must be viewed with a holistic angle, considering the host, pathogen and environment and their inter-relationships. Health management in aquaculture is defined as a process encompassing pre-border (exporter), border, and post-border (importer) activities, as well as relevant national and regional capacity-building requirements (infrastructure and specialized expertise) for addressing aquatic animal health related activities, and development and implementation of effective national and regional policies and regulatory frameworks to reduce the risk of disease spread through movements (intra- and international) of live aquatic animals. Hence, treatment of disease should not consider the pathogen alone. Management of disease problems must comprise of broader ecosystem management with a view to control farm-level environmental deterioration and to take preventative measures against the introduction of pathogens to aquatic animals. The emphasis should be on better management for prevention, which is likely to be more cost effective than treatment, involving both on-farm management and the management of the environment. Steps must be initiated towards reducing the use of chemicals and drugs. Regulations with respect to water usage, environmental protective measures, inputs that go into the aquaculture systems, farm-wise and region-wise must be put in place by the Government for disease management of aquatic animals and sustainable development of aquaculture at large. In addition, research, training programs, extension, and information exchange would be more effective and responsive to farmers' needs if based on System Management Approach (SMA). The FAO's Code of Conduct for Responsible Fisheries would provide a good base for the national and international cooperation in harmonizing aquatic animal health management activities

**6.7 Probiotics**

Microbes play both direct and indirect roles in aquaculture. They not only cause diseases but also are beneficial. As a soil flora, they too influence the aquatic environment. Their beneficial role had been recognized more than fifty years ago and the beneficial bacteria had been defined as probiotics in animal husbandry. They have been used to raise healthy and disease resistant farm animals. They have been accepted as better, cheaper and more effective in promoting animal health than antibiotics, in farm animals. Of late researchers tried to look for beneficial bacteria for use in aquaculture. Large number of isolates have been isolated that are useful in imparting resistance to disease and improving soil and water quality. However, the results are not always encouraging. This may probably be due to the selection of inappropriate microorganisms. Before recommending an organism as a probiotc, it is necessary that the bacteria have to be evaluated whether it is able to impart resistance and compete with the potential pathogenic bacteria. It should be able to colonize and prevent the establishment of the pathogenic bacteria. This involves the viability of the strain and its ability to live within the larvae and in the environment. The pathogenesis of the organism to the target animal has also to be tested in actual farm condition apart from the laboratory experiments. If these characteristics are positive it may be an efficient probiotics. The next step would be to determine the route of administering the strain either by bath or by mixing with the feed Finally economic evaluation has to be done to see whether it is worth the investment. Certain characteristics, such as the ability to produce adhesins, inhibitory substances like bacteriocines, antibacterial substances and siderophores, competition with pathogens for chemicals and energy, and the ability to boost the immune response, in addition to being non-pathogenic to the target animal have been suggested as traits required in an organism to be a candidate probiotics However, in most instances selection of bacteria as putative probiotics thus far has been based on an empirical approach In aquaculture, the use of probiotics.

Probiotics are defined as microbial cell preparations or components of microbial cells, which have a beneficial effect on the health and well being of the host (Salminen *et al.* 1999). Probiotics can help to build up the beneficial bacterial flora in the intestine and competitively exclude certain pathogenic bacteria Many studies elucidate the use of lacticacid bacteria as probiotics (Gatesoupe 1994; Robertson *et al.* 2000;Verschuere *et al* 2000) The microbial cultures produce a variety of enzymes like amylase, protease, lipase, xylanase, and cellulase in higher concentrations compared to the native bacteria, which help to degrade waste. These bacteria have a wide range of tolerance for variations in salinity, temperature, and pH, which usually exist in aquaculture operations.Probiotics is a big business today in Indian aquaculture, worth 109 million $, and most of them are imported. A survey in Andhra Pradesh, the leading State in India for aquaculture activities has revealed that farmers are using both water and feed probiotics (Rao *et al*. 1999).

The water probiotics contain multiple strains of bacteria like *Bacillus acidophilus*, *B. subtilis*, *B. licheniformis*, *Nitrobacter sp*., *Aerobacter sp*., and *Saccharomyces cerevisiae* while feed probiotics contain *Lactobacillus sp*., *Bacillus sp*. or Saccharomyces *cerevisiae* .Probiotic supplementation of live microorganisms in aquaculture aids in preventing disease, thereby increasing production and decreasing economic loss. Probiotics applied through feed beneficially act upon shrimp growth, ultimately increasing production.Water quality plays an important role in aquaculture production. Water quality deteriorates during culture mainly due to the accumulation of metabolic wastes of living organisms, decomposition of unutilized feed, and decay of biotic materials. Changes in water quality can influence survival of organisms as they become vulnerable to disease. But an addition of beneficial bacterium as probiotics helps maintain water quality, thereby improving survival and growth. Dissolved oxygen in the culture medium is an important factor not only for the respiration of aquatic organisms but also to maintain a favorable chemical and hygienic environment in the water body. The pH of the culture medium plays an important role on the organisms. It changes with the accumulation of residual feed, dead shells, and excreta. The toxicity of ammonia is pH-linked. Ammonia is the main end product of protein catabolism in aerobic conditions. Nitrate is reduced to ammonia in anaerobic conditions. Microorganisms can convert ammonia into nitrate by nitrification through the intermediary product nitrite.

### 6.8 Immunostimulants

The Invertebrates encounter all the usual sorts of challenges to self-integrity. Their habitats are laden with infectious agents: viruses, bacteria, fungi, protists, and other animals. Shrimps have innate defense systems, including the phagocytic cells, production of toxic oxygen and nitrogen metabolites, and melanization pathways, use of RNA interference (RNAi), pattern-recognition receptors (PRRs), anti-microbial peptides (AMPs), which effectively help in combating infection. However, with the advancement in aquaculture technology, application of extraneous substances to boost immune system of shrimps has come into practice. These are usually chemical substances, which aid animals (shrimp) in defending themselves against disease outbreaks and are called immunostimulants. β-1, 3 / 1, 6- glucans have been reported to be most promising substances with immunostimulatory properties. A number of other substances, such as laminarin, chitosan, saponins, barley glucans, lactoferrin, zymosan, dextran, peptidoglycans (PG), lipopolysaccharides (LPS), inulin, levamisole, herbal extracts, *etc*. are also reported to be useful in enhancing shrimp immune system.Management of the pond environment is probably the most important factor for disease prevention in shrimp aquaculture. But it is often not sufficient since the pond is an open system impacted by human activities in the surrounding landscape as well as by regional and global transportation. mangroves provide key inputs and support to shrimp farming. However, overexploitation of the mangroves exceeds the environment's carrying capacity for clean water and recycling of nutrient wastes, which may trigger disease problems. The removal of mangroves will eventually also lead to a shortage of wild larvae and adult breeders, which then need to be brought from other areas, increasing the risk for spread of pathogens. The general approaches include

1. Lower intensity and pond densities
2. Sterilize pond environment .Treat and re-circulate pond water
3. Integrate systems for effluent treatment and resource management
4 Keep farming within carrying capacity of local environment
5. Judicial use of antibiotics and medicines

**6.9 General guidelines for shrimp health management**

Shrimp disease is a major constraint to aquaculture production. The most successful strategies for controlling diseases in shrimp ponds are Better Management Practices that emphasize non-stressful environment for the shrimp which has a great influence on the efficiency of shrimp production. Hence maintaining good water quality is very important to reduce disease risks and to achieve better shrimp production.

1. Check the pond daily for sick or dead shrimp or other signs and record them
2. Check the health of the shrimp regularly using a clean and dry cast net or check tray
3. In sick shrimp observe for white spots, check gills, gut content, water quality and pond bottom condition
4. If shrimp are swimming in the morning (oxygen problem), change 15-20 cm water immediately and reduce the feeding rate
5. Plankton bloom is essential for successful shrimp culture. In early stages of culture (4 to6 weeks) if the color of the pond water is clear, add mixture of organic (10-30 kg./ha.) and inorganic fertilizers (1-3 kg./ha.) to get bloom.
6. Sufficient water must be kept in the pond to reduce risks of the growth of benthic algae. The water depth in the shallowest part of the pond should be at least 80 cm.
7. If there are benthic or floating algae in the pond, remove them manually
8. During water exchange, each time the exchange should not exceed 30% of water in the pond and ideally it should be 10% of the water each time.
10. It is recommended to use water for exchange only from a reservoir. Water should be left for at least 7 days in reservoir before pumping to the grow-out ponds
11. Do not exchange water when there is drainage from nearby disease affected pond.
12. If the water color is too dark, do not use any chemicals to kill the algae. Exchange 10cm of water.
13. Agrilime should be applied regularly to control water pH within the optimum range of 7.5-8.5, and limit diurnal pH fluctuation. Agrilime should be used after every water exchange or after periods of heavy rain. For acid soil or orange water, quick lime (CaO) should be applied along the pond banks
14. Do not use in pond any equipment (nets, bowls, floats etc) which are used in other pond/s, as they might carry pathogens
15. Do not through the black soil on the pond slopes. Remove it away from the pond
16. The pond bottom soil should be checked weekly once, especially at the feeding area or trench for black soil, benthic algae and bad smell

17. Water should be filtered using twin bags of 10 holes/cm mesh at the water inlet point to avoid entry of carrier fish and crustaceans which may be predator / competitors for shrimp.
18. Maintenance of pond management records is necessary to identify problems pond environment to identify and rectify the problems at the initial stages
19. Do not use of harmful/banned chemicals, pesticides and antibiotics
20. Dissolved oxygen (D.O) should not be allowed to drop below 3 ppm at any time. Provide adequate aeration.

# 7. BETTER MANAGEMENT PRACTICES IN SHRIMP FARMING

**M.Muralidhar, B.P.Gupta and P. Ravichandran**

## 7.1 Introduction

Shrimp farming is one of the most important contributors for the national income that provides economic opportunities for the coastal population in India. The momentum of growth in shrimp aquaculture acquired during late eighties and early nineties started declining since late nineties due to occurrence of white spot syndrome virus (WSSV), and stipulations of Supreme Court. In recent years, the sustainability of shrimp farming has been questioned in view of the various environmental and social concerns raised. The major concern is the environmental safety of the coastal zone since shrimp farming is an integral part of the coastal environment.

Shrimp farming, like many other farming activities, is dependent upon the use of natural resources water and land. It is essentially the use of these resources along with major inputs seed and feed by aquaculturists that determines the nature and scale of environmental interactions. The present day shrimp aquaculture is able to thrive even under severe environmental, physical and biological stresses which are manipulated based on the understanding of experiences of successful management practices adopted by different culturists over the years. Some of these suggested practices could potentially result in positive benefits to the environment and differ from regions to regions. Adoption of proper management strategies depending on the site environment characteristics, system of culture, the type of management and the needs of the local population will definitely lead to sustainable development of shrimp farming. Globally, these management strategies are generally outlined in the form of Codes of Conduct, Guidelines and Better Management Practices (BMP) issued by the various agencies. FAO, NACA, UNDP, WB and WWF published International Principles for Responsible Shrimp Farming in 2006. The salient points pertaining to soil and water parameters are presented under the headings of water use and feed management along with the guidelines for implementation Publication pages of NACA (www.enaca.org) gives several examples of BMP programs in Asia, including extension manuals and guide books from several countries Experience on well designed and implemented BMPs in several Asian countries support producers in reducing the risk of shrimp health problems and the impacts of farming on the environment, producing quality produce and improving the social benefits from shrimp farming and its social acceptability and sustainability

These guidelines can never be considered as a solution for all the problems but at best can be taken as an indication of possible solutions since the environmental and social issues are all very site-specific. Although the terms BMP, good aquaculture practices (GAPs) and others have been used almost interchangeably to define practices for the sustainability of the aquaculture sector, GAP often refers to practices that address food safety as opposed to BMP that tend to include practices relevant to environmental protection, food safety, social responsibility and disease management Many of the practices no doubt improve the production efficiency in the long run, but poor cost – benefit ratio may deter farmers in adopting some of them. BMPs can be country specific, or developed for a particular location, taking account of site characteristics, local farming systems, social and economic context, markets and environments. In India, for example, experiences of NACA have shown that although principles are widely applicable there is considerable local variation in BMPs. BMP are often voluntary practices, but can also be used as basis for local regulations, or even certification programmes. While extension messages are often focused on ways to increase production and quality of the product, BMPs can facilitate the farmer to farm shrimp in a more sustainable way taking into account also environmental and socio-economical considerations.

### 7.2 Better management practices

Management strategies for sustainable shrimp farming can be done at two levels – one is at the level of the farm which involves proper utilization of resources and inputs and has to be followed by the farmer and the other is at the level of policy makers so as to integrate shrimp farming in the overall development plan of the coastal zone.

#### 7.2.1 Farm level strategies

- Farm siting, design and construction
- Pond preparation
- Seed quality and stocking densities
- Soil and water quality management
- Feed quality and management
- Health Management
- Waste water management
- Harvesting

#### 7.2.2 Policy level strategies

- Integrated coastal development for sustainable shrimp farming
- Proper land use zoning and provision of buffer zones
- Regulations regarding permitted and not permitted activities
- Regularization of issue of licenses/permits for the permissible activities
- Introduction of non-regulatory mechanisms in the form of incentives, voluntary codes of conduct and introduction of best management practices
- Provision of infrastructure in the form of 'Aquaculture estates'
- Capacity building among the different stakeholders and creating awareness regarding coastal zone management
- Encouraging the various users of the coastal zone to form self-help groups, formal and informal associations for self-monitoring the environmental impacts of the different activities.

### 7.3 Development of location specific BMPs

A framework was developed to study and develop location specific BMPs (Fig.1). Questionnaire survey has to be conducted at each site and based on the survey existing farming systems have to be classified and categorised in relation to management practices and environmental conditions. Adoption rate of BMPs and the factors influencing the adoption have to be assessed. Investigations are to be carried out on soil and water quality and shrimp health status and crop performance from each site to assess the performance of BMPs. Specific experimental studies have to be conducted and based on the scientific data and wide consultations, refinement of BMPS will be done and they will be adopted/translated into location specific BMPs after subjecting to economic, social and environmental costs.

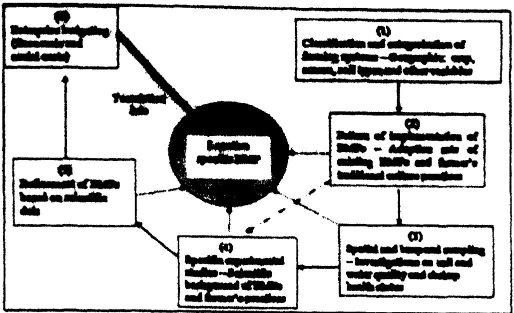


**Fig.1. Framework for the development of location specific BMPs**

### 7.4 Cluster farming

Some of BMPs can be easily implemented by farmer's cooperation and forming societies. More positive points can be realised in the cluster farming through societies compared to independent farmers. Societies can target small and poor aqua farmers and creating awareness on BMPs such as decrease in the use of chemicals/probiotic/inputs that could reduce the production cost and stopping the use of banned antibiotics. Co-operation in buying high-quality farm inputs such as seed at competitive price, access to credit from the banks, increased co-operation in general improvement works such as deepening inlets are few benefits from societies.

### 7.5 Conclusion

Most of the general BMPs are being adopted by an increasing number of farmers in India. Lack of discipline and co-operation among the farmers is the most important BMP responsible for the setback of shrimp farming. Hence, farmers should be facilitated to adopt and adapt management practices suited to local conditions so that crop insurance would become a risk management tool. Wide spread adoption of BMPs in the shrimp farming sector, leading to improved yield, traceability and a safe, quality and environmentally sound shrimp product for domestic and international shrimp markets. Many of the practices are not cost-effective. More in-depth studies are required for the development of location and system specific and cost-effective BMPs incorporating principles of eco-based management and bio-security protocols and to demonstrate and validated them further to make the shrimp farming sustainable.

# 8. AQUATIC BIOREMEDIATION IN COASTAL AQUACULTURE

**K.K.Krishnani and B.P.Gupta**

The best growth performance of shrimps can be achieved only in optimum condition of water quality parameters. Often, the increasing impairment of coastal water quality affects the aquaculture profitability. The water released from aquaculture ponds contains nutrients, organic matter, suspended solids and microorganisms, causing algal blooms, DO depletion and stress, which are unfavorable to the animals but favorable to the disease causing agents, particularly when the intake and drainage systems of the aquaculture farms are both based on the same water source. Adverse pond conditions such as low DO, high nutrient load, ammonia and nitrite in the aquatic environment may cause non infectious diseases; muscle necrosis, body cramp, incomplete molting, asphyxiation, acid sulfate disease (acidosis), black gill disease, red disease and soft shell. The most common procedures for removal of toxic metabolites of aquaculture water are aeration and water exchange. The physical methods are not economically feasible because of odour problems and vast area requirements. Water exchange can be effective if enough, good quality water is available to rapidly exchange the pond water. Aeration can not reduce toxicants effectively in brackishwater ponds. Most of the previous works also highlight the use of commercially available activated carbons / bioaugmentation materials and ion exchange using zeolite, which are relatively expensive and less feasible to use in developing countries. Furthermore zeolite can not reduce ammonia from brackishwater and the large amount of zeolite needed to significantly reduce ammonia concentration would be impractical. Furthermore, application of bacterial augmentation products seems redundant as bacteria in these products are already available naturally in the ponds. Successful aqua-farming requires the safe removal of the contaminants from aquatic environment. Therefore, development of newer technologies / methods for their safe removal from the environment is essential.

## 8.1 Bioremediation

Bioremediation is a biotechnological tool which involves the use of indigenous and non indigenous micro-organisms or its enriched culture in ponds to enhance the rate of the biodegradation of contaminants and mineralization of organic matter and to get rid of undesirable waste compounds. Bioremediation can provide a low cost alternative to other remediation techniques. Bioremediation greatly improves water quality and reduce the pollution level of wastewater before its release into the environment. During the process, micro-organisms, usually bacteria feed on the contaminants and they provide enzymes to enhance mineralization of organic matter and to convert toxic complex molecules into water and carbon dioxide or other harmless smaller molecules. Other advantages of bioremediation are improving immunity of cultured animals to pathogenic micro-organisms and prevent the level of infection and the frequent outbreaks of diseases. In addition, beneficial bacteria competitively exclude the pathogenic bacteria or produce substances that inhibit the growth of the pathogenic bacteria.

## 8.2 Anaerobic ammonia oxidation

The culture of marine and brackishwater organisms in aquaculture systems generates nitrogenous metabolic loads mainly ammonia in the ponds. Conventional bioremediation for ammonia removal involves nitrification and denitrification.

However, nitrification requires high oxygen supply coupled with side effect of mild acidification whereas denitrifiers produce potent green house gases. Conversely, anaerobic ammonia oxidation (Anammox) is an innovative biotechnological process, which is based on energy conservation from anoxic ammonium oxidation with nitrite as the electron acceptor. Rates of anammox are higher in the coastal sediments, which is promising for low cost ammonia removal from wastewaters. Closing the nitrogen cycle in the water treatment system by integrating anaerobic ammonium oxidation (anammox) process in culture ponds and re-circulating systems is advantageous due to the complete nitrogen removal through oxidation of ammonia by nitrite under anaerobic condition without any organic electron source.

### 8.3 Plant assisted bioremediation

Apart from microbial bioremediation, green remediation or phytoremediation is one of the alternatives technologies for removing toxicants from the environment. Organisms such as algae and zoogleal and filamentous bacteria growing on aquatic macrophytes and other submerged substrates/surfaces are called as periphyton. It improves production and water quality. Periphytic bacteria in the biofilm play a key role in the production of enzymes and degradation of organic matter and environmental toxicants. The improved growth has been attributed to the enhancement of the colonization of epiphytic biota by the additional surface area created by the substrates which in turn provides a natural food supplement for the shrimp.

### 8.4 Green-water technology

Green water culture system is biological approach integrating the culture of other economically important species with shrimp farming for bioremediation of chemical and microbial pollutants in the system. Euryhaline fishes having broad diet spectrum and tolerance to poor water quality are ideal candidate species for use in green water technology. Greenwater technology applied with zero water exchange and re-circulation systems have the following advantages: Condition water by bioremediation of chemical and microbial pollutants; Economical because of reduced capital investment and operating costs; Environmental sustainable due to reduced water use through zero water exchange and recirculatory system; Prevents entry of possible toxic contaminants and pathogens from external water sources and thus controls disease outbreaks; Avoids use of commercially available costly bioaugmentors / water additives; Recycles biodegradable nutrients.

### 8.5 Summary

It is clear that water resources will be under increasing pressure for human use and future demands for aquaculture based food supply will increase water demands from the sector. During culture period, even under emergency situations, many farmers are unable to exchange water due to non availability of good quality water from the source. Often shrimp ponds are completely drained to facilitate harvest. This wastewater may be particularly high in organic matter, nutrients, suspended solids and microorganisms due to mechanical disturbance of the pond bottom and the large volume of discharge. These nutrients and organic matter are biodegradable. Under these circumstances, treatment of aquaculture water in the culture pond itself and for its reuse purposes is a sensible mean to support the further growth of aquaculture industry without excessive water demands that are environmentally unsustainable. Hence, the development of simple and cost effective bioremediation technology for the augmentation of aquaculture water may offer advantages of water and area savings, reduced risk of contamination and better environmental control. This assists the farmers to improve culture water / wastewater quality and make their farming practices more sustainable.

# 9. INTRODUCTION TO NANOPARTICLES AND ITS APPLICATIONS

R. Saraswathy, K.K. Krishnani, M. Muralidhar and B.P. Gupta

In 1959, Richard Feynman, a professor at Cal Tech introduced the world to the expansive concept of Nanotechnology and he explained that "There's Plenty of Room at the Bottom", hypothesizing that atoms and molecules could be drastically manipulated. The fact that water doesn't stick on lotus leaf lends itself to the concept of nanotechnology. Although nanotechnology is a latest development for us, our forefathers used nanoscience knowingly or unknowingly in the preparation of Indian medicine for effective treatment.

Nanoparticles are defined as particulate matter, a sub-fraction of colloids, with a dimension of less than 100 nm. A given quantity of a chemical made up of nano sized particles have a vastly greater amount of surface area to volume ratio than the same quantity of chemical at a conventional size, as a result, nano sized catalyst can consume less energy and generate less waste. Environmental nano technologies contribute to economic growth and innovation while at the same time allowing sustainability by getting more function on less space.

## 9.1 Properties of nanoparticle

Physical and chemical properties of nanoparticles are different than larger particles of same material. The reasons are:

1. Increasing surface area depends on the changes in the distribution of surface edges, steps, kinks and terraces
2. Surface free energy will change as a function of particle size thus influencing the thermodynamics and chemical reactivity
3. Atomic structure variations by changes in bond lengths, bond angles and other defects near and on surfaces
4. Size quantization effects modify the electronic structure of the material as the band structure well known in bulk material, begins to resemble discrete energy states of small molecules
5. Nanoparticles stability can be drastically altered if water chemistry changes. Example, Sea water mixing with river water was shown to remove all inorganic nanoparticles from the suspended load due to salt induced aggregation

## 9.2 Types of nanoparticles

There are two types of nanoparticles, naturally occurring and synthesized nanoparticles.

Natural nanoparticles have existed in volcanic dust, most natural waters, soil and sediments and they can profoundly influence the quality of the environment. Aquatic nanoparticles influence the nature of engineered water chemistry and systems differently than similar materials of large size. Natural nanoparticles are generated by a wide variety of geological and biological processes. Organisms have also evolved in the environment containing natural nanoparticles.

Synthesized nanoparticles are produced by different methods such as physical, chemical and environmentally friendly manufacturing processes using living organisms and live & dead plants. Manufactured nanoparticles show some complex colloid and aggregation chemistry, which is likely to be affected by particle shape, size, surface area and surface charge as well as the adsorption properties of the material. Abiotic factors such as pH, ionic strength, water hardness and organic matter will alter aggregation chemistry and are expected to influence toxicity. To overcome the negative impact of nanoparticles produced by physical and chemical methods on the environment, now the green nano technology (Nano bio synthesis) is getting explored. Green nano technology enables environmentally friendly manufacturing processes that reduce waste products.

**9.3 Behaviour of nanoparticles**

To better understand the fate and behaviour of nanoparticles in aquatic systems, it is essential to understand their interaction with natural water components such as environmental colloids and natural organic matter under a variety of physico-chemical properties like pH, ionic strength and type & concentration of cations.

Surface properties of nanoparticles such as surface coating, aggregation and disaggregation will largely determine the bioavailability, fate and behaviour of nanoparticles. These are influenced mainly by pH and humic acid. At low pH (pH 2), nanoparticles are present as individual and positively charged in the presence or absence of humic acid due to high electrophoretic mobility (EPM), whereas at pH 4, large aggregation occurs in the presence of humic acid due to decrease in EPM. High pH (pH 6) leads to porous aggregates in the presence of HA and compact aggregates in the absence of humic acid. Porous aggregates leads to slow sedimentation and keep nanoparticles in water column for long period.

In aquatic systems, nanoparticles play an important role in the solid/ water partitioning of contaminants. Contaminants can be partitioned by adsorption to the surface of nanoparticles, absorption into the nanoparticle, co-precipitation during formation of a natural nanoparticle or trapped by aggregation of nanoparticles. Aggregation and Stabilization are two factors that affect contaminant sorption onto nanoparticles. Aggregation leads to settling of particles and reduced transportation. Stabilization maintains nanoparticles in water column and increase their transportation rate and distance.

**9.4 Application of nanoparticles**

Nano technology promises environmental benefits such as reducing green house gas emissions, environmental remediation, generating and using energy more efficiently and even cleaning up existing contamination. Nanoparticles may impact the environment in four possible ways: a) Direct effect on biota, b) Changes in the bio availability of nutrients, c) Indirect effects on ecosystem (i.e.) break-up of refractory natural organic substances and d) Changes on the environmental micro structures.

Several natural and engineered nanoparticles have strong antimicrobial properties as they are excellent adsorbents, catalysts and sensors due to their large specific surface area and high reactivity. These nanoparticles are not strong oxidants and are relatively inert in water. Therefore, they are not expected to produce harmful DBPs (Disinfection byproducts).

Nanoparticles like zero valent iron and iron oxide are currently under active investigation for soil remediation. These natural nanoparticles occur in a wide spectrum of pH, salinity and geological settings and are involved in catalysis and organic transformation. Naturally occurring environmental nanoparticles can play a key role in important chemical characteristics and the overall quality of water. It destroys unwanted matter like dissolved salts and chemical compounds in water by using u-v light and visible light.

NZVI is highly useful to reduce bromate in water which is carcinogenic and for dechlorination of dissolved Poly chlorinated biphenyl (PCB) and also for reductive immobilization of Cr (VI) in water and in sandy loam soil. Naturally occurring calcite is useful to reduce nickel content in drinking water. Silica magnetite nanoparticles are helpful for isolation and purification of DNA from soil by simple, rapid and inexpensive method.

**Some of the common nanoparticles and their applications are listed below:**

| Nanoparticles | Applications |
|---|---|
| Nano zero valent iron (NZVI) | Dechlorination of polychlorinated hydrocarbons<br>Pesticides & organic solvents<br>Remediation of inorganic ions<br>Immobilization of heavy metal in water and soil |
| Iron, $Fe^{++}$ & FeO | Improves phytoplankton growth<br>Removal of chromium and dechlorination of hydrocarbons |
| Aluminium silicate | Carbon sequestration & pollution trapping |
| FeS, ZnS & CuS | Metal ion transport in oxic & anoxic aquatic systems |
| Chitosan | Personal care products, biomedical products, food wraps flocculants in water & wastewater treatment |
| Nag | Portable water filters, clothing, coating for washing machine, refrigerator & food containers |
| $TiO_2$ | Air purifiers, water treatment systems for organic contaminant degradation |
| ZnO | Antibacterial creams, lotions and ointments, deodorant, self cleaning glass and ceramics. |

To summarize, nanoparticles are small but its benefit to this world is huge. Nanoparticles can help us enormously in varied fields like agriculture, environment, medical science, etc., when used prudently. The world foresees that nanoparticles hold the key for future development and to regain lost ground.

# 10. AQUACULTURE WASTEWATER MANAGEMENT

B.P.Gupta and M.Muralidhar

The shrimp farm wastewater is the most significant of all factors that contributes to the degradation of environment and causes 'self pollution' with in the system due to intensification of technology. The terms 'discharge' or 'wastewater' are more appropriate rather than effluent since aquaculture is a farming operation and not a process industry. Discharge from aqua farms ultimately reach the receiving waters (rivers, creeks, estuary and Sea) or to the land. Aquaculture farms are developed in groups and in certain locations the inlet from one farm takes off water from outlet of the nearby farm. These may lead to spreading of diseases on an epidemic scale in certain locations.

## 10.1 Characteristics of shrimp farm wastewater

A comparison of shrimp farm effluent with wastes from other potential sources of pollution (Table 1) showed that the shrimp farm waste water is considerably less polluting than that of domestic and industrial effluents.

Table 1. Comparision of shrimp farm wastewater from different sources

| Parameter | Waste water | | | |
|---|---|---|---|---|
| | Shrimp farm | Domestic (untreated) | Domestic (treated) | Fish processing |
| BOD (mg/l) | 4.0 – 10.2 | 300 | 200 | 10,000 – 18,000 |
| Total Nitrogen (mg/l) | 0.03-1.24 | 75 | 60 | 700 – 4530 |
| Total Phosphorus (mg/l) | 0.01- 2.02 | 20 | 15 | 120-298 |
| Solids (mg/l) | 30-225 | - | 500 | 6880-7475 |

Although the quality of shrimp farm wastewater is far less polluting than some other sources of wastewater, water pollution problems may arise because of the large volumes discharged, particularly when shrimp farms become too concentrated in areas with limited water supplies or poor flushing capacity. Unfortunately it has been all too common in Asia for many investors to rush into the same area, such that one farm's discharge becomes another farm's intake. In India, such unregulated development was observed in certain areas of Andhra Pradesh and Tamil Nadu. Because of such overloading, shrimp farmers are the first to be affected because of the poor quality of the intake water. The quality of the wastewater is essentially dependent on the type of culture system.

In composition, shrimp pond wastes from semi-intensive and intensive farms consist of (a) solid matter (uneaten food, faeces, phytoplankton and colonising bacteria) and (b) dissolved matter (ammonia, urea, carbon-di-oxide, phosphorus and other chemicals, drugs and antibiotics). The former component is the result of physical qualities of feed and fertilization levels while the latter component is influenced by the chemical composition of the feed ingredients and the fertilisers. It has been reported that 77.5% of nitrogen and 86% of phosphorus added to the intensive ponds in Thailand are lost to the environment.

Biological and Chemical Oxygen Demands (BOD and COD) of the wastewater is an indication of the level of microbial and chemical interactions. Soil particles are also suspended by water flowing through canals and water currents generated by wind action and mechanical aeration. Another major source of suspended solids is the draining of pond for shrimp harvest. The out flowing water suspends sediment from pond bottoms, and effluents during the final phase of harvest are especially high in suspended solids.

## 10.2 Effect of effluents in receiving water bodies

Discharged water from farms often has significantly different dynamics than the receiving waters. Hence, some information on the effects of effluents on receiving waters is necessary. The receiving water can assimilate pollutants through various physical, chemical and biological processes. Shrimp farm effluents contain high concentrations of dissolved salts from brackishwater and seawater used to fill ponds, exchange water, and maintain water levels, so discharge of effluents into freshwater areas can cause salinization. Obviously, indiscriminate discharge of shrimp pond effluents can cause eutrophication, excessive turbidity, sedimentation, toxicity, and salinization in aquatic habitats. Reduced dissolved oxygen in receiving waters due to discharge of wastewater low in dissolved oxygen and breakdown of dissolved and particulate organic matter and other waste materials (BOD and COD). These negative impacts can reduce the value of coastal ecosystems for other uses and adversely affect the native flora and fauna. It is important to reduce the volume and enhance the quality of shrimp pond effluents and minimize the possibility for adverse environmental impacts. It should be possible to greatly reduce these impacts through better practices. Nevertheless, it is impossible, at least in the near future, to eliminate discharge from shrimp ponds.

The concentrations of water quality variables provide useful information on the relative pollution strength of effluents, but the pollution load cannot be estimated from concentration alone. The load of a pollutant in effluents can only be determined when both effluent volume and concentration of pollutant are known. For example, two effluents might each have a biochemical oxygen demand ($BOD_5$) of 15 mg/L, but volume might be 1,000 $m^3$/day for one effluent and 100,000 $m^3$/day for the other. The $BOD_5$ load would be 15 kg/day for the smaller effluent and 1,500 kg/day for the larger effluent. Obviously, the pollution potential of the larger effluent is much greater than that of the smaller one. The principal waste materials from semi-intensive and intensive shrimp culture and their probable effects are presented below:

| Waste material | Primary effect | Secondary effect |
|---|---|---|
| Uneaten food, faeces and dissolved excreta | Increased nutritional loading, reduced oxygen in receiving waters; Increased sedimentation | Environmental changes; Reduced carrying capacity of ponds; Pollution of source water. |
| Therapeutant drugs and chemicals | Ecotoxicological impacts | Mortality; Sublethal effect on target and non-target organisms; Poor water quality; Pollution. |
| Antibiotics | Increased antibiotic resistance among microorganisms. | Increased problem of treating bacterial diseases; Residues in marketed shrimp. |

The influence of pollution on a water body depends upon the input of pollutants and the capacity of the body of water to dilute and assimilate pollutants. Thus, larger, thoroughly-mixed bodies of water that are well-aerated by wind action have a greater capacity to dilute and assimilate pollution without negative impacts on water quality and aquatic life than do smaller, less-mixed water bodies. Where there is rapid exchange of water between estuaries and the open sea through tidal action and currents, the potential for water pollution is greatly diminished. Thus, even if we know the pollution load from shrimp farming in coastal water, it would usually be impossible to estimate the effects this pollution load will have on coastal water quality because the assimilative capacity of the coastal water is seldom known. Furthermore, even if the assimilative capacity of the coastal waters is known, we would need to know the quantities of all natural inputs and all other inputs of pollutants from human activities to determine if the effluent from shrimp farming would cause water quality impairment.

### 10.3 Treatment of pond effluent

Treatment of shrimp pond effluent offers considerable potential for reducing impacts on the water quality in the external environment. Low cost but effective methods for the treatment of effluent are needed to help in the total effort to make shrimp culture as sustained industry. One major problem is the dilute but high volume nature of effluent in comparison with traditional forms of wastewater. Despite this complication cost effective technology is now available in several temperate countries to reduce loads of biochemical oxygen demand, suspended solids, nitrogen and phosphorus. Effluent treatment systems can be divided into physical and biological. Chemical methods are generally ineffective. Combinations of physical and biological methods are advocated for the removal of various suspended and dissolved matter from the wastewater.

Nutrient and organic matter concentrations in effluent are highest during shrimp harvesting and subsequent cleaning of ponds, when effluent quality can be very poor due to disturbance and release of material previously bound to the sediment. Effluent targets could be met in many circumstances by concentrating management efforts on treating harvest water and sediment. A significant proportion of nutrients and organic material is tied up in bottom sediments, and consequently some countries have placed restrictions on indiscriminate discharge of shrimp farm sediments.

It is also becoming clearer that controlling effluent loads to coastal environments requires a 'holistic' type approach. This should be based on understanding of the local farming systems, properly defining problems (if any), and development of locally appropriate solutions depending on individual farming systems or location specific environmental concerns.

#### 10.3.1 Physical methods

Physical treatment systems remove solids. The two physical treatment processes mostly used and best developed for shrimp culture effluent are settlement ponds and rotating filters, both designed to reduce BOD, suspended solids and nutrient loads. They do so with varying degrees of efficiency. Other possibilities for reducing TSS and BOD levels are decreased stocking rates (which would also lower disease potentials and cut maintenance costs) and increased aeration rates.

**Settlement ponds**

Sedimentation of the wastes is the most cost-effective method of treating them. The effectiveness of sedimentation ponds depends on the design, the surface area available for settling and the retention time of the effluent. It was found that a period in excess of 3 days necessary to remove over 60% of the suspended solids According to another study, upto 90% of suspended solids, 60% of BOD and 50% of total phosphorus loads can be removed by settlement treatment

It has been reported that one hectare of setting pond is required to handle 900 $m^3$ of shrimp pond effluent per day. But they need to be well maintained otherwise they would not be as efficient and even act as the source of dissolved nutrients Use of coagulants would further improve effluent setting However, studies have shown that settlement ponds during operations will be ineffective due to the presence of phytoplankton, bacteria and algae. They would be of greater use during and following the harvest of shrimps when solid loads are a greater and particulates more dense Settlement ponds at this time will prevent the release of most pollutants and be easier to operate than during normal operation.

**Filtration systems**

Usually mechanical screens made of mesh or sand are generally expensive but are self contained units requiring less land per unit of effluent flow than settlement ponds. Filtration appears to be the best treatment process to remove suspended solids with less than 10 mg/l possible under various conditions. However studies have found these systems inefficient at reducing particulates and BOD.

Constructed wetlands could also curb wastewater discharges. If properly monitored wetlands may eliminate secondary treatment.

### 10.3.2 Biological treatment

Biological treatments have variously been tried in shrimp culture. They use plants and/or animals to reduce nutrient loadings and particulate matter from intensive shrimp culture. There are numerous options for biofiltration, including use of molluscs, seaweeds, finfish ponds, and recent studies have been done on the use of halophytes for treatment of saline aquaculture effluent, such as *Suaeda* and *Salicorna, which* are succulent marsh species, which can be used as fodder for some livestock The effluent discharged during normal shrimp farm operation is rich in nutrients and microorganisms are potentially suitable for culturing finfish, molluscs and seaweed

The dissolved nutrients could be removed by culturing seaweeds, which can absorb them and the light suspended solids which have not settled can be removed by culturing molluscs which are filter feeders. Sea cucumber can be used for the removal of settled particulate matter. The seaweed *Gracilaria* is an attractive species to grow in polyculture with mussels in a biological treatment system, because it can remove soluble nutrients (N and P). The disadvantage include sensitivity of some species to salinity fluctuations, light limitation in turbid waters and smothering of weeds by solid matter and microbial growth in the highly turbid shrimp pond effluent One advantage of *Gracilaria* is that it can be processed for extraction of agar as an additional small source of income.

Another alternative biological method is to use mangroves to treat shrimp pond effluent, either by retention of a mangrove buffer zone close to the shrimp ponds or by replacing mangroves for the deliberate purpose of wastewater treatment. But care is required, not to overload the system.

### 10.4 Water quality monitoring programs

Monitoring programs to assess shrimp farm effluents are needed. These monitoring programs can determine if best management practices (BMPs) installed on shrimp farms actually improve effluent quality and reduce pollution loads. Water quality monitoring programs provide information on concentrations of water quality variables in effluent and at selected locations in water bodies receiving effluents. A great number of water quality variables could be measured, but for practicality, only the important variables should be measured. The variables of most importance in shrimp farming effluents are those most likely to cause deterioration of water quality conditions

**Location, frequency and time of sampling**

The selection of sampling stations for water quality monitoring programs will vary with location and purpose of the monitoring effort. Generally the sampling stations should be at the water intake (pump station) and at the effluent outfall. Once the sampling stations have been selected, they should be permanently marked in the field and on a map so that samples can always be taken from the same places. Sampling should be done at weekly intervals or more frequently. All samples should be taken on the same day if possible, but it usually will require several hours to collect them. Hence it is recommend to begin sampling early in the morning and complete the procedure as quickly as possible.

### 10.5 Effluent Regulation

Modes of regulating effluents include disallowing discharge, allowing discharge only if effluent quality is within specified standards (water volume restrictions also may apply), allowing discharge only if best management practices (BMPs) are implemented. Concentration limits for pollutants often are established for effluents in countries that have systems for regulating effluents through discharge permits. These limits must be established with consideration of the composition of the effluents, the discharge pattern of the effluents, other uses of the receiving water and especially the most beneficial use of the receiving water, the capacity of the receiving water to assimilate pollutants, the ability to treat effluents, and a variety of other factors. The permissible concentrations of potential pollutants in effluents depend both on effluent volume (pollutant loads) and receiving water characteristics, and acceptable concentrations in effluents are greater than concentrations considered acceptable within the receiving water body as a whole. The concentrations of these variables also are permitted be somewhat greater in the mixing zone than in the water body as a whole. However, effluent limits should prevent toxicity and adverse environmental impacts even within the mixing zone. Thus, we cannot make general suggestions on concentration limits for shrimp pond effluents. It must be emphasized that these guidelines apply to the water bodies receiving effluents and not to the effluents themselves.

## 10.6 Effluent standards

One way to reduce the risk of water pollution from shrimp culture ponds is to apply effluent standards. The simplest standards have criteria regarding the permissible concentrations of selected water quality variables in effluent. A standard might specify the acceptable ranges of pH, minimum dissolved oxygen concentration and maximum concentrations of BOD, TSS and other variables.

Standards may also indicate the maximum daily quantity of a pollutant that can be discharged, for example the BOD load in the effluent cannot exceed a specified amount. Standards also may restrict the increase in a variable above the ambient concentration in the receiving water. For example, TSS concentration cannot be more than X mg/l higher than in the receiving water. Limits also may be put on the total volume of discharge per day. Qualitative criteria regarding sensible properties of effluents are occasionally included in standards.

The following standards (Table 2) have been prescribed for the waste water from shrimp culture ponds in the Guidelines issued by Ministry of Agriculture, which has been fixed at much lower levels than the General Standards for discharge of environmental pollutants prescribed under Environmental (Protection) Act vide Gazette Notification dated 19th May 1993.

In India, according to the guidelines issued by the Ministry of Agriculture, GOI, farms above 40 ha should have wastewater treatment systems incorporated in the design. More than 80% of the shrimp farms in India are less than 5 ha area and the nutrient load from each of these farms may not be very high. But overcrowding of such small farms in a given coastal area or creek may lead to cumulative nutrient loading. In such cases common wastewater treatment facility should be developed by the Government or by the local farmers' associations. Co-operation among the farmers from a given local area will mitigate this type of problems.

**Table 2. Standards for shrimp farm wastewater**

| Parameters | Final Discharge Point | |
|---|---|---|
| | Coastal Marine Waters | Creeks/estuaries |
| pH | 6.0-8.5 | 6.0-8.5 |
| Suspended Solids mg/l | 100 | 100 |
| Dissolved Oxygen mg/l | Not less than 3.0 | Not less than 3.0 |
| Bio-chemical Oxygen Demand (BOD) mg/l | 50 | 20 |
| Chemical Oxygen Demand (COD) mg/l | 100 | 75 |
| Dissolved Phosphate (as P) mg/l | 0.4 | 0.2 |
| Total Nitrogen (as N) mg/l | 2.0 | 2.0 |

# 11. PESTICIDES AND HEAVY METALS IN AQUATIC ENVIRONMENT

**K.K.Krishnani, B.P.Gupta and M.Muralidhar**

The increasing impairment of coastal water quality resulting from the discharge of domestic, agricultural and industrial waters in coastal waters has affected the aquacultural profitability in certain areas. The aquatic environment is ultimate sink for all chemicals and pollutants. Any compound that has been used in large quantities ultimately reaches to the aquatic ecosystem, although, often the aquatic environment is not the primary site of application of pesticides. Two sources of contamination of the aquatic ecosystem are recognised: Point and non point sources. Former refers to a single source of contamination such as effluents from pesticide manufacturing or formulation plants and accidental spillage and latter refers to a contamination of widespread and diffuse nature such as run off from agricultural lands and urban areas and sewage etc. Pesticides that are transported to the aquatic environment are primarily of agricultural origin.

Chemicals used as pesticides may be categorised under four major classes:

i. Organochlorine pesticides(OCP'S): These are polychlorinated organic compounds mainly with dichloro diphenyl trichloro ethane(DDT) or diene group eg. DDT, BHC, Endosulphan, Aldrin/dieldrin, endrin, heptachlor, toxaphene, chlordane and methoxychlor.

ii. Organoposphorous pesticides : These are phosphorous containing organic compounds. eg. Malathion, methyl parathion, chlorpyrifos and dimethoate

iii. Carbamates : Nitrogen containing organic compounds used as insecticides are derivatives of carbamic acids eg. Carbofuran and carbyl.

iv. Synthetic pyrethroids : eg. cypermethrin, fenvalerate and permethrin.

### 11.1 Persistence and bioaccumulation of pesticides

Many countries have banned the Organochlorine pesticides(OCP's) such as HCH, DDT, aldrin and dieldrin etc. Even though, the use of pesticides in developing countries is low, residues problems have become quite alarming which due to the continuous and uncontrolled use of highly persistent pesticides in agriculture and public health programmes. The residues that reach the hydrosphere are concentrated in certain parts of the aquatic ecosystem and persist for long time.

Due to lipophilic (bio-accumulative) nature of many of these pesticides, they tend to accumulate in fatty tissues of aquatic animals and can cause many alternations in aquatic animals from change of colour and alteration of behaviour to severe histopathological injuries to various organs and tissues. Apart from the lethal effects of pesticides, the sub lethal effects have been responsible for indirect effects such as disturbance of population dynamics, changed food habits and reproductive behaviour. The rate of bioaccumulation in aquatic environments generally appears to be higher than that in terrestrial environments which might be due to the lipophilic nature of the persistent insecticides.

## 11.2 Toxicity and permissible safe limit of pesticides

Pesticides and their residues are usually very toxic to the aquatic animals. Organochlorines(OCP's) are more toxic than organophosphorous compounds(OPC's). Among OCP's, endrin and cyclodienes (DDT) are highly toxic and present a greater potential hazard in the environment due to their greater persistence and affinity for fatty tissues and HCH(BHC) is least toxic. Endosulphan has been found to be extremely toxic to the fishes in aquatic systems and it is not considered to be very recalcitrant.OPC's have negligible chronic toxicity but some of them have moderate to high acute toxicity. Pyrethroids are not persistent in the environment but their acute toxicity is higher to fishes.

Permissible safe limit is a concentration of the toxicant that may be considered harmless or safe and does not produce any adverse sub lethal effects. In the context of supposed safe level, one tenth of the $LC_{50}$ value is used. $LC_{50}$ is a concentration of a toxicant that would kill 50% of the animals in 24 to 96 hours. The $LC_{50}$'s of some pesticides to fishes, shrimps and crabs and safe levels recommended by U.S. Environmental protection agency(EPA) to aquatic organisms are presented in Table-1.

**Table 1. Toxicity(96 h $LC_{50}$ value in ppb) of some pesticides to a wide range of aquatic animals**

| PESTICIDE | Estuarine fish | Freshwater fish | Shrimp | Safe levels recommended by U.S.EPA |
|---|---|---|---|---|
| <u>OCP's</u> | | | | |
| DDT | 0.24-0.9 | 6.0-43 | 0.6-2.1 | 0.001 |
| BHC | 30-104 | 240-1400 | < 10 | 4.0 |
| ENDOSULFAN | 0.3-2.9 | 0.2-8.1 | ---- | ---- |
| ENDRIN | 0.4-0.63 | 0.7-2.1 | 1.7 | 0.004 |
| HEPTACHLOR | 1-4 | 7-230 | -- | 0.001 |
| <u>OPP's</u> | | | | |
| Ethyl parathion | --- | < 1000-3300 | ---- | ---- |
| Acephate | ---- | 100-1000 | ---- | ---- |
| Malathion | ----- | 1200-9000 | 82 | ----- |
| Ethion | ---- | 500-7600 | ---- | ---- |
| Chlorpyrifos | ---- | 2.4-280 | --- | ----- |
| Phorate | ---- | 6-280 | ---- | ---- |
| <u>CARBAMATES</u> | | | | |
| Carbaryl | --- | 2000-39000 | --- | ----- |
| Carbofuran(ppb) | --- | 150-870 | --- | ----- |
| **SYNTHETIC PYRETHROIDS** | 0.5-12 | ---- | ---- | ----- |

The safe level recommended by U.S.EPA is well below the lowest concentration of a pesticide reported to harm aquatic organisms in laboratory toxicity tests. Tamil Nadu pollution control board has fixed up standards as tolerance limits for pesticides present in the industrial effluents discharged into marine coastal areas. According to board's recommendations, pesticides should be absent in industrial effluents.

## 11.3 Decontamination of pesticide residues from aquatic environment

The monitoring of pesticide residues in aquatic environment is indispensable due to their known lethal effects, unknown long term dire consequences and bioaccumulative toxic nature. To lessen the effect of pesticides on aquatic organisms, it would be ideal if the entry of pesticides into the aquatic environment could be prevented. However, this is not possible.

Aquatic toxicity testing is a means of identifying the risk to the non target organisms, arising from the continued use of pesticides and other chemicals which is an impossible task, if every species has to be protected from the effect of every pesticide. It is in this direction, hazard evaluation and predictive toxicology play a useful and important role. Hazard evaluation depends on identifying the sources and sinks of these chemicals in the aquatic environment. Thus it is now possible to identify pesticides and other chemicals that can be potentially hazardous to the aquatic life, without resorting to extensive experimental studies. At different levels, the risks involved and potentially hazard of a chemical including that of all new pesticides, is evaluated. And if the risks are low or negligible, further testing is discontinued and chemical may be marketed. On the other hand, if a potentially risk is indicated, further extensive tests of a complicated nature are conducted and the advisability of permitting or preventing the manufacture and marketing of such a pesticide can be made. For instance, if a pesticide is readily degradable, has low toxicity or is produced in only small quantities, further testing would be wasteful. If on the other hand, compound is to be widely used or a potential for bioaccumulation is indicated, further extensive testing is required and perhaps a decision to disallow its environmental use has to be taken.

Key factors for protecting ponds from pesticides are as follows : locate prawn farm a considerable distance from pesticide treated fields ; construct topographic barriers(ditches or trenches) to prevent run off from fields to ponds ; use proper methods of pesticide application to fields ; the pesticides chosen should be such that when used they should leave the least amount of residues ; the residues should be photodegradable and also preferably biodegradable.

Microbial degradation has been found to be very effective method to decontaminate the toxic chemicals from industrial waste. Much work has been reported on the biodegradation of chlorinated pesticides eg. HCH, endosulphan and DDT. A number of bacterial species., actinomycetes and fungal sp. are known to degrade the pesticides to various extent. As aquatic animals lack the ability to metabolise persistent organochlorines, this method can pave the way in elimination of the pesticide residues from agricultural fields and aquaculture ponds by degrading them into simpler non toxic molecules. The natural degradation products of pesticides, in general, are less toxic than the parent compounds but occasionally degradation products may turn-out to be more toxic than the parent compounds to the aquatic organism.

## 11.4 Heavy metals in aquatic environment

The wide spread contamination of aquatic ecosystem with heavy metals pose a serious environmental hazards because of their persistence and toxicity. The addition of these metals through number of industrial waste waters including those from the textiles, leather tanning, electroplating etc. in to aquatic ecosystem turn out to be serious problems of its possible entry into the food chain.

Heavy metals are among the conservative pollutants that present different problems, as they are not subject to bacterial attack or other breakdown, and are permanent additions to the marine environment. At higher concentrations, heavy metals act as enzyme inhibitors and can results in the demise of large numbers of susceptible organisms. Free metal ionic activity in sea water is a function of metal toxicity, rather than the total concentration of the metal(absorbed, chelated or complexed form etc.). Brackishwater for the culture of animals contain suspended clay particles and organic matter. Heavy metals are absorbed onto clay particles and chelated by organic matter. Some of the heavy metals also form complexes with oxides, hydroxides, and carbonates in waters. High concentration of bicarbonates and total hardness(Ca and Mg) may reduce the toxicity of metals because of their competitions for sites with high cationic forms of heavy metals.

The metals may be stored in the skeletal structure, concretions or heavy intracellular matrices of an organisms and they are released in faeces and moulting products. Sub lethal doses of heavy metals are known to have number of physiological and genetic effects on several species of fish and other aquatic organisms. Hence, toxicological studies of the heavy metals upon aquatic organisms are very important from the view point of environmental consequences. The toxicity(in mg/l) of various heavy metals to a variety of species of freshwater and marine animals, mostly fish are given below.

| Metal | 96h $LC_{50}$ value | Derived safe level | USEPA Safe level |
|---|---|---|---|
| Cd | 80-420 | 0.80-0.42 | 0.010 |
| Cr | 2000-20000 | 20-200 | 0.10 |
| Cu | 300-1000 | 3-10 | 0.025 |
| Pb | 1000-40000 | 10-400 | 0.100 |
| Hg | 10-40 | 0.10-0.40 | 0.0001 |
| Zn | 1000-10000 | 10-100 | 0.10 |

In order to save the life of aquatic organisms maximum permissible levels of the heavy metals are established by applying an application factor of 0.01 to 96 h $LC_{50}$ value. The safe levels recommended by USEPA are conservative estimates, which are 10-100 times lower than the lowest concentration which have been reported to harm organisms in laboratory toxicity tests.

Mercury is one of the heavy metals to cause most concern in the marine eco-system because its elevated toxicity especially when present in the organic form (Methylated mercury). The inorganic mercury is converted into organic mercury by anaerobic bacteria. Almost all mercury found in fish tissues is present in methylated form. The major incidents occurred in Minamata and in Iraq, all involving methyl mercury, put in evidence the hazard risks derived from consuming food rich in this chemical form of the metal. Cadmium is a ubiquitous non-essential element, which possesses high toxicity and is easily accumulated from the environment by aquatic organisms. On the other hand, many of these elements remain essential for proper metabolism of biota at lower concentration. Chromium is essential for plant and animal metabolism (glucose metabolism, amino acid and nucleic acid synthesis), however, it can be lethal for animals at elevated concentration. There are two predominant forms of chromium - trivalent and hexavalent which are found in industrial wastewaters. Hexavalent form is more hazardous to biological activity.

Sometimes wrong conclusions may be drawn from sediment analysis due to strong fluctuations in heavy metal content which is a result of flood water drainage, varying sedimentation rates and non homogenous distribution of heavy metals in sediment.

## 11.5 Conclusion

The misuse or overuse of pesticides and improper application techniques may contribute to the pesticides getting into the aquatic environment. The major thrust thus lies in decreasing the pesticide load by substituting with readily degradable or soft pesticides such as the organophosphates etc. Even among the newer compounds, the time has come to review and identify compounds that are relatively environment friendly (REF) and fit into an Integrated Pest Management (IPM) approach. As the aquatic sector is important as it provides substantial food by way of fishing and aquaculture, it is very essential to monitor heavy metal at as many trophic levels as possible in aquatic eco-system, in order to determine overall heavy metal pollution.

# 12. ENVIRONMENTAL MANAGEMENT OF AQUACULTURE FARMS

**M.Muralidhar and B.P.Gupta**

During the past two decades aquaculture has become the fastest growing food-producing sector and is an increasingly important contributor to national economic development, global food supply, food security and nutrition. Traditional shrimp culture is in vogue in India since long. With the advent of scientific methods, semi-intensive and intensive shrimp farming have come into practice. During the early nineties, shrimp aquaculture developed rapidly in the east coast states of Andhra Pradesh, Orissa and Tamil Nadu. Expanding area under shrimp culture coupled with increased production has compounded the problems threatening the sustainability of shrimp culture industry. Lack of regulation governing establishment of shrimp farms, led in some places to improper siting, overcrowding, changes in land use pattern and conversion of other habitats. While poorly planned and managed shrimp aquaculture operations have resulted in negative impacts on ecosystems and communities, aquaculture has also been negatively impacted by other unplanned activities As a result of this shrimp farmers experienced disease outbreaks in shrimp ponds. This has necessitated to evolve sound management measures for maintaining healthy pond environment in the farm.

The issues related to aquaculture and environment belongs to two broad categories - impact of aquaculture on environment and impact of environment on aquaculture. Aquaculture has both positive and negative impacts, which have received more attention than impact of environment on aquaculture. The range and severity of the adverse effects of aquaculture have been exaggerated, possibly due to high visibility of the sector, failure to distinguish between actual and hypothetical hazards and inadequate coverage of its beneficial impacts

In India, shrimp aquaculture and its unregulated growth during the early nineties also resulted in the matter being taken to the Supreme Court as a public interest litigation. The complaints included decline in quality of agricultural lands, salinisation of ground water resources, destruction of mangroves, decline in catches of shrimp and fish, nutrient loading in coastal waters, change in biodiversity, prevention of access to coastal areas for traditional users, flooding of villages, deterioration of human health, displacement of labour, etc., Following the directions of the Honourable Supreme Court, Government of India issued Gazette notification (No. 76 dt. 6.2.1997) regarding the constitution of the Aquaculture Authority of India Subsequently, THE AQUACULTURE AUTHORITY BILL, 1997 (Bill No. XVII-C of 1997) was presented in the Parliament and it was passed by the Rajya Sabha on 20$^{th}$ March, 1997.

## 12.1 Sustainable Aquaculture

The full socio-economic benefits of coastal aquaculture development can only be achieved by adopting the principles of sustainable development, which is defined by FAO as "Sustainable Development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant and genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".

Sustainable aquaculture needs adequate interaction among the social, economic and ecological changes, which accompany development. This can be achieved through an integrated approach to planning and management of coastal aquaculture. The biggest initiative for sustainable aquaculture has to come from the farmers and entrepreneurs.

Many of the problems affecting both environment and shrimp culture could be avoided by better awareness of overall coastal zone management issues, improved site selection and better shrimp farm management. At farm level proper attention need be given to site selection, designing and operation of farms so that the farming efficiency is increased and waste discharge is reduced. And at the coastal area management level, suitable integration of farming in the coastal zone is to be done in such a way that its impact on other activities as well as the impact of pollution from other sources on farming are avoided as far as possible. Due consideration must be given to the potential risks inherent in the site (soil and water quality), the potential impacts on the external environment (effluent discharge effects) and potential impacts from the external environment (pollution from agriculture or industrial sources). Each of these factors should be incorporated into risk analysis.

## 12.2 Environmental standards

Unplanned and uncontrolled developments are the main reasons for environmental problems in shrimp culture. To satisfactorily manage the scale of enrichment and ensure that ecological change does not exceed pre-determined and accepted levels, a management framework should be adopted prior to development. Such a framework should include the establishment of environmental quality objectives (EQOs) and environmental quality standards (EQSs) and must include scope for environmental impact assessment (EIA) and a monitoring programme.

### EQOs and EQSs

EQOs define the conditions to protect a particular use. EQSs are levels of particular variable associated with that use which may be imposed to ensure that the objectives are not compromised. Some of EQSs to be followed are

- Shrimp farmers must register with the local district office of the Department of Fisheries.
- Shrimp farms over 8 ha must have a waste water treatment (sedimentation) pond equal to 10% of farm area.
- Saltwater must not be discharged into public freshwater resources or agricultural areas.
- Sludge and pond bottom sediment must be confined and not pumped into public areas or canals.
- BOD of discharge water must be less than 10 mg/l.

### 12.3 Environmental impact assessment (EIA)

Environmental impact assessment (EIA) can be an important legal tool and the timely application of EIA (covering social, economic and ecological issues) to larger scale coastal aquaculture projects can be one way to properly identify environmental problems at an early phase of projects, enabling proper environmental management measures (which will ultimately make the project more sustainable) to be incorporated into project design and implementation. FAO recognise the importance of EIA and emphasised that "environmental and socio-economic impact studies should be conducted as part of the developmental process, with special regard for preserving natural marine ecological systems and the cultures of the local fishing peoples utilising them". Sri Lanka, Indonesia and Malaysia already have some EIA regulations covering development of large scale shrimp culture, but more widespread and effective use of EIA may be worthwhile. EIAs have frequently consisted of collections of largely descriptive data with a little priori consideration of the specified changes to be expected from the proposed development. Data and model predictions from the EIA are needed to design efficient monitoring programmes. A major problem with EIAs is that they are difficult (and generally impractical) to apply to smaller-scale shrimp farm developments and cannot take account of the potential cumulative effects of many small scale farms.

**Use of models in EIA**

The use of EIA in the management of coastal aquaculture development requires the application of ecological knowledge. Models can be an important tool in management both for predicting impacts and as an aid in the design of monitoring programs. For example, with respect to wastes from shrimp culture operations, there are three processes to model, the quantity of material generated, dispersion after release of discharge and biological consequences. Models may be empirical or mechanistic. The former is based on a statistical relationship between variables derived by observation, and does not necessarily require any understanding of underlying principles. Mechanistic models describe the relationship between cause and effect with the exception that all variables have significance within the natural system. Complex ecosystem models are typically mechanistic and have generally been developed in relationship to large scale or multiple developments

A sequential approach should therefore be adapted That is, to use simple models as a first stage and if the results of the investigation indicate that such models is inadequate, the second stage would be to evaluate the conceptual framework, and if necessary, increase the complexity of the model. Simple models may therefore provide an efficient means of screening for potential ecological impacts from shrimp culture and other developments in coastal environments. Data are required to initialise the model and validate predictions.

### 12.4 Environmental management plans

1. Formulation of coastal aquaculture management plan
2. Preparation of master plans for all suitable sites
3. Sustainable aquaculture plans
4. Improvement of management operations
5. Regulations

**Environment management Strategies**

Some of the important environmental management strategies to be followed are given below.

- Aquaculture should be considered as a regulated activity within the CRZ since it requires good quality saline water in sufficient quantities. Shrimp aquaculture outside CRZ will require laying of pipelines which requires high investment and will prevent the small farmers from taking up shrimp aquaculture. Sustainable shrimp farming can be developed when it is ensured that it will not adversely impact the environment and it will not displace existing activities which provide employment or produce food (rice, salt, etc.,) to coastal communities. However, these can be achieved if three major aspects are taken into consideration - (i) location and siting of the farm, (ii) concentration of farms in a given area and (iii) the level of stocking density

- Farmers should be advised to form local associations or farmers groups for resolving conflicts in water usage and other related activities. Shrimp farming through co-operatives should be encouraged to improve their socio-economic conditions.
- The integration of brackishwater aquaculture with coastal zone planning and management will be an important step for making it sustainable. Integrated coastal zone management plans should be prepared for each coastal state/ union territory with zoning for different activities and with buffer zones for preventing salinisation of soil and freshwater aquifers.
- Continuous monitoring of the environment in areas of intense farming activity should be taken up to identify the impact levels before any damage occurs to the environment. R & D support is required in developing models for assessing the 'carrying capacity' of various creeks and canals. Technical and Extension support should be made available to the farmers. Wastewater treatment should be made compulsory and common effluent treatment plants should be set up for treating the effluents of small farms.
- A systematic study should be carried out regarding the land-use pattern within the CRZ and a proper land lease policy should be adopted, which will minimise the conflict between the different users and make the landless labourer become an aquafarmer.
- Since most of the impacts are site-specific, it is essential that EIA and environment monitoring are made mandatory for larger farms. Farm siting and design approval should be mandatory. Buffer zone depending on the quality of the soil, should be provided between a shrimp farm and (i) agricultural land, (ii) village settlement and freshwater source, and (iii) the neighbouring farm.
- Best farm management practices will reduce the level of nutrient loading in the environment and lead to good growth and survival of shrimps. Guidelines already issued by the Aquaculture Authority for increasing production and productivity from improved traditional method of farming should be followed.

**12.5 Case studies on environmental impact assessment methodology for soil and drinking water salinisation study**

With the advent of scientific farming, there was a shift from inter-tidal area to supra-tidal areas, which led to conflicts regarding salinisation of adjoining lands and freshwater aquifers through seepage. Unfortunately, the issue of salinisation because of shrimp farms is blown out of proportion without any substantiating data. Studies conducted by CIBA have shown that salinisation of soil and drinking water resources due to seepage from shrimp farms is site-specific and is dependent on the quality of the soil, level of compaction of the dykes, level of usage of the freshwater and distance from the farm. In some places there is no effect on soil or freshwater resources adjacent to shrimp farms, while in other places though there is salinisation, it is restricted to a short distance from the farm. Provision of buffer zones between the different land use areas, depending on the soil quality, will resolve this conflict.

All people have a right of access to drinking water in quantity and quality equal to their basic needs. There have also been some localised conflicts between aquaculture and the villages inhabiting the neighbouring villages on account of the salinisation of the potable water supplies. In countries like Taiwan, the Philippines and Thailand, abstraction of freshwater from underground aquifers for use in intensive shrimp farming was reported to have resulted in salt-water intrusion and salinisation of freshwater aquifers.

### 12.5.1 Methodology

In order to assess the salinisation of soil and drinking water, studies were conducted in Nagai, South Arcot and Thanjavur Districts of Tamil Nadu and Nellore District of Andhra Pradesh To study the salt intrusion from shrimp farms, various sites around the farm were selected at fixed distances away from farm (0,50,100,250,500 m etc.) where, the electrical conductivity (EC) of soil is less than 4 dS/m. Soil samples were collected depth wise (surface, 50 cm and 100 cm) and analysed for the following parameters. Drinking water samples were collected from existing drinking water wells in the study area (shrimp farm) and from wells adjacent to farming area. Water samples were analysed for total dissolved solids (TDS) and chloride concentration. The data on the following aspects was also collected

- Depth of water column
- Use of water- stagnant or not
- Collect details on alternative arrangement for supply of drinking water in villages if any.

A schematic representation of selection of sites for collection of soil samples and bore wells is shown in Fig.1.

### 12.5.2 Soil salinisation

Salinity levels were high up to 250 m from the shrimp farms in the Nagai district while in Thanjavur and South-Arcot districts, the salinisation was seen only up to 100 m. But such salinisation was not solely due to the shrimp farms but due to the combined effect of both the creek and the farm. In Nagapatinam district, no agricultural activity was seen near the creeks irrespective of the presence or absence of shrimp farms, indicating that the soil salinisation was not due to shrimp culture alone. In South Arcot District, the salinisation effect was not felt much as cereals, mulberry and vegetables were grown near the shrimp farms with good yields.

The soils in the three districts of Tamil Nadu were highly saline compared to that of Nellore district of Andhra Pradesh. A survey conducted in 1984 by Soil Survey and Land Use Organisation, Government of Tamil Nadu, has reported that a total of about 20,000 ha in Nagapatinam district were affected by surface, sub-surface and complete salinity and alkalinity. Salinity problem is dominant in coastal areas in dry season due to high evapotranspiration. Hence one can't blame the shrimp farming as the sole cause of soil salinisation because shrimp farms are located in already salinated areas.

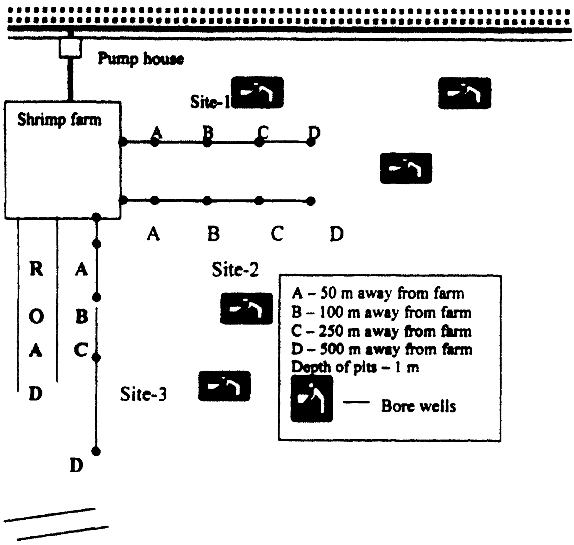



**Fig. 1. Sampling points for land and drinking water salinisation study around shrimp farms**

### 12.5.3 Drinking water salinisation

In South-Arcot district, where the intensity of shrimp farming is low, a study was made on the quality of drinking water in a village. The village has 26 bore wells and samples from 5 bore wells were chosen randomly and the potability of the water was analysed with TDS and Chloride as parameters. Considering the permissible levels of TDS (500-1500 ppm) and chloride (200-600 ppm), only one borewell situated 500 m away from the shrimp farm had potable water.

A similar study was carried out in seawater-based farms in Nellore district of Andhra Pradesh. The water near one farm is not suitable for drinking. In the remaining 3 farms, the water is potable. In the study area it was observed that water is generally brackish up to a depth of 20-30 m. Freshwater table is available at a depth of about 60 - 200 m. At such depths, the salinisation cannot occur due to shrimp farms. Further, the sea-based farms in Nellore are located between the sea and the Buckingam canal, which is a saline drainage canal, connected to the sea during monsoon months. The canal is in existence even before the aquaculture activity started and any salinisation effect would have been due to the saline water flowing in the canal. The salinisation of ground water in coastal villages is known to occur much before the initiation of shrimp farming.

# 13. CARRYING CAPACITY OF SOURCE WATER FOR AQUACULTURE PLANNING

M.Muralidhar, B.P.Gupta, M.Jayanthi and R.Saraswathy

## 13.1 Introduction

The World Commission on the Environment and Development defines sustainable development as meeting the needs of current generations without compromising the ability of future generations to meet their own needs. Sustainable development requires pragmatic management of natural resources through positive and realistic planning that balances human expectations with the ecosystems carrying capacity. The concept of sustainable development is closely linked to the carrying capacity of ecosystems. Ecosystem carrying capacity (ECC) provides the physical limits to economic development and may be defined as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined planning region without progressively impairing bio-productivity and ecological integrity. A key of sustainable development of aquaculture is to stay within the "carrying capacity" of the environment. It is difficult to manage one particular coastal natural resource or activity in isolation as it has impact on others or affected by others. Hence different coastal activities viz., fishing and aquaculture, navigation, settlement, ports and harbours, recreation and tourism, industries, waste disposal, exploitation of minerals, oil and natural gas etc. need to be managed together to sustain them. Ideal way to sustain any resource or activity is adoption of concept of integrated management.

The country has witnessed a faster development of shrimp aquaculture since 1990. The present day failure rate in shrimp farming experienced in the country is at least partly related to the very high concentration of farms in certain areas i.e., the unplanned and uncontrolled expansion of shrimp aquaculture and declining water quality. Because of the proximity of the shrimp farms to source water and the large volumes of water exchange there is a great concern that accumulation of waste byproducts from the shrimp culture facilities will impose a limit to the number of ponds that can be operated i.e., exceeding the carrying capacity of the source water bodies..

## 13.2 Importance and necessity

Most environmental assessment guidelines require analysis of the relationship between new developments or development programs and ECC. The Honduras government had stopped further development of shrimp farms until an objective determination of carrying capacity has been achieved and guidelines provided for considering further increase in area under shrimp farming for the various estuaries in Gulf of Fonseca, a large estuarine embayment on the Pacific coast of Central America. NACA study on the preliminary assessment of carrying capacity of Kandaleru Creek in Nellore District, Andhra Pradesh has recommended that Government should limit any development (intensification and or horizontal expansion). Codes of conduct and codes of practice refer to carrying capacity either explicitly or implicitly. According to FAO Code of Conduct for Responsible Fisheries, under Aquaculture development "States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities" (Article 9.1.3). In many countries there is a continued need for aquaculture and planning authorities to produce and regularly update comprehensive plans for promoting, regulating and reporting on the aquaculture sector. Given the possible contributions of aquaculture to enhanced food supply and rural development, it may be very useful to design aquaculture development plans with due consideration of existing plans and efforts aiming at food security, sustainable agriculture and rural development. Bangkok FAO Technical Consultation on Policies for Sustainable Shrimp Culture held in December, 1997 recommended that appropriate research should be undertaken to determine carrying capacity of coastal ecosystems for shrimp culture with an emphasis on application of this knowledge to local areas. International Principles for Responsible Shrimp Farming mentioned that do not locate new shrimp farms in areas that have already reached carrying capacity for aquaculture. Coastal Aquaculture Authority, Government of India in the report submitted to Supreme Court, suggested that the type of culture system and the magnitude of intensification permitted should be clearly defined for each zone based on the carrying capacity of the zone to prevent nutrient loading in the ecosystem.

The operational framework for internalization of the concept of capacity in decisions related to environmentally compatible developmental planning process involves estimation of supportive capacity, estimation of assimilative capacity and optimal allocation of resources. The carrying capacity based developmental planning process involves generation of alternative socio-economic developmental scenarios by incorporating aspirations and preferences of people, assessment of decision-makers choices and expert opinion within the assimilative and supportive capacities in the region. The supportive capacity of a region is the capacity of the ecosystem to provide resources for various anthropogenic activities in the defined planning region without impairing bio-productivity and ecological integrity. The formulation of models using water quality and estuarine dynamics data for predicting carrying capacity of water bodies will be of immense benefit to the shrimp aquaculture sector for environmentally compatible development planning.

### 13.3 Carrying capacity of water source

Carrying Capacity (CC) is the number of organisms, or number of enterprises, or total production, which can be supported by a defined area, ecosystem or coastline. Environmental capacity is sometimes confused with carrying capacity and has been subject to a range of interpretations and definitions. Environmental capacity is a property of the environment and its ability to accommodate a particular level of activity with acceptable levels of impact i.e., the rate at which nitrogen can be assimilated. While carrying capacity determination depends on both environmental capacity and the rate of waste output from aquaculture. In shrimp aquaculture CC of a water body can be used to estimate the maximum area under shrimp farming that can be accommodated without excessive water quality degradation. The water sources (brackishwater canals, estuaries, creeks, agricultural drains) are a common property and withdrawal of water from and discharge of wastes by the farms into the same water source leads to potential eutrophication and hence there is a need to study the carrying capacity of such water source. In relation to the water body receiving the discharge water from shrimp farming CC can be defined in terms of the maximum nutrient loading which can be assimilated by the water body without exceeding the permissible levels. This self limiting density *i.e.*, the number of ponds that can be operated sustainably must be quantified as a basic management parameter and its estimation requires detailed field studies and modeling. As the water quality deteriorates, carrying capacity actually shrinks, leaving the water body no longer able to support even the number of ponds existing. Carrying capacity of the water bodies is likely to become a significant issue as levels of shrimp culture activity increase.

### 13.4 Conceptual basis

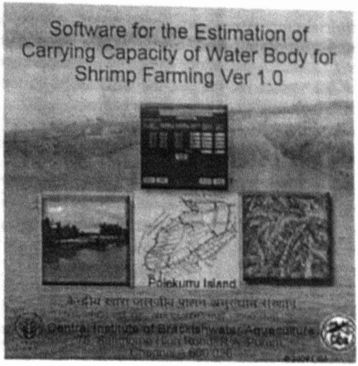
The conceptual model for carrying capacity based planning process uses various modelling and analytical techniques to estimate changes in carrying capacity indicators. The development of shrimp culture requires an evaluation of water quality in the regions of existing and proposed shrimp farm operation, especially how the water quality is influenced by the anticipated waste loads from the shrimp farms and from other wastewater discharge sources located in the region. If the combined effect of effluent loads is to reduce water quality below an acceptable value, then it can be said that the carrying capacity of the system has been exceeded. The interaction between individual farms, in which the effluent from one farm is drawn into the intake of another, may necessitate the detailed field studies and development of suitable mathematical models in a simple and cost-effective way to determine the concentration of important parameters that result from a given level of waste loading.

Carrying capacity depends largely on the rate at which the water body (creek) can dilute the effluent. The dilution rate is of great importance in predicting nutrient enrichment in the creek. Creek bathymetry and hydrology (flushing rates, volumes at high and low tide), morphology of the creek (influence water movement, mixing and stratification) along with impact from other land uses and freshwater runoff from the catchment area decides the final level of nutrients. The flushing time can be estimated in relation to the dilution rate, which is the inverse of the flushing time. A greater density of farms can be developed in areas with higher flushing rates. Current flows and water depths are important in calculating dilution rate. Phosphorous is the limiting factor for fresh water, whereas nitrogen is the limiting factor for coastal and marine water. Since both, fresh water and saline water environments persist in the brackishwater bodies it is necessary to apply fresh water as well as coastal water model. Mass balance equation with a dilution term can be used to predict the nutrient loading.

The calculated carrying capacity is very sensitive to the driving parameters, which may be site dependent and also vary with time. They are contingent on technology, preferences, and the ever-changing state of interactions between the physical and biotic environment. It is a function of position i.e., based on well mixing areas and dead zones. The distribution of critical regions in a water body (well circulated areas or poorly circulated areas) and the resultant carrying capacity will vary with the hydrodynamic conditions.

### 13.5. Methodology for the estimation of carrying capacity

The carrying capacity of different tropical aquatic systems is not well established and is likely to vary significantly according to local physical, chemical and ecological conditions. A variety of mass balance, steady state and dynamic dilution and dispersal models have been developed for the estimation of environmental capacity in respect of organic matter and nutrient loads, based mainly on temperate conditions and semi-closed water bodies. Some approaches go further, and seek to model the impact on phytoplankton dynamics, with a view to predicting more subtle impacts associated with nutrient loads, or the impact of shellfish farming on plankton density and composition. Majority of the works related to carrying capacity of water bodies were centered on bivalve culture and there is very limited studies available pertaining to shrimp culture.




Simple mass balance models were applied to Kung Krabaen Bay lagoon in Eastern Thailand for the estimation of carrying capacity. These models may tend to be inaccurate when applied to complex lagoon systems, and are difficult to apply to estuarine and delta systems. Furthermore, the rate processes and environmental quality standards required to estimate environmental capacity are poorly specified for tropical aquatic systems, as are biological indicators. The Norwegian LENKA project used mixed theoretical-empirical modeling to assess environmental capacity of different coastal systems in relation to aquaculture. Some of the studies were conducted at Rio Chouleteca Delta on the Gulf of Fonseca, Southern Honduras based on water quality, farm chemical budgets and estuarine fluid dynamics.

Central Institute of Brackishwater Aquaculture has developed the methodology for the assessment of carrying capacity of source water bodies in relation to shrimp farming with the below mentioned step-wise activities.

1. Data collection on land use pattern and existing shrimp farm area, culture system and management practices, average shrimp production.
2. Establishment of environmental quality parameters and standards
3. Quantification of the amount of nutrient load (N and P) released into the water body from shrimp farms and other activities. The nutrient overload could be from aquaculture and also from other activities on the land.
4. Use of numeric models to predict the total nutrient load in the water body and the resulting level of nutrients.
5. Estimation of carrying capacity by relating the predictions to the pre-culture values.

### 13.6. Software package for carrying capacity

Decision support software has been developed in Visual Basic to estimate the maximum allowable shrimp farming area, for a particular creek or drainage canal. The flow chart of process for the estimation of carrying capacity is depicted in Fig.1.

### 13.7. Case studies conducted

Case studies were conducted to validate the computer model in Andhra Pradesh and Tamil Nadu, where discharge water was only from shrimp farms or from both shrimp farms and paddy fields and the area recommendations for shrimp aquaculture were made by taking into account of rules of Coastal Regulation Zone and Coastal Aquaculture Authority and supportive capacity of the ecosystem. Based on the studies carried out, the tool can be customized and applied to determine the carrying capacity of other water bodies.

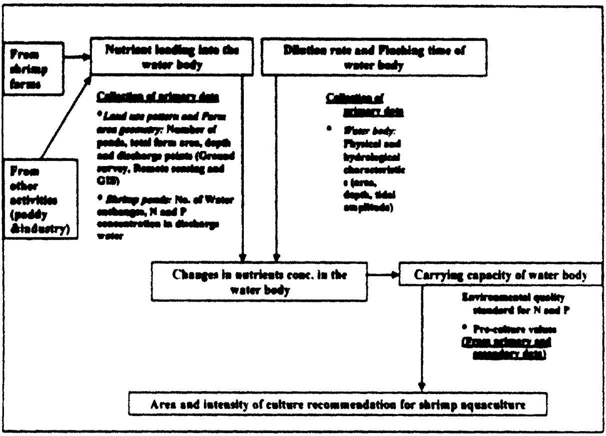



**Fig. 1. Flowchart of steps in CC estimation software**

## 13.8. Utility of software

1. The tool will help state governments and other regulatory organizations to regulate the level of shrimp farming activity for each receiving water body.
2. It will also results in awareness among shrimp farmers of the impact of shrimp farming on the environment and encourages them to pursue sustainable production methods.
3. The software permits a reliable estimation of the combined impacts of the shrimp farms and other land use impacts in a region under various scenarios of increased development
4. The carrying capacity models will provide information necessary for the formulation of strategies (preferred scenario) to integrate shrimp farming into coastal zone management.
5. The water quality data generated through field sampling and analysis will serve as the baseline to monitor the long-term trends in quality of water bodies.
6. It will help in framing future guidelines and policies for sustainable development of shrimp farming.
7. The tool increases the capacity of fishery and planning professionals to develop management systems that will reduce the likelihood of aquaculture development having deleterious impact on the environment.

8. For private entrepreneurs who would like to develop large areas for shrimp farming, this software can be used as a planning tool so as not to exceed the carrying capacity of the receiving water body.

### 13.9. Conclusion

The carrying capacity based developmental planning aims at the delineation of guidelines for decision-making related to overall regional development within the region and can be used to sensitize stake holders of the issues involved in and guide the agencies that are interested in environmentally sustainable shrimp development. The carrying capacity of all the coastal water bodies should be assessed and guidelines to be provided for considering further increase in area for aquaculture in the coastal region. Almost all of the discussions on carrying capacity focus on its estimation rather than on the issue of how to ensure that it is not exceeded or how to manage or allocate it once it has been estimated. Furthermore, approaches must take account of other resource users, both in terms of their contribution to the problem (e.g nutrient and organic wastes) or their susceptibility to it. Allocation depends critically on the nature of ownership and/or access rights as well as other broader legal, institutional, and socio-political circumstances. Allocation issues are therefore best addressed through a case study approach, covering a range of socio-political systems.

# 14. GUIDELINES FOR REGULATING SHRIMP AQUACULTURE

**M.Muralidhar, B.P.Gupta and P.Ravichandran**

Coastal aquaculture means culturing, under controlled conditions in ponds, pens, enclosures or otherwise, in coastal areas, of shrimp, prawn, fish or any other aquatic life in saline or brackish water; but does not include fresh water aquaculture., Coastal area means the area declared as the Coastal Regulation Zone, for the time being, in the notification of the Government of India in the Ministry of Environment and Forests. The central government shall take all such measures as it deems necessary or expedient for regulation of coastal aquaculture by prescribing guidelines, to ensure that coastal aquaculture does not cause any detriment to the coastal environment to protect the livelihood of various sections of the people living in the coastal areas under the Coastal Aquaculture Authority Act, 2005.

## 14.1 Powers and functions of Coastal Aquaculture Authority (CAA)

CAA exercises the following powers and performs the following functions for the sustainable development of coastal aquaculture.

**Powers**

a) Makes regulations for the construction and operation of aquaculture farms within the coastal areas
b) Inspection of coastal aquaculture farms with a view to ascertaining their environmental impact caused by coastal aquaculture
c) Registration of coastal aquaculture farms
d) Ordering the removal or demolition of any coastal aquaculture farms which is causing pollution after hearing the occupier of the farm; and

**Functions**

1. Ensures that the agricultural lands, salt pan lands, mangroves, wet lands, forest lands, land for village common purposes and the land meant for public purposes and national parks and sanctuaries shall not be converted for construction of coastal aquaculture farms so as to protect the livelihood of coastal community.
2. Survey of the entire coastal area of the country and advise the Central Government and the State/ Union territory Governments to formulate suitable strategies for achieving eco-friendly coastal aquaculture development.
3. Advise and extend support to the State/ Union territory Governments to construct common infrastructure *viz*., common water in-take and discharge canals by the coastal aquaculture farms and common effluent treatment systems for achieving eco-friendly and sustainable development of coastal aquaculture.
4. Fix standards for all coastal aquaculture inputs *viz*., seed, feed, growth supplements and chemicals/ medicines for the maintenance of the water bodies and the organisms reared therein and other aquatic life.
5. Carryout and sponsor investigations and studies/ schemes relating to environment protection and demonstration of eco-friendly technologies in coastal aquaculture
6. Collection and dissemination of data and other scientific and socio-economic information in respect of matters related to coastal aquaculture
7. Preparation of manuals, codes and audio visual material relating to sustainable development of coastal aquaculture and activities

8. Organise through media and other means of communication a comprehensive programme regarding sustainable utilization and fair and equitable sharing of the coastal resources for aquaculture purpose;
9. Plan and organise training of personnel engaged or likely to be engaged in programmes for sustainable utilization of the coastal resources for aquaculture purposes
10. Preparation of technical manuals, code of conduct, etc.
11. Direct the owners of the farm to carry out such modifications to minimize the impacts on coastal environment including stocking density, residual levels/ use of antibiotics, chemicals and other pharmacologically active compounds.
12. Orders on seasonal closure of farms for ensuring sustainability of the coastal aquaculture practices
13. Orders on closure of coastal aquaculture farm in the interest of maintaining environmental sustainability and protection of livelihoods or for any other reasons considered necessary in the interest of coastal environment.
14. Canceling the certificate of registration where it is satisfied that any person has obtained a certificate of registration by furnishing false information or contravened any of the provisions of the rules or of the conditions mentioned in the certificate of registration
15. To make suitable recommendations to the Government for amending the guidelines from time to time taking into account the changes in technology, farming practices, etc, and incorporating such modifications in the guidelines to ensure environmental protection and the livelihoods of the coastal communities.

**14.2 Registration of coastal aquaculture farms**

No person should carry on, or cause to be carried on, coastal aquaculture in coastal area or traditional coastal aquaculture in the traditional coastal aquaculture farm which lies within the Coastal Regulation Zone. A person who intends to carry on coastal aquaculture shall make an application for registration of his farm before the CAA in the prescribed form accompanied with such fees as may be prescribed for the purpose of registration. The fees includes Rs. 200 per ha (or fraction of a ha), subject to a minimum of Rs. 500/-up to 5.0 ha water spread area, Rs. 1000 plus Rs. 500 per ha (or fraction of a ha) in excess of 5 ha from 5.1 to 10 ha water spread area, Rs. 3500 plus Rs. 1000 (or fraction of a ha) in excess of 10 ha from 10.1 ha water spread area. The fee for registration has to be paid in the form of Demand Draft in favour of the Member Convenor of the District Level Committee set up by the Authority. The Authority will consider the application in the prescribed manner and after considering the application either register the farm or reject the application. The Authority shall not reject the application without recording the reason for such rejection. The Authority after registering a farm will issues a certificate or registration in the prescribed form to the person who has made the application. In the case of a farm comprising more than two hectares of water spread area, no application for registration to commence any activity connected with coastal aquaculture. Once the registration made it is valid for a period of five years and may be renewed from time to time for a like period.

No coastal aquaculture shall be carried on within two hundred meters from high tide lines (the line on the land up to which the highest water line reaches during the spring tide) and no coastal aquaculture shall be carried on in creeks, rivers and backwaters within the Coastal Regulation Zone declared.

**14.2.1 Renewal of registration**

A person, who intends to renew the registration of the farm may make an application within two months before the expiry of earlier registration to the Authority in the prescribed form accompanied with the prescribed fees. The Authority may refuse to renew the registration of a farm if not satisfied that the person to whom such registration is made has failed to utilise such farm for coastal aquaculture purposes.

**14.2.2 Punishment for carrying on coastal aquaculture without registration**

If any person carries on coastal aquaculture or traditional coastal aquaculture without registration, then he shall be punishable with imprisonment for a term which may extend to three years or with fine which may extend to one lakh rupees, or with both.

**14.2.3 Processing of application for registration**

On receipt of an application, the District Level Committee shall verify the particulars given in the application in respect of all coastal aquaculture farms irrespective of their size; and

(a) in the case of coastal aquaculture farms up to 2.0 ha water spread area, the District Level Committee upon satisfaction of the information furnished therein shall recommend the application directly to the Authority for consideration of registration under intimation to the State Level Committee.

(b) in the case of coastal aquaculture farms above 2.0 ha water spread area, the District Level Committee shall inspect the concerned farm to ensure that the farm meets the norms specified in the guidelines with specific reference to the siting of coastal aquaculture farms and recommend such applications to the State Level Committee, which upon satisfaction shall further recommend the application to the Authority for consideration of registration.

In case any defect is noticed in the application, the attention of the applicant shall be drawn in writing, requesting him/ her to rectify the defect within a specified period and in case of failure on the part of the applicant to rectify the defect within such period, the registration shall be refused. Where the application for registrations is refused, the reasons for such refusal shall be recorded in writing and a copy of the same along with the order of refusal shall be furnished to the applicant. The applicant can apply afresh for registration after six months of the rejection made after rectifying the defects and can fully comply with the standards specified by the Authority. The Certificate of Registration is not transferable. Any change in the layout, design, area and stocking density should be got approved by the Authority.

**14.3 Conclusion**

The guidelines were issued by CAA for regulating shrimp aquaculture covers the entire gamut of shrimp farm management and measures to reduce the environmental impact of the wastewater discharged from shrimp farms, treatment of such wastes and mitigation of the adverse impact of such wastes on the environment as well as resolution of social conflicts, which could lead to sustainable development of shrimp aquaculture. Areas Fresh farms in such areas can be permitted only after studying the carrying/ assimilation capacity of the receiving water body where already a large number of shrimp farms are located should be avoided. The guidelines are intended to assist the farmers in adopting better management practices.

# 15. ADOPTION OF INNOVATIVE ENVIRONMENTAL TECHNOLOGIES FOR SUSTAINABLE BRACKISHWATER AQUACULTURE

K.Ponnusamy

Sustainable aquaculture warrants adoption of eco-friendly technologies. The disease outbreak in the aftermath of 1994 was reported to be due to lack of proper adoption of environment enrichment technologies and management measures like designing of farms with proper inlet and outlet channels, reservoir ponds, allowing farms in excess of carrying capacity of water sources etc. Shrimp aquaculture has developed as the largest aquaculture practice within a decade in India. But, most the developments have been restricted to the estuarine and brackishwater areas. Consequent to Supreme Court verdict, Government of India stipulated a lot of measures including adoption of recommended technologies and practices. Intensive efforts are being undertaken by research organisations in developing innovative technologies and approaches for practising sustainable brackishwater aquaculture. However, adoption of these technologies by the farmers is subject to influence of a variety of socio-economic and bio-physical factors. Hence, it is important to understand the conditions / factors which facilitate / hinder the adoption of technologies for ensuring sustainable brackishwater aquaculture.

## 15.1 Issues in brackishwater aqua farming

Extensive farming methods are considered as sustainable and produce little waste. However, farms which stock higher stocking density discharge effluents carrying nitrogenous excretory waste, uneaten feed, residues of chemicals and drugs that cause damage to the ecosystem. Conversion of mangroves and agricultural lands are also serious concerns for conflicts arising out of competitive utilisation of limited natural resources. International trade has affected both fishing and aquaculture. In particular, capital intensive activities have been promoted by many countries. As a result, fisheries management and environmental and/or community problems have become serious (Matsuda, 2008). There are also reports of salinisation of ground water and agricultural land through seepage from aquaculture ponds (Patil and Krishnan, 1998). Other reported concerns include mangrove destruction resulting in land acquisition with extremely low prices for local residents, no trespassing, depletion of fisheries resources, flooding, and increases of natural hazards such as damages from storms, high tide and earthquakes, and destruction of self-sufficiency, water and soil pollution due to heavy feeding, disease and drug use, little contribution to the local economy since the industry's interest is in her own profits and not the benefits of the community and hike of domestic shrimp prices.

Numerous conflicts and litigations forced the government to issue the Coastal Regulation Zone (CRZ) notification, 1991 under the Environment (Protection) Act, 1986, which restricts construction of shrimp farms landward boundary upto 500 m from high tide line (HTL) and has put an end to the construction of coastal farms. While aquaculture development is controlled by state governments, its overall supervision is done by the Central Ministry of Agriculture, which in 1995, issued guidelines for sustainable development and management of brackishwater aquaculture. It seeks to discourage conversion of agriculture lands, mangroves and other ecologically sensitive wetlands for aquaculture. Also, Environmental Monitoring and Management Programme (EMMP) and Environment Impact

Assessment (EIA) have been made mandatory for shrimp farms of 10-40 ha and >40 ha, respectively, which require a 'No Objection Certificate' from the State Pollution Control Boards for all the qualifying aquaculture units. Coastal Aquaculture Authority (CAA) has also come into force, which consists of representatives of Pollution Control Boards, Revenue Authorities, Fisheries Departments, Developmental bodies and Research Institutions, who have been assigned the role of regulating shrimp culture in a sustainable manner in the country. However, small scale farmers who constitute more than 80 per cent of total shrimp farmers find it difficult to adopt many recommendations in view of lack of higher investment and risk bearing capacity and poor cooperation from fellow farmers. Although, there is a greater awareness of the need to adopt sustainable aquaculture methods like low stocking density, minimum usage of chemicals and feeds and prevention of conflicts at most of the major shrimp farming centres, the major issues facing coastal aquaculture need to be tackled with appropriate technological interventions coupled with extension and policy support.

A case study on adoption of certain important management practices in brackishwater shrimp farming in Krishna district of Andhra Pradesh and Nagapattinam district of Tamil Nadu was conducted in 2007 and the details are presented in Table 1.

**Table 1. Adoption of important management practices in shrimp farming**

| Sl. No | Important management practices | Krishna district (N=54) | | Nagapattinam district (N=37) | |
|---|---|---|---|---|---|
| | | No. | Percent | No. | Percent |
| 1. | Source of water for shrimp farming | | | | |
| | Creek | 39 | 72.23 | 21 | 56.76 |
| | Canal | 1 | 01.85 | 0 | 0 |
| | Canal + borewell | 1 | 01.85 | 0 | 0 |
| | Creek + borewell | 12 | 22.22 | 14 | 37.84 |
| | Creek + canal | 1 | 01.85 | 2 | 05.40 |
| 2. | Membership in association | 10 | 18.52 | 37 | 100 |
| 3. | Carrying out initial pond scraping | 53 | 98.15 | 37 | 100 |
| 4. | Disposal of scraped soil- On the dyke | 20 | 37.74 | 37 | 100 |
| | Outside the dyke | 33 | 62.26 | 0 | 0 |
| 5. | Filtration of source water | 45 | 83.33 | 37 | 100 |
| 6. | Source water filter-single | 23 | 51.11 | 32 | 86.49 |
| | Source water filter-multiple | 22 | 48.89 | 5 | 13.51 |
| 7. | Presence of reservoir pond | 15 | 27.77 | 36 | 97.30 |
| 8. | Carrying out pond water treatment | 29 | 53.70 | | 81.08 |
| 9. | Usage of aerators in the pond | 21 | 38.89 | | 72.97 |
| 10. | Feed monitoring using check tray | 42 | 77.77 | 37 | 100 |
| 11. | Probiotic usage | 42 | 77.77 | 37 | 100 |
| 12. | Farm fencing | 4 | 7.41 | 22 | 59.46 |
| 13. | Crab fencing | 4 | 7.41 | 17 | 45.95 |
| 14. | Bird fencing | 8 | 14.81 | 19 | 51.35 |

It is found that there is a need for comprehensive extension support to facilitate sustainable brackishwater aquaculture in all the regions of coastal India.

## 15.2 Innovation

Anything that is perceived as new is called as innovation. It is the successful exploitation of ideas. Innovation as a lever for sustaining competitiveness has gradually occupied centre stage in strategy of many organisations. Interpretations of what constitutes innovation range from out of box creativity and technology breakthroughs to incremental improvement of existing paradigms. While research and development plays a central role in directing the development of ideas into commercially viable products, the ideas for innovations flow from different directions both within and outside organisation. Concepts like zero water exchange and technologies like farmer operated analysis kits progressed from ideas to products. Anyone in or associated with an organisation could spark the idea for an innovation In fact, sparks for innovation could originate from a farmer explaining why he is unable to meet a production target or from a team of college students taking a tour of environment lab. Apart from various functional groups within an organisation, suppliers also provide information, knowledge and unique insight that accelerate the process of innovation. Forming trustworthy relationships and having a mechanism for continuous dialogue with various stakeholders are keys to leveraging the resources for innovation.

## 15.3 Diffusion and adoption of innovations

The main function of aquaculture extension is to communicate the different stakeholders the latest technologies emanating from research institutions and other organisations. The diffusion and adoption of new ideas and practices has received increasing attention in the present context of decreased returns over the increased cost of production. Roger's (1995) theory of diffusion of innovations is based on the five stages in the adoption process *viz.*, awareness, interest, evaluation, trial and adoption According to this theory, an individual before finally adopting a new idea passes through a mental process comprising of all or some of these stages. Since the time taken to pass through a mental process is not the same for all individuals, adaptors can also be categorised into five groups based on the time taken for adoption. These categories are innovators, early adopters, early majority, late majority and laggards.

## 15.4 Characteristics of innovations

Five characteristics of innovations have also been delineated, having a bearing on the rate of adoption. These are:

**1. Relative advantage**

It is the degree to which an innovation is superior to the ideas it supersedes.

**2. Compatibility**

It is the degree to which an innovation is consistent with existing values and past experiences of adopters

**3. Complexity**

It is the degree to which an innovation is relatively difficult to understand and use

**4. Divisibility (Trialability)**

It is the degree to which an innovation may be tried on a limited basis

**5. Communicability**

It is the degree to which the results of innovation may be diffused to others

The knowledge of the process of adoption and diffusion and its implications may be of immense value to extension workers in pushing through successfully an innovation in the field of coastal aquaculture.

### 15.5 Adoption and its process

Adoption is a decision to make full use of an innovation as the best course of action available. Ryan and Gross (1943) were probably the first to recognise that the adoption of a new idea consisted of stages. They distinguished between 'awareness' of hybrid corn, 'conviction' of its usefulness, trial 'acceptance' and 'complete adoption' of the innovation. Wilkening (1953) described the adoption of an innovation as a process composed of learning, deciding, and acting over a period of time. The adoption of a specific practice is not the result of a single decision to act but series of actions and thought decisions. He identified four adoption stages-awareness, obtaining information, conviction and trial and adoption. Adoption is essentially a decision-making process. According to Johnson and Haver (1955), decision-making involves the following steps-

(i) Observing the problem
(ii) Making analysis of it
(iii) Deciding the available courses of action
(iv) Taking one course and
(v) Accepting the consequences of the decision

The North Central Rural Sociology Subcommittee for the Study of Diffusion of Farm Practices (1955) identified five stages of the adoption process which received world-wide attention. These are (i) awareness, (ii) interest, (iii) evaluation, (iv) trial and (v) adoption. According to them, adoption is not an instantaneous act. It is a process that occurs over a period of time and consists of a series of actions. According to Singh (1965), the stages of adoption are dynamic and not static. The same five stages do not occur with all the adopters and the practices. Sequence is not always the same. Sometimes one stage appears more than once. In some cases, some stages are as short as to be imperceptible and in other cases, some stages seem to be skipped. There are no clear-cut differences and sometimes the whole process is capsuled and looks like a unit act. The scheme of stages according to him is (i) need, (ii) awareness, (iii) interest, (iv) deliberation, (v) trial, (vi) evaluation and (vii) adoption.

### 15.6 Reason for poor adoption and non-adoption of technologies

Improved technologies even though sound by technical standards, are of limited value if they cannot be adopted due to their unsuitability to a particular aquatic ecosystem and socio-economic situation. The adoption pattern of recommended technologies is not uniform across the country and many of the potential technologies are either being partially adopted by the farmers or totally rejected by them. However, studies indicate that most of the farmers in favourable and risk-free farming situations accept the recommended technologies, there is little uptake of technologies in the unfavourable farming situations.

Earlier, non-adoption of modern technologies by small and resource poor farmers was attributed to inadequate support systems for small-farm agriculture like extension services, credit, input supplies, etc. These conditions are well appreciated and recognised but they are only a part of the problem. An important reason put forth for non-adoption of improved technology is the attitudinal constraint on the part of small farmers such as innate conservatism, ignorance, resistance to change besides a resource crunch.

The major reasons for low acceptance of technologies are: they are not operationally feasible, economically not viable, not stable, not matching with farmers' needs and not compatible with the farmers' overall farming system. The technologies themselves are not appropriate to small farmers and their production situations if blanket recommendations of these technologies are made.

## 15.7 Factors controlling the adoption

Participation of producers in programs, training, socio-economic conditions, investment capacity of producers, homophily nature of aqua farming community in a particular locality, availability of extension machinery and credit support are the major factors controlling the adoption of innovative environmental brackishwater aqua farming technologies. The important stakeholders to adoption are not only target farmers but also the research and extension personnel, input dealers and policy makers. The further development of environment friendly aqua technologies require to put major emphasis on improving the competence of all concerned by capacity building, strengthening research-extension linkages, facilitating institutional collaboration and empowering national teams.

## 15.8 A suggested strategy for the introduction of an innovation in phases

### Pre-introduction phase

1. Care should be taken to see that the innovation is simple, compatible with current cultural practices and there is a genuine need for the same
2. Its economic advantages should be very large and manifest
3. Its social consequences, if any, should be anticipated and provisions made to deal with them.
4. The adoption stages from awareness to evaluation should be adequately arranged by wide publicity and suitable demonstrations
5. All stakeholders should be fully involved through their opinion leaders and a mood of mutuality should always prevail on the part of change agents.

### During the introduction

1. As far as possible, on the spot guidance should be provided to the potential adopters.
2. Attention should be focused more on opinion leaders and active rejecters
3. The users should be encouraged to be self-dependent and appreciative of new ideas.
4. A constant evaluation of the programme should be made and suitable changes brought out.

### After the introduction

1. An effective follow up should be ensured till complete adoption
2. The experiences gained should be utilised in bettering the present programme and in planning future strategies of change.

3. Success should be measured more in terms of creation of favourable attitude towards innovativeness rather than success in a particular programme

4. Maximum responses and reactions of adopters should be obtained to ensure an effective feedback and to complete the process of communication.

### 15.9 Strategies for facilitating adoption of environment enrichment technologies

Numerous innovations that arise from research organisations need to be transferred to the end users for bringing out the desired changes in the brackishwater aqua farming. Some of the approaches and strategies which are being already followed and newer strategies which required to be followed are discussed here:

**1. Cluster approach in brackishwater aquaculture**

The approach which is being popularised by MPEDA through its field offices needs to be further strengthened by analysing the felt needs and unfelt needs of society members. Certain factors are considered to facilitate factors the successful running of societies. These are listed and below:

**(i) Complete membership**: Compulsory membership is essential for the society / aqua club / association to be successful due to the similar nature of farming system and the dependence on the same water source by all farmers.

**(ii) Deliverability of the association**: Disease incidence needs to be managed effectively. Economic (tangible) deliverables and accountability are also critical. Compensation to the disease affected farmers will bear testimony to it.

**(iii) Social cohesiveness**: The fact that all the farmers belonging to the same community or locality is also a critical factor for its success. Strong community bond and being related to one another could promote good rapport among the farmer members. Community leadership is being respected and listened.

**(iv) Conviction of the members**: Conviction that group action alone could ensure success of all the members could ensure the availability of quality seed, technical know-how, adoption of best practices by all, compensation scheme and voluntary cooperation of the farmers.

**2. Public-Private Partnership (PPP)**

The potential aqua entrepreneurs need to be identified and supported with adequate technological back-up particularly in the area of incubators categories wherein there is need for public-private partnership in coastal aquaculture. For instance, CIBA entered into an agreement with one private entrepreneur for promoting micro brackishwater analysis kit in 2008. This approach provides enough moral support and encouragement to potential entrepreneurs and also becomes a success case for others for emulation.

**3. Clientele-centered communication strategy**

Communication strategy has an important role to play in the context of effective dissemination of innovations. There cannot be a uniform / universal communication strategy for all sorts of disseminations. Active communication channels like personal localite and personal cosmopolite channels provide information to an individual that motivate him / her to adopt. They carry messages that are tailored closely to the particular needs of an individual. Passive communication channels like audio, video, audio-visual, print media and electronic media provide information about an innovation's existence, how it works, where it can be obtained and how to adopt it. This information is applicable to mass audience. The types of clientele for whom the communication strategy has to be made are aqua farmers, extension officers, researchers, input dealers, private operators and students.

**4. Appropriate methods to transfer innovations**

Methods are the ways and means of relating the extension workers and farmers for transferring innovations. The utility of extension worker lies in the fact that he helps in facilitating the learning process and transferring innovations. Many methods are used in transferring the innovations to the stakeholders. An extension worker seldom resorts to one method in any given meeting. For instance, he could conduct a field-trip, make use of resource person and have a learner give a demonstration. The table 1 indicates a list of some of the methods used and classified according to individual, group and mass bases which illustrates the extensiveness of choices available.

**Table 2. Methods of transferring innovations**

| Individual methods | Group methods | Mass methods |
|---|---|---|
| 1. Farm and home visit | 1. Demonstration | 1. Film |
| 2. Personal letter | 2. Role playing | 2. Radio |
| 3. Telephone calls | 3. Panel | 3. Television |
| 4. On farm trials | 4. Symposium | 4. Newspaper |
| 5. Circular letter | 5. Study tour | 5. Farm publications |
| 6. Case study/success story | 6. Group discussion | 6. Exhibition |
| 7. Facsimile (FAX) | 7. Conference | 7. ICT initiatives |
| 8. E-mail | 8. Training | |
| 9. E-chat | 9. Farmers interaction meet | |
| 10. Pager | 10. Lecture | |
| 11. Telegram | 11. RRA / PRA | |
| 12. internet phone | | |

## 15.10 Technology assessment and refinement in aquaculture

In the context of growing concern for the environment, globalisation, household food security and eco-regional imbalances, there is a need for new directions to transfer the technologies by designing more effective linkages between scientists and farmers keeping with diverse needs of different agro-climatic situations. Technology assessment and refinement refers to the process or a set of activities before taking up new scientific information for its dissemination in a new production system. It is this process or activity which can relate the research with technology application and further dissemination. Since the situation under which the scientific information developed differs from those operated by the farmers, the research information is to be reviewed in terms of specific needs, opportunities and constraints faced by the farmers in different production systems. Assessment and refinement of technology needs farmers' involvement as well as inter-disciplinary approach in order to provide specific, holistic, and technical solutions to the existing problems in the field of coastal aquaculture.

Certain PRA tools will help extension workers to assess the present resource availability, socio-economic situations, identify and prioritise the problems and finally prepare the action plans for implementation. PRA tools include village transect, resource map, social map, seasonal map, livelihood analysis, time line, trend analysis problem cause diagram, technology matrix, prioritization of problems by matrix ranking and formulation and implementation of action plan. Action plan can be prepared by the aqua farmers and extension functionaries based on the identified and prioritized problems in various production systems in the village. The extension functionaries could facilitate the farmers in implementing the action plan. The action plan will consist of proposed area of aquaculture based on the assessment of physical, economical, market and environmental considerations; species to be cultures; facilitation of aqua farmers as well as marketing of the farm produce. Before the development of aquaculture in a particular village, it is vital for planning with critical stakeholders like farmers. An active participation of the beneficiaries in the planning and implementation can ensure the sustainability of the coastal agro-ecosystem.

**15.11 Conclusion**

The extension support of both public funded and private operated organisations is essential to create awareness among various stakeholders on availability of innovative environmental technologies and facilitate the adoption through novel approaches taking into consideration of local farming systems as well as resource availability, opportunities, constraints and capability of farmers.

# 16. ADVANCES IN FISH CULTURE FOR SUSTAINABLE BRACKISHWATER AQUACULTURE

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## 16.1 Introduction

Aquaculture has developed rapidly over the last three decades and has become as an important growing industry for generating the revenue, providing employment and nutritional security for the million of people. The ever increasing population and the raising demand for animal protein is causing pressure on fisheries development globally. Fish and fishery products contribute around 15% of the animal protein supporting the nutritional security. The world fish production is in the order of 146.3 million metric tons, of which 50% is contributed by aquaculture. The contribution of aquaculture to the total fish production was around 15% in 1990 which has grown about 50% in 2005. Farming of aquatic organism including fish, molluscs, crustaceans and aquatic plants with the intervention in some form or other in the rearing process to enhance production such as regular stocking, feeding, protection from predators and health care is aquaculture. In global fish production, eight top countries occupied by Asian countries, where India stands 2nd position after China. China has produced 70% of global production which formed 50% in value, where as India is a distant 2nd with 5% production and 4% in value. The global average per capita consumption of fish is around 15 kg. The present average per capita consumption in India is around 9 kg. Even in countries like Japan and some of the South East Asian countries the average per capita consumption is more than 100 kg. Even to reach the global average of 15 kg, taking into consideration of 50% of Indian population will be fish consumers, by 2020 the domestic requirement itself will be in the order of 9 million tons. The average fish production in India is around 7 million tons equally contributed by fresh water and marine. The maximum sustainable yield is static and the capture fisheries trend is declining. It is necessary that the coastal aquaculture has to make a greater contribution in the fish production in the Indian context. By 2020, the coastal aquaculture in India is expected to support to the tune of around 3,50,000 tons, from the current production of around 1,50,000 tons. This implies that a quantum jump has to be made in the ensuing years. Out of this, shrimp is expected to contribute around 250,000 tons and rest has to come through fishes and other non conventional groups.

Development of aquaculture has become imperative for the following reasons:

- Means of protein rich fish production for "Nutritional security"
- Generation of employment – Livelihood security
- Economic status and social upliftment – Social security
- Reduce pressure on wild stock – Conservation
- Biological indicator for Water Quality
- Culture of Nutrient utilizers like Sea weeds, mollusks improve water quality - Environment security
- Integrated farming like paddy cum fish culture – Reduce other inputs

## 16.2 Resources

India is bestowed with Coastal line of 8129 km, Estuaries of 3.50 million ha, Backwater of 3.90 million ha, Mangrove of 0.40 million ha, potential brackishwater area suitable for aquaculture, about 1.19 million ha, freshwater reservoirs of 3.15 million ha, Ponds and tank of 2.25 million ha, Bheels and Ox-bow lake of 0.82 million ha, Medium & large Reservoirs of 2.04 million ha, Irrigation canals of 1, 46,000 km. These aquatic systems are either underutilized or unutilized. These areas can be brought into the aquaculture and production and productivity can be increased.

**16.3 Status of Coastal Aquaculture**

Coastal aquaculture is a traditional practice in India. In the low lying fields of Kerala (Pokkali), West Bengal (bheries and gheries), Orissa, Goa (khzan) and Karnataka (kar) which experiences influx of salt water, traditional farming of fish/shrimp were practiced. The practice is just allowing juveniles of fish/shrimp in the fields; allowing them to grow; feeding without any supplementary; facilitating water exchange through tidal waters and harvesting periodically at 3-4 months. With the improvement of technologies and realizing the importance of aquaculture, these practices were improved with the supplementary stocking of feeding with water quality management with higher production. The technology improvement made in the aquaculture sector opened new areas for the scientific farming which is called as Semi-intensive and Intensive farming following all the protocols for farming with production as much as 10 tons per ha per culture period of 4-5 months mainly shrimp in the coastal area. The technology advancement helped in the establishment of more than 380 hatcheries with a production capacity of 5 – 300 million seeds totaling around 20 billion and more and more areas were brought under shrimp farming. The present area of operation in the coast line is around 160,000 ha and producing around 150,000 tons of shrimp.

The coastal aquaculture witnessed a phenomenal growth during 1980s and in the beginning of 1990s. But the growth has not progressed as visualized from the later part of 1990s due to socio, economic environmental issues coupled with the outbreak of uncontrollable diseases like WSSV on shrimp. One of the reasons attributed for this is the unregulated development and unforeseen disease outbreaks. The coastal aquaculture in India was also solely dependent on single species, Tiger shrimp *Penaeus monodon*.. The effect of which has brought the pronounced impact on the coastal farming sector questioning the very sustainability of the coastal aquaculture.

**16.4 Diversification in the coastal aquaculture**

For the sustainable eco-friendly aquaculture practice, diversification to other species is considered as one of the important component. Fishes like Asian seabass (*Lates calcarifer*), Grouper (*Epinephelus tauvina*), Snappers (*Lutjanus* Sp.) which are high value carnivorous fishes and Grey mullet (*Mugil cephalus*), Milk fish (*Chanos chanos*), Pearl spot (*Etroplus suratensis*), Rabbit fish (*Siganus*Sp.) which are herbivorous/omnivorous farming in the coastal eco-system are available. The species like Cobia (*Rachycentron canadum*) and Silver pomfret are being considered as candidate species for farming. Efforts have been made to develop comprehensive technology packages for seed production under controlled conditions and farming for these candidate species. Technologies have been developed else where in the world.

In Indian scenario, successful technology has been developed by the Central Institute of Brackishwater Aquaculture for the seed production of Asian seabass, *Lates calcarifer* under controlled conditions and farming. The controlled breeding of

Groupers *Epinephelus tauvina* and Grey Mullets *Mugil cephalus*, Pearlspot *Etroplus suratensis* has also been successful. Development of broodstock for the captive seed production of milk fish is in progress. Cobia and Silver pomfret have been taken up as priority species owing to their high value in the domestic and international markets.

### 16.5 Technology development for fish culture in coastal waters

The following discussion will be on the recent technologies developed on the seed production of Asian seabass *Lates calcarifer* which can be a model for the production of marine finfish seed under controlled conditions.

### Seed production technology for Asian seabass, *Lates calcarifer*

#### 16.5.1 Broodstock Development and management

Successful seed production in the hatchery depends upon the availability of healthy matured fishes. Viable broodstock under captive conditions are developed. Adult and sub-adult seabass are procured from wild catch or from farm reared stock. The fish procured for broodstock should be devoid of external injuries or internal hemorrhage. The fish should be healthy and free from any parasitic infection. The fish can be treated with Acriflavin (1 ppm) for 10 minutes and later with antibiotic, Furozolidone (10 ppm) for one hour as prophylactic treatment to avoid infection due to minor injuries if any during collection and transportation. Fishes are maintained @1kg/$m^3$ in the broodstock tank and fed with trash fish @ 5% of the body weight in frozen form. The Asian seabass, *Lates calcarifer* can be made to breed under controlled conditions both spontaneously (natural spawning) and by induced spawning with exogenous hormone administration.

This can be achieved by the manipulation of some of the important water quality parameters like salinity, temperature, pH, etc. required for the maturation process, stimulating the conditions prevailing in the marine environment with a flow through arrangement wherein the sea water pumped into the broodstock maturation tanks is recycled using the biological and pressure sand filters so that the water conditions are stable. With this process, the fish could be made to spawn spontaneously throughout the year, even beyond the normal spawning seasons. This has paved way for the production of seed under controlled conditions throughout the year.

#### 16.5.2 Induced spawning

#### 16.5.2.1 Induced Spawning by Hormone Injection

The commonly used hormones in the finfish hatcheries for induced spawning are: LH-RHa, Luteinizing Hormone Releasing Hormone analogue (Available with SIGMA CHEMICALS - USA - ARGENT CHEMICALS), HCG- Human Chorionic Gonadotropins. (Available in Pharmacy - medical shops) Ovaprim, Puberogen, Carp pituitary glands - Pimozide. After selecting the gravid fishes the requirement of hormone to be injected is assessed. The dosage level has been standardized as LHRHa @ 60 - 70 µg/kg body weight for females and 30 - 35 µg/kg body weight for males. Since the spawning normally occurs in the late evening hours, when the temperature is cool, hormone is injected normally in the early hours of the day between 0700 – 0800 hours.

It is a protracted intermittent spawner and in one spawning the fish may release 1.0 – 3.0 million eggs. The process of spawning will follow during subsequent day also. If the condition is good, both female and male respond simultaneously resulting spontaneous natural spawning and fertilization is effected.

The eggs collected from the spawning tank are washed to remove the debris that would have adhered to and transferred to the hatching tanks for incubation and hatching. The hatching incubation tanks can be 200 – 250 litres capacity cylindro-conical tanks. Eggs are kept @ 100 - 200 nos./litre density. Continuous aeration is provided. Temperature of 27 – 28°C is desirable. The eggs will hatch out in 17 – 18 hours after fertilization. After hatching the larvae are transferred to larval rearing tanks.

**16.5.3 Larval rearing tanks and stocking density**

Tanks in the size of 4 - 5 tonne capacity are preferable for operational convenience. Freshly hatched larvae from the incubation tanks are transferred carefully to the rearing tanks. Larvae are stocked initially @ 40 – 50 nos/litre. Depending upon the age and size, the larval density is reduced to 20 – 25 nos/l on 10th day and later and after 15 days, the density is maintained around 10 – 15 nos/l.

**16.5.3.1 Feed and feeding during larval rearing**

Green unicellular algae like *Chlorella* sp *Tetraselmis* sp *Nannochlorpsis* or *Isochrysis* sp are needed for feeding the live feed (zooplankton), Rotifer and for adding to seabass larval rearing tanks for water quality maintenance. Rotifer (*Brachionus plicatilis*) or *B. rotundiformis* is the most preferred diet for the fish larvae in their early stages. The size of the Rotifers varies from 50 – 250 µm. The early stage larvae (up to 7 days) are fed with small sized rotifer i.e. less than 120µm and later assorted size rotifer can be fed. Brine shrimp, *Artemia* in nauplii stage are required for feeding the larvae from 9th day to 21 days and afterwards *Artemia* biomass can be given. Rotifer (*Brachionus plicatilis*) are given as feed to the larvae from 3rd day.

**16.5.3.2 Water exchange**

To maintain water quality in the larval rearing tanks, 30 – 40% water change is done daily. The salinity should be maintained around 30 ppt. And the desirable range of temperature is 27 – 29°C. The water level reduced (30 – 40%) in the rearing tank is leveled up with filtered quality seawater and green water after taking cell count of the algae in the rearing tank. Algal water is added daily upto 15th day. After bottom cleaning and water reduction, while water change is done, algal water is also added depending upon the concentration, (around 20 thousand cells/ ml in the rearing tank).

**16.5.4 Nursery rearing**

**16.5.4.1 Nursery Rearing in Hatcheries**

Seabass fry of 25 – 30 days old in the size of 1.0 – 1.5 cm can be stocked in the nursery tanks of 5 – 10 ton capacity circular or rectangular (RCC or FRP) tanks.

Outdoor tanks are preferable. The tanks should have water inlet and outlet provision. Flow through provision is desirable. *In situ* biological filter outside the rearing tanks would help in the maintenance of water quality.

**16.5.4.2 Nursery Rearing in Ponds**

Nursery ponds can be around 200-500 $m^2$ area with provision to retain atleast 70 – 80 cm water level. The pond is prepared before stocking. If there are any predator/pest fishes they have to be removed.

In order to make the natural food abundant, the pond is fertilized with chicken manure @ 500 kg/ha keeping the pond water level 40-50 cm. The water level is gradually increased. After 2-3 weeks period when the natural algal food is more, freshly hatched *Artemia* nauplii are introduced. Normally 1 kg of cyst is used for 1 ha pond. These stocked nauplii grow and become biomass in the pond forming food for the seabass fry. Seabass fry is stocked @ 20-30 Nos/$m^2$. Stocking should be done in the early hours of the day. Fry should be acclimatized to the pond condition.

**16.5.4.3 Nursery Rearing in Cages/Hapas**

Floating net cages/hapas can be in the size of 2 x 1x 1 to 2x 2x 1 m depending upon necessity. Cages are made with nylon/polyethylene webbing with mesh size of 1 mm. Fry can be stocked @ 400 – 500/$m^2$. Feeding rate can be as that described to tank nursery. The net cages have to be checked daily for damages those may be caused by other animals like crabs. The net cages will be clogged by the adherence of suspended and detritus materials and siltation or due to foulers resulting in the restriction of water flow. This would create confinement in the cages and unhealthy conditions. To avoid this, cages/hapas should be cleaned everyday. Regular grading should be done to avoid cannibalism and increase the survival rate. Even in higher stocking density @ 500/$m^2$ farmer could get survival of 80% in the farm site when the fry were reared in happas adopting the trash fish feeding and other management strategies mentioned above.

**16.5.5 Farming:**

**16.5.5.1 Traditional coastal aquaculture in India**

Seabass is cultured in the ponds traditionally as an extensive type culture throughout the areas in the Indo-pacific region where seabass is distributed. In low lying excavated ponds, whenever the seabass juveniles are available in the wild seed collection centers. The juvenile seabass introduced in the pond will prey upon the available fish or shrimp juveniles as much as available and grow.

Seabass are allowed to grow for 6-7 months of culture period till such time water level is available in these ponds and then harvested. At the time of harvesting there will be large fish of 4 to 5 kg as well as very small fishes. This is a common scenario in many coastal areas. In this manner production up to 2 ton/ha/7-8 months have been obtained.

**16. 5.5.2 Pond based fish farming**

Seabass seed can be stocked in a prepared pond @10000/ha. The seed size of 2.0 gm and above is preferable for stocking in the growout farms. Water depth should be maintained not less than 1.0 M. Seabass fishes stocked can be fed with minced meat of trash fish. Cheaper fishes like Tilapia, Sardines, horse mackerels which may not fetch more than Rs.5/- per kg can be bought from the commercial fish landing centers, washed and freezed in cold storages as required

### 16.5.5.3 Fish farming with formulated feed

Seabass is cultured with extruded floating pellets in Australia, Thailand, Malaysia and Singapore. Being a carnivorous fish seabass needs high protein diet, the pellet should be slow sinking and should be in the column for reasonable time so that the fish can ingest the food before it reaches the bottom.

### 16.5.5.4 Grow out Culture of Seabass in Cages

Fish culture in cages has been identified as one of the eco-friendly at the same time intensive culture practice for increasing in fish production. Cages can be installed in open sea or in coastal area. The former is yet to be developed in many countries where seabass is cultured but coastal cage culture is an established household activity in the South East Asian countries. There are abundant potential as in India also for cage culture in the lagoons, protected coastal areas, estuaries and creeks. Since, cage culture of seabass has been proved to be a technically feasible and viable proposition this can be taken up in a large scale in suitable areas. Cage culture system allows high stocking density, assures high survival rate. It is natural and eco-friendly and can be adopted to any scale. Feeding can be controlled and cages can be easily managed. Fishes in the cages can be harvested as per the requirement of the consumers, which will fetch high unit price. Above all, cage culture has got low capital input and operating costs are minimal. Cages can be relocated whenever necessary to avoid any unfavorable condition.

### 16.5.5.5 Stocking Density

In the cages, fishes can be stocked @25-30nos/$m^2$ initially when they are in the size of 10-15 gm. As they grow, after 2-3 months culture, when the fish attained a mean body weight of 150 gms stocking density has to be reduced to 10-12 nos/$m^2$ for space. Cage culture is normally done in two phase – till they attain 100-150gms size in 2-3 months and afterwards till they attain 600-800 in 5 months.

### 16.5.5.6 Feeding in Cages

Fishes in the cage can be fed with either extruded pellets or with low cost fishes as per the availability and cost. Floating pellets have advantages of procurement, storage and feeding. Since, a lot of low cost fishes are landed in the commercial landings in the coastal areas which are fetching around Rs.3-5/kg only used as feed for seabass culture. Low cost fishes like also serve as feed for seabass in ponds and in many cage culture operations. The rate of feeding can be maintained around 20% initially and reduced 10% and 5% gradually in the case of trash fish feeding and in the pellet feeding, the feeding rate can be around 5% initially and gradually reduced to 2-3% at later stage.

In the feeding of low cost fish feed conversion ratio (FCR) works out around 6 or 7. In the case pellet feeding FCR is to be 1 to 1.2 in Australia. However, the cost effectiveness of the pellet feeding for seabass in grow out culture has to be tested

Under cage culture, since seabass can be intensively stocked and properly managed, the production will be high. Frequently culling and maintenance of uniform sized fishes in to the cages will ensure uniform growth and high production. Production of 6-8 kg/m$^2$ is possible in the cages, under normal maintenance and production as high as 20-25 kg/m$^2$ is obtained in intensive cage management in the culture of seabass.

## 16.6 Problems in the Coastal Aquaculture:

### 16.6.1 Viable production technology:

- Availability of adequate quantity and quality seed is the major constraint in the development of farming of fishes. Till date in India, except in the case of Asian seabass (*Lates calcarifer*) for many other species the technology for seed production under controlled conditions is not available.
- The growout technology package for almost all the species of fishes identified suitable for farming is to be standardized. Though technical viability has been demonstrated in some cases like the seabass, groupers, milkfish, mullets and pearlspot the economic viability needs to be standardized and the farmers need to be convinced.

- Eco-friendly farming in enclosures like cages and ponds for the culture of fishes in coastal waters is suggested both for increasing production of fish as well as livelihood option for coastal folk. However, the techno-economic viability and technology package is not available though the feed demonstrations are successful.

### 16.6.2 Market price:

- The economic viability of any farmed product is mainly dependent on the market price it fetches. As such compared to export oriented shrimp price, fishes fetch lower price though the production cost does not vary much.

- Salt water fish availability in the market is highly variable. Many are in lower priced compared to other animal protein and few groups only are highly priced and the price is variable with location and demand.

- There is no organized trade for the Brackishwater formed fishes as that of shrimp. Domestic market network for farmed fishes and export niche are yet to be explored.

### 16.6.3 Resources utilization and conservation:

- The coastal resource is multifaceted. And the varying interest for different stakeholders with conflicts. The major problem is utilizing the resources for aquaculture without conflicts between stakeholders.

### 16.6.4 Environmental and social issues:

- Coastal aquaculture has attracted greater debate on its impact on the environment than many other activities. Though, aquaculture is an activity dependent on the hygiene of the environment, due to the unregulated high density aquaculture activity experienced in some places has evoked negative response from the environmentalists calling for remedial measures and the attention of all associated in aquaculture activity to evolve a guideline for sustainable aquaculture.

### 16.6.5 Development of suitable feed and feeding strategies for finfish culture

- Feed is an important input in the aquaculture practice. Absence of cost effective feed suitable for fish farming in different culture system like pond, cage or pen is the major constraint in the expansion of brackishwater fish aquaculture.

## 16.7 Future scope

- Vast coastal aquaculture resources can be utilized
- New candidate species in crustaceans, mollusk, fin fishes, seaweed can be taken up to utilize the vast areas in island and other coastal states
- Cage and pen farming must be developed to avoid pond based pollution due to coastal aquaculture
- Employment opportunities for coastal fisherman

## 16.8 Thrust areas for future research

Captive broodstock development, captive maturation and induced breeding technology of different cultivable marine fin fish

- Live feed culture technology development (Rotifer, Artemia, Moina, Daphnia, Copepod etc)
- Health management in broodstock development and post hatching phase
- Genetic improvement and selective breeding
- Development of transgenic fishes for better growth and health
- Feed development for maturation process of fish and different fish larvae
- Development of pen and cage culture system for fin fish
- Bio-security in hatchery and farming system

## 16.9 Conclusion

The importance of coastal aquaculture will become more apparent in the coming year with demanding pressure from an ever increasing world population. Coastal aquaculture has great potential for the production of food, alleviation of poverty and generation of wealth for people living in coastal areas, many of whom are under privileged. The assurance of mature and sound techniques in coastal aquaculture is the most important channel towards a sustainable aquaculture industry. Therefore some strategies should be worked out. The first is to speed up the completion of unfinished current research on different aspects of aqua farming. The second is to formulate and implement systematic regulations and self controls. An integrated regulation system must be imposed to ensure that the environment is not harmed by practice of coastal aquaculture, that natural traits of propagated fish are not lost in the process. Thirdly it is important to strengthen regional, national and international communications and information exchange. Exchange of technical know-how is necessary to prevent research duplication for human resource management. Development of technologies should be prioritized and international cooperation is prompted.

# 17. SOIL ANALYSIS

R.Sarswathy, M.Muralidhar and A.Nagavel

## 17.1. Collection of soil samples

Collection of representative soil sample for different analyses merits greater attention since, error at the time of sampling can not be corrected at a later stage. Soil tests and their interpretations are based on the soil samples sent in for analysis. It is therefore important that soil samples should be properly collected and be representative of the area to be tested. Methods of sampling depend largely on the purpose for which the sample is drawn.

**Materials required**

Spade, Auger, Tins, Polythene bags, Khurpi

Procedure

⇒ The area from which the soil samples are collected should be divided in to different sampling units. The size of plot or the farm area that could be represented by one 'composite sample' depends on the spatial variability in the fields. Sampling units should not be more than 10 per hectare. Thus for each acre (approximately 4000 $m^2$) field one composite sample may be sufficient. For this purpose after scraping the surface litter a thin 1/2" to 3/4" slice of soil from 8-10 spots, scattered uniformly over the area (preferably a zig-zag pattern) should be collected.

⇒ The depth to which samples should be obtained for analysis depends on the land use. Proper sampling tools should be used. Any of the tools such as tube auger, screw type auger, post hole auger or a spade can be used for digging the soil. Spade or tube auger is satisfactory for moist and soft soil. Screw type auger is convenient for hard and dry soil, while post hole auger is useful for wet soil. For samples up to 30 cm depth, a cut in the soil can be made with a spade and a thin slice of soil taken at a desired depth (0-15 and/ or 15-30 cm) with the help of khupra. If samples from deeper soil layers have to be taken an auger should be used. For collecting depth-profile core samples (0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm), soil core sampler can be used.

⇒ After collecting the sub samples, they should be combined together and mixed thoroughly. All the lumps should be broken and mixed well in the container or on a clean cloth. The size of the composite sample should be reduced by successive quartering to about half a kilogram.

⇒ The sample has to be dried in the shade, till it dried, ground to fine powder with the help of wooden hammer, passed initially through a 2 mm sieve and finally through a 80 mesh sieve and packed in a air tight polythene or ordinary cloth bag for subsequent analyses, with sufficient information.

**Precautions**

- Ensure that soil samples are not taken immediately after rains, irrigation, fertilisation
- Do not sample sites near to/ along an irrigation canal, lateral drain, bounds, farum yard manure pits, shady trees, roads etc.
- Sampling in summer season should be done only after scraping the while crust patches.

## 17.2 Soil reaction

The soil reaction (pH) is meant to express the acidity or alkalinity of soil. The pH is very important property of the soil because it determines the capacity for the growth of phytoplankton, availability of nutrients and influences microbial activity and physical properties of a soil. The pH of a solution, a term introduced by Sorrensen has been defined as the negative logorithm of the hydrogen ion activity

$$pH = -\log a^{H+}$$

Where, $a^{H+}$ represents to the acidity of $H^+$ ions which refers strictly to a true solution in which the ions are completely dissociated. But in soil-water system the dissociation is not complete as in true solution.

**Measurement of pH**

There are two main methods to determine pH of solution

(i) Colorimetric method

(ii) Potentiometric method

**Colorimetric method**

This method is based on the assumption that an indicator gives the same colour in two different solutions having same pH. Of the colorimetric methods,the most commonly used one is Kuhn's colorimetric method.

**Principle**

The underlying principle of the method being that when a soil suspension is shaken vigorously with very pure barium sulphate, the later flocculates the soil colloids and leaves a clear and colourless solution. If the indicator which is not absorbed by the soil is present, its colour will denote the soil reaction. This colour is compared with Lovibond colour disc to know the pH of soil. The amount of $BaSO_4$ necessary to give a clear suspension depends upon the amount of colloids present. For loam and heavy soils it is necessary to reduce the quantity of soil used.

**Procedure**

Place a one cm thick layer of neutral $BaSO_4$ in a 50 ml clean dry test tube. Then add 10 g of air dry soil sample and 25 ml of distilled water. Shake vigorously for about a minute and keep it for settling for about half-an hour. Take out 10 ml of supernatant water and determine pH value colorimetrically, by comparing colour with that of colour charts, colour discs etc.

**Potentiometric method**

Potentiometric method with electrically or battery operated pH meter with the help of suitable electrodes is used for determination of soil pH values for greater accuracy.

**Principle**

If a metallic rod is dipped in water or in a solution of one of its salts, it is found to acquire an electric charge which reaches a maximum value after some time. This is due to the fact that either the metal gives ions to the solution or takes ions from the solution. An electric potential is thus developed due to the differences in the electric charges of the rod and the surrounding solution. This is called electrode potential. If we can find the electrode potential developed by dipping it in the solution, we can calculate pH. Such an electrode is called 'Half Cell' and is called indicator electrode. It is not practicable to find the E.M.F of this half cell and therefore, coupled with another half cell of constant value which is called reference electrode.

**Instrumentation**

pH meter with glass and calomel electrodes

**Materials and reagents**

1. Glass beakers 50 ml
2. Glass rods
3. Buffer solutions

(a) 0.05 M Potassium hydrogen phthalate has a pH value of 4.001 at 20°C and 4.02 at 35°C. Dissolve 10.21g of potassium hydrogen phthalate in distilled water and dilute to 1 litre.

(b) 0.01 M Borax solution has a pH value of 9.22 at 22°C: Dissolve 3.81 g of borax in distilled water and dilute to 1 litre.

(c) Standard buffer tablets/ solutions.

**Procedure**

Take exactly 10 g of prepared soil sample in a clean beaker and add 25 ml of distilled water. Shake it occasionally by stirring with glass rod and keep it for about half-an-hour. Then dip the electrodes of pH meter into soil solution which has already been checked with standard buffers of known pH. The indicator of the pH meter shows the pH readings directly. The pH meter should be calibrated routinely at pH 7.0 and then accuracy verified by testing a pH 9.2 buffer.

**Observations** :

Soil pH (1:2.5 Soil-water ratio) :

**17.3 Determination of electrical conductivity**

Electrical conductivity (E.C) is commonly used for indicating the total concentration of the ionized constituents of solutions. It is closely related to the sum of cations (or anions) as determined chemically and usually correlates closely with total dissolved solids. As the soluble salts content controls the osmotic pressure of soil solution, highly saline soils reduce the water availability due to high osmotic pressure and also reduces availability of other nutrients. A fairly quantitative estimate of the salt content of solutions extracted from soils can be made from their electrical conductance. It is a rapid and reasonably precise determination that does not alter or consume any of the sample.

**Principle**

When water is added to the soil, the soluble salts gets dissolved. solutions offer resistance to the passage of electric current through them depending upon the concentration and type of ions present. Higher the salt content, less the resistance to the flow of current. The resistance (R) by Ohms's law is defined as the ratio of electric potential (E) in volts and strength of current (I) in amperes. Electrical conductivity (E.C) is the reverse of the resistance and is expressed in reciprocal of Ohms or as mhos per cm. As the values of E.C obtained for soil solutions are very small, it is therefore, convenient to express them in milli mhos per centimeter.

**Instrumentation**

Conductivity meter

**Materials and Reagents**

1. Glass beaker
2. Glass rod
3. 0.02M potassium chloride - Dissolve 1.4912 g of kcl in distilled water and dilute to one litre. The specific conductance of this solution at 25°C is 2.268 mmhos/cm.

**Procedure**

Same soil-water (1 : 2.5) suspension for pH estimation may be used for electrical conductivity determination also. Meanwhile the instrument is put on by connecting the conductivity cell to the proper electrodes and calibrated with 0.02 M kcl solution. Rinse the conductivity cell with distilled water and then twice with soil water suspension. Dip the electrodes in the soil-water suspension and the multiplier is brought to the suitable range and the compensation knob is brought to the temperature of the solution and read directly the specific conductance of the solution.

**Observations and calculations**

E.C m mhos/cm (L) = Dial reading X Cell constant X multiplier range

Milli equivalents of salts/ litre of soil solution = L m mhos/cm X 10 (approximately)

ppm of salts in soil solution = 640 L m mhos/cm

Osmotic pressure of soil solution = 0.36 L m mhos/cm

**17.4 Estimation of organic matter**

Organic matter in a mineral soil is regarded as an index of its fertility status. Organic matter is a direct source of nutrient elements and the release of which depends upon microbial activity and by affecting the cation exchange capacity. The initial soil in pond bottoms usually is low in organic matter content. The organic matter from a nearly constructed pond is often in the form of soil humus and not highly reactive. Once the pond is filled with water, organic matter from uneaten feed, application of manure, dead plankton and fish/prawn excrement continually reaches the pond bottom. Organic matter does not degrade completely and it tends to accumulate slowly in pond bottoms. The organic matter content of soils can be obtained by organic carbon estimation.

Determination of organic carbon of soil can be done by dry combustion and wet digestion methods. The dry combustion method is most accurate, but it is time consuming and can not be applied to soils containing carbonates. Wet combustion methods are suitable for use in soils containing carbonates, but the application of a correction factor is required to compensate for the incomplete oxidation of the organic matter. The rapid titration method of Walkley and Black has an advantage that it excludes the less active elementary carbon and includes those parts of organic carbon of soil which play an important role in nutrient availability. This method is widely used for estimating the organic carbon content of freshwater pond soils and with some modifications may be used for brackishwater fish pond soils also.

**Principle**

A known quantity of soil is digested with known excess of chromic acid using the heat of dilution of sulphuric acid. The excess chromic acid which is not utilized for the oxidation of organic carbon is back titrated against standard ferrous ammonimm sulphate solution using diphenyl amine indicator till the bright blue colour changes to light green colour.

Reactions in digestion:

$K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3(O)$

$3C + 6(O) \rightarrow 3CO_2$

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

Reactions in Titration

$K_2Cr_2O_7 + H_2SO_4 + 6FeSO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3\,Fe_2(SO_4)_3 + 7\,H_2O$

**Reagents**

(a) 1N potassium dichromate solution : Dissolve 49.04g of solid $K_2Cr_2O_7$ in distilled water and make the volume to 1 litre.

(b) Sulphuric acid with silver sulphate : Dissolve 5 g of $AgSO_4$ in 100 ml of conc. $H_2SO_4$.

(c) 85% orthophosphoric acid ($H_3PO_4$); Commercially available

(d) Diphenylamine indicator : Dissolve 0.5 g of reagent grade diphenyl amine in 20 ml water and 100 ml conc. $H_2SO_4$

(e) 1N Ferrous ammonium sulphate: Dissolve 392.2 g of ferrous ammonium sulphate in 800 ml distilled water containing 20 ml conc. $H_2SO_4$ and dilute to 1 litre with distilled water.

(f) Sodium fluoride salt: Commercially available.

**Procedure**

Take 1 g soil sample in a 500 ml conical flask and moisten with few ml of distilled water. After about 10 minutes add exactly 10 ml of 1N $K_2Cr_2O_7$ and 20 ml of $AgSO_4$ mixed $H_2SO_4$. The contents of the flask are stirred slowly for 5 minutes and then flask is placed on asbestos plate and allowed for digestion of contents for 30 min with intermittent shaking. After digestion about 100 ml of distilled water is added followed by 5-10 ml of $H_3PO_4$ About 1g of NaF and 10-20 drops of diphenylamine indicator should be added. The contents are thoroughly shaken and titrated against 1N Ferrous ammonium sulphate solution. The colour is dull green at the beginning which turns to a turbid blue as the titration proceeds and at the end point sharply changes to a brilliant green. A blank titration is conducted without soil sample.

**Observations and Calculations**

Organic carbon (%) = (Blank titration value - sample titration value) X 0.3

% organic matter in soil = Organic carbon X 1.724

### 17.5 Determination of available nitrogen in soils

The inorganic form of nitrogen (N) constitutes a very small fraction of total N in most soils and it is this form which is available to phytoplankton. Although total soil nitrogen content of a mineral soil gives some idea of its supplying power, the practical value of reliable methods providing an index of the availability of soil N has long been appreciated. In upland soils available form of N which predominates is nitrate ($NO_3$) while in the submerged or flooded soils ammonium ($NH_4$) predominates. Some times nitrite may be detected also, but generally its magnitude is small that it could be ignored in the determination of available nitrogen. Among different methods of available soil N, the alkaline permanganate method of subbiah and Asija which includes the easily oxidisable organic nitrogen, has been reported to have good correlation with productivity of brackishwater ponds.

**Principle**

A Known weight of soil is mixed with excess of alkaline potassium permanganate and distilled, where by $NH_4$ - N is released (from the oxidisable organic matter) in the form of ammonia gas. The liberated ammonia is collected in boric acid with mixed indicator and titrated against standard acid.

Reactions:

$(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + NH_4OH$

$2NH_4OH + H_3BO_3 \rightarrow (NH_4)_2B_4O_7 + H_2O(NH_4)_2B_4O_7 + H_2SO_4 + 5H_2O \rightarrow (NH_4)_2SO_4 + 4H_3BO_3$

**Reagents**

(a) 0.32% potassium permanganate: Dissolve 3.2 g of $KMnO_4$ crystals in distilled water and make up the volume up to 1 litre.

(b) 2.5% sodium hydroxide ;Dissolve 25 g of pure NaOH pellets in 1 litre of distilled water.

(c) liquid paraffin: Commercially available.

(d) 0.02 N sulphuric acid ; Dilute 30 ml of Conc. $H_2SO_4$ to 1 litre with distilled water to get approximately 1N stock solution. To make 0.02 N $H_2SO_4$ , take 20 ml of this stock solution and dilute to one litre with distilled water. Standardise this solution against 0.02N $Na_2CO_3$ using methyl orange as indicator.

(e) 4% Boric acid: Dissolve 40 g of boric acid in distilled water and make up the volume to 1 litre.

(f) Bromocresol green and methyl red mixed indicator: About 99 mg of Bromocresol green and 66 mg of methyl red indicator are dissolved in 100 ml of ethyl alcohol. This will give 0.1% mixed indicator. The colour of the indicator is mild blue pink. The pH should be between 4.7 - 5.0. 5 ml of mixed indicator should be added for every litre of boric acid.

**Procedure**

Take 10 g of air dried soil sample in 800 ml distillation flask, add 100 ml of 0.32% $KMnO_4$ solution. To that contents add 1 ml of paraffin wax and few glass beads. Attach the flask to distillation set and add 100 ml of 2.5% NaOH and close the flask. Then start distillation and collect the distillate in 20 ml of boric acid. After collecting 100 ml distillate the boric acid is titrated against N/20 standard $H_2SO_4$, till the green colour of indicator changes to pink colour at the end point. A blank titration is also conducted without soil sample.

**Observations and calculations**

1 ml of 0.02N $H_2SO_4$ = 0.00028 g N

Titre Value = y ml of 0.02 N $H_2SO_4$

10 g soil contains = y X 0.00028 g N

1 g soil contains = y X 0.000028 g N

The amount of available N kg/ha = 2.24 X $10^6$ X 0.000028 X y = 62.72 y

## 17.6 Determination of available phosphorus in soils

Phosphorus (P) in soil occurs as orthophosphate in different forms and combinations. A small portion of total phosphorus is available to phytoplankton. A wide variety of soil chemical tests are being employed for the extraction of phosphates. The choice for a suitable method depends largely on the nature and properties of soils. Due to slightly alkaline reactions of majority of brackishwater fish

**Principle**

The pH of the extracting solution is kept nearly constant at 8.5. This solution extracts P from calcium phosphates by lowering the Ca concentration by causing precipitation of calcium as $CaCO_3$ and there by increasing P concentration in solution (based on solubility product principle). In acid soils containing aluminium and iron phosphates, P concentration in solution increases as the pH rises. Secondary precipitation reactions in acid and calcareous soils are reduced to a minimum as Al, Ca and Fe concentration remain at low level in the soil extract. The extract containing available P on treatment with acidic molybdate gives phosphomolybdate which is on reduction with $SnCl_2$ develops characteristic blue colour. This intensity of blue colour depends upon the P concentration of the solution which can be measured at 660 nm by spectronic - 20.

**Reagents**

A. Standard P solution (100 ppm) : Dissolve 0.4390 g dried $KH_2PO_4$ in 400 ml distilled water, add 25 ml of 7 N $H_2SO_4$ and make up to 1 litre. From this standard P solution (5 ppm) can be prepared by diluting with distilled water.

B. Stannous chloride stock solution: 10 g of crystalline stannous chloride dissolved in 25 ml HCl by volume. The contents are warmed. Store this solution in amber colour glass bottle under a 1 cm of mineral oil to protect from oxygen and light.

Dilute stannous chloride (0.05N) : 0.5 ml of stock $SnCl_2$ solution is diluted to 66 ml with distilled water.

C. 2.5% sulphomolybdic acid: : 25 g of ammonium molybdate is dissolved in 200 ml of distilled water at 60°C. In another glass container, dilute 275 ml of phosphorus free concentrated $H_2SO_4$ to 750 ml with distilled water. After both the solution have cooled down add ammonium molybdate solution to the dilute $H_2SO_4$ slowly by constant stirring. Cool down the mixture to room temperature, make up the volume to 1 litre with distilled water and store in amber coloured bottle.

D. Sodium bicarbonate solution (0.5M) (Olsen's reagent): Dissolve 42g of $NaHCO_3$ in distilled water and make up the volume to 1 litre. Adjust the pH of solution to 8.5 by NaOH.

E. Activated charcoal: Washed with 0.5 M $NaHCO_3$ and dilute HCl. After washing with HCl, distilled water washings should be continued till the leachate is chloride free.

F. 2,4 Dinitrophenol indicator: 250 mg of Dinitrophenol is dissolved in distilled water and make up the volume to 100 ml.
G. 2N $H_2SO_4$ : 5.4 ml of 36N $H_2SO_4$ is dissolved in distilled water and diluted to one litre.

**Procedure**

Preparation of standard curve:

0, 0.5, 1, 2, 4, 6, 8, and 10 ml 5 ppm 'P' solution is transferred to 50 ml volumetric flasks. 5 ml of Olsen's reagent is added followed by 5 ml of sulphomolybdic acid in each flask and little amount of distilled water is added. Then 1 to 2 drops of 2,4 dinitro phenol indicator is added to each flask and yellow colour is developed. Then 2 N $H_2SO_4$ is added drop wise in each volumetric flask until the yellow colour disappears. (Then the pH of test solution is at 3). Now add 1 ml of 0.05 N $SnCl_2$ in each flask and make up the volume to 50 ml with distilled water. Then the solutions are kept for reading colour intensity within 12 minutes of preparation. A standard curve is drawn between concentration of P and absorbance.

Preparation of soil extract:

Take 5 g of soil in 150 ml conical flask and add 50 ml of Olsen's reagent followed by 1 or 2 g of Darco-G-60 (free of phosphorus). Shake the contents for 30 min in mechanical shaker. After shaking filter the solution with whatman No. 40 filter paper. If the solution is still coloured, add some more amount of Darco-G-60 and the contents are shaken and the solution is filtered. Take 2 ml of phosphorus extract in to 50 ml volumetric flask, add 5 ml of sulphomolybdic acid and 1-2 drops of 2,4 dinitrophenol indicator. Add 2N $H_2SO_4$ drop wise until the yellow colour disappears. Then 1 ml of 0.05 N $SnCl_2$ is added, make up the volume to 50 ml. Colour intensity is measured by spectronic 20 and phosphorus concentration is obtained form standard curve.

**Observations and Calculations**

Phosphorus concentration = y ppm (ug/ml) from graph
50 ml of solution contains = 50 X y ug p
2 ml of extract contains = 50 X y ug p
Actual extract prepared is 50 ml from 5 g soil
Therefore, 50 ml of extract contains = 50 y X 50 / 2 ug p
5 g of soil contains = 50 y X 50 / 2 ug p
1 g soil contains = y X 50 / 2 X 5 ug p/g
p in kg/ha = ppm X 2.24
p in lb/acre = ppm X 2

**17.7 Determination of available potassium in soil**

The term available k incorporates both exchangeable and water soluble forms of the nutrient in soil. The readily exchangeable plus water soluble potassium is determined in the neutral normal ammonium acetate extract of soil.

**Principle**

The ammonium ion provides a sharp and rapid separation from exchangeable complex while the other cations bring about a gradual replacement of either lesser or greater amount of k which generally increases with the period of contact. The estimation of the in the extract is carried out with the help of flame photometer.

Chemical methods being rather elaborate and time consuming are not suitable far soil testing purpose.

**Reagents**

1. Neutral normal ammonium acetate: Dilute 114 ml of glacial acetic acid (99.5%) with distilled water to a volume of 1 litre. Add 138 ml of conc. $NH_4OH$ and add water to get a pH 7 and dilute to 2 lit with distilled water. Alternatively dissolve ammonium acetate crystals (27.08g) in 400 ml of distilled water and dilute to 1 litre and adjust pH to 7.0

2. KCl stock solution: A stock solution of 1000 ug k/ml is made by dissolving 1.908 g of A.R grade KCl (dried at 60°C for 1 hr) in distilled water and made to 1 litre.

**Procedure**

Preparation for standard curve:

0, 5, 10, 20, 30, 40, 50 ppm of k solution are prepared from standard stock solution .Each solution is fed to flame photometer and the readings are noted and a standard curve is prepared.

Preparation of soil extract:

5 g of soil is shaken with 25 ml of neutral normal ammonium acetate for 5 min and filtered immediately through a dry filter paper (Whatman No.1). First two ml of filtrate may be rejected. k concentration in the extract is determined by the flame photometer. In the same way water soluble k is estimated by shaking the soil with distilled water for one hour and estimated by flame photometer.

**Observations and calculations**

Exchangeable k = Ammonium acetate extractable k - water soluble k (mg/100 g soil).

**17.8 Determination of soil texture**

The pond soil consists of a mixture of inorganic soil particles of various sizes and organic matter in various stages of decay. The texture of a mud refers to the distribution by size group of particles comprising the mud. In order to assess the texture, a sample of mud is dried and subjected to a mechanical analysis. The proportion of larger particles may be determined by sieve analysis and the smaller particles by hydrometer and other techniques. It is an important soil property because it is closely related to the rate of water intake, water retaining power, the fertility, erosiom, aeration and energy required to fill the soil. After the three types of particles are estimated, the soil texture is determined from the soil textural triangle given in the figure. Soil textural diagram is a diagram by means of which the textural name of soil may be determined from mechanical analysis.

**Principle**

The aim of textural analysis of soil is to determine the percentage of soil material contained in different size fractions and this can be done by means of mechanical analysis. Mechanical analysis consists essentially of two distinct operations, namely dispersion of the soil to ultimate soil particles and grading the dispersed particles according to their size groups.

**Reagents**

(a) 6% Hydrogen peroxide: $H_2O_2$ is generally available at 30% concentration. Dilute 20 ml of this to 100 ml with distilled water before analysis.

(b) 2 N Hydrochloric acid : Dilute 100 ml of concentrated HCl to 600 ml with distilled water to give approximately 2 N HCl.

(c) 2 N Sodium hydroxide: Dissolve 40 g of NaOH in about 300 ml distilled water and dilute upto 500 ml with distilled water.

(d) 5% Silver nitrate: Dissolve 5 g silver nitrate in 100 ml of distilled water.

**Procedure**

Take 20 g soil in a 500 ml beaker, add 250 ml of water and boil for 10 minutes, allow the suspension to settle and decant the supernatent water. Now, digest the soil with 35 ml of 6% $H_2O_2$ on a water bath adding more $H_2O_2$ till no frothing takes place. Add 30-35 ml of 2 N HCl and 100 ml of distilled water and allow to stand for 1 hour with occasional stirring to make the soil free from carbonates. Filter the soil and wash free of HCl with hot water by testing with $AgNO_3$ solution. Transfer, the suspension to a suitable glass container, add 5 ml of 2 N NaOH and shake for half an hour. Transfer the content to a 1000 ml tall cylinder, make up the volume, shake for 1 minute and allow to stand. After 4 minutes lower a 20 ml pipette at 10 cm depth and collect 20 ml of the content, dry it in a 50 ml beaker and find out the weight of clay + silt. Repeat the same procedure after 6 hours to get the weight of clay alone.

**Observations and calculations**

If weight of clay + silt be x g
and that of clay only be y g
then, % of clay = y X 250
% of silt = (x-y) X 250
% of sand = 100 - (x X 250)

# 18. ANALYSIS OF BRACKISHWATER

**R.Saraswathy, K.K.Krishnani and A.Nagavel**

## 18.1 Collection of water samples

Since it is not possible to analyse the whole of a water body, samples, which are considered representative of whole of a water mass are taken for different analyses. Sampling method depends largely on the parameter to be measured. Use only sample bottles with glass or plastic stoppers. Unbreakable polyethylene and polypropylene bottles are much more convenient.

**Preservation of water samples**

| Parameter | Preservation |
|---|---|
| pH, $CO_2$, Alkalinity, Hardness | Add 5 ml/l of chloroform. Exclude light and air. |
| Dissolved Oxygen | Fix the Sample using two Winkler reagents, immediately. Exclude any bubble |
| $NH_3$-N, $NO_2$-N, $NO_3$-N | Freeze or add 5ml/l of 2M $H_2SO_4$ |
| $PO_4$-P | Add 5 ml/l of chloroform or 2M $H_2SO_4$ |

## 18.2 pH

**Principle:** pH can be measured more accurately and conveniently with a pH meter and combination glass electrode

**Procedure (Potentiometric) :** Take the water sample in a clean beaker and dip the electrode of the pH meter into it. The indicator of the pH meter shows the pH readings directly. The meter should be calibrated routinely at pH 7.0 using appropriate buffer solution and then accuracy verified by testing a pH 9.2 buffer.

## 18.3 Alkalinity

**Principle:** It can be measured by titrating the water sample with a standard acid using methyl orange.

**Reagents :**

(a) **0.02 N Sulphuric Acid** : Dilute 30 ml of concentrated $H_2SO_4$ to 1 litre with distilled water to get approximately 1N stock solution. To make 0.02N $H_2SO_4$, take 20 ml of this stock solution and dilute to 1 litre with distilled water. Standardise this solution against 0.02N sodium carbonate using methyl orange as in indicator.

(b) **0.02 N Sodium carbonate** : Dissolve 5.3 g anhydrous sodium carbonate in 1 litre distilled water. Dilute 50 ml of this solution to 250 ml to get 0.02 N sodium carbonate.

(c) **Methyl orange indicator** : Dissolve 0.05 g reagent in 100 ml of distilled water.

**Procedure :** Add 2 drops of methyl orange indicator to 50 ml of water sample. If the sample remains colourless, no alkalinity is there. If it is yellow, titrate with 0.02N $H_2SO_4$ till the colour turns faint orange.

**Calculation**

Total alkalinity (ppm of $CaCO_3$) = volume of 0.02 N $H_2SO_4$ required for titration x 20

### 18.4 Turbidity

**Principle (Nephelometric method):** Turbidity can be caused either by planktonic organisms or by suspended soil particles. Turbidity due to suspended soil particles be measured by Nephelo-turbidity meter which is based on the scattering of light beam produced by tungsten filament lamp by particulate material. The quantity of light scattered is taken as a measure of turbidity in NTU. The higher the intensity of scattered light, the higher the turbidity.

**Reagents:**

(a) Turbidity free water

(b) Standard turbidity suspension

**Solution-I** : Dissolve 1g hydrazine sulphate in distilled water and dilute to 100 ml in a volumetric flask

**Solution-II** : Disoolve10 g hexamethylene tetramine in distilled water and dilute to 100 ml.

Mix 5 ml each of Solutions I and II. Let stand 24 hours at 25oC. Dilute to mark and mix. The turbidity of this suspension is 400 NTU. Dilute 10 ml of this stock suspension to 100 ml with turbidity free water. Prepare daily. The turbidity of this suspension is 40 NTU.

**Procedure**: Calibrate the instrument using standard turbidity suspension. Shake the sample thoroughly. Wait until air bubbles disappear and pour sample into turbidimeter tubes. Place the tube in instrument and read turbidity in NTU directly from instrument scale.

### 18.5 Transparency

A standard Secchi disc is a circular metal plate having 10 cm radius. The upper surface of the disc is divided into four quadrants, painted in black and white colours. The disc is gradually lowered into the water and the depth(cm) at which the upper surface just disappears is noted(d1). Now the disc is slowly lifted upward and the depth at which the disc reappears is noted(d2). The value (d1+d2)/2 in cm gives a measure of transparency.

### 18.6 Total Settleable solids

**Principle**: This is a portion of organic and inorganic solids that settles in 1 h in an Imphoff cone and is measured in terms of ml/l.

**Procedure** : Shake the water sample vigorously and pour 1 litre water into Imhoff cone graduated at the lower end and leave it for 1 h. Measure the quantity of settleable solids in ml/l.

## 18.7 Total Suspended Solids (TSS) and Total Dissolved Solids

**Principle:** A well mixed sample is filtered though a weighed standard glass fibre filter disc or Gooch crucible made of porcelain and the residues retained on the filter is dried to constant weight at 103oC to 105oC. The increase in weight of filter represents the total suspended solids.For total dissolved solids, the filtrate is evaporated to dryness in a weighed dish and dried to constant weight. The increase in dish weight represents the total dissolved solids.

**Procedure:** Wash filter disc with three successive 20 ml volumes of distilled water using vacuum. Continue suction to remove all traces of water. Filter a measured volume of well mixed sample through the glass fibre filter disc or Gooch crucible. Wash with three successive 10 ml volumes of distilled water allowing complete drainage between washings and continue suction for about 3 minutes after filtration is complete. Transfer filtrate to a weighed evaporating dish for measurement of total dissolved solids.

TSS:

Dry filter disc/crucible containing residues for at least 1h at 103°C-105°C in an oven. Cool in a dessicator and weigh. Repeat the cycle of drying, cooling, desiccating and weighing until a constant is obtained.

$$\text{TSS (mg/l)} = \frac{(A\text{-}B) \times 1000}{\text{Sample volume (ml)}}$$

A = Weight of filter or crucible + dried residue(mg)
B= Weight of filter or crucible(mg)

**Total Dissolved Solids:**

Evaporate the filtrate in dish to dryness on a steam bath. Dry for atleast 1h in an oven at 180°C, cool in a desiccator and weigh. Repeat drying, cooling, desiccating and weighing until a constant weight is obtained.

$$\text{Total dissolved solids(mg/l)} = \frac{(A\text{-}B) \times 1000}{\text{Sample volume ml}}$$

A = Weight of dried residues + dish (mg)
B = Weight of dish(mg)

## 18.8 Salinity

**Principle ;** The salinity of sea water can be determined by titrating the precipitable halides ($Cl^-$,$Br^-$ and $I^-$) with silver nitrate solution as silver chloride using a chromate end point, the mohr titration.(Rapid low precision method) :

**Reagents :**

(a) **Silver nitrate solution** : Dissolve 6.82 g of pure $AgNO_3$ in 250 ml of distilled water and store in a dark bottle. Standardize the solution by titrating against standard sodium chloride solution using potassium chromate indicator solution.

(b) **Standard sodium chloride solution** : Dissolve 2.06 g analytical NaCl in 250 ml of distilled water. Each ml of this NaCl contains 5 mg of $Cl^-$.
(c) **Indicator diluent solution**: Dissolve 5 g potassium chromate in 80 ml of distilled water and dilute to 100 ml.

**Procedure** : To 5 ml of sample , add a few drops of indicator. Titrate with standard silver nitrate solution, with constant agitation of flask, until the colour just changes permanently from yellow to brown red and will not return to yellow with further shaking. Salinometer (Refractometer) : Low precision salinity measurements in the field can also be made using Salinometer.

**Calculation**
Chlorinity (ppt) = volume of $AgNO_3$ used for titration
Salinity (ppt) = 0.03 + 1.805 x Chlorinity (ppt)

**18.9 Dissolved Oxygen**

**Principle** : DO can be determined by Winkler's method. In this method a divalent manganese solution, followed by strong alkali, is added to the sample. Any dissolved oxygen rapidly oxidises an equivalent amount of divalent manganese to basic hydroxides of higher valency states. When the solution is acidified in presence of iodide ions, the oxidised manganese ions again reverts to divalent state and iodine, equivalent to the original dissolved oxygen content of the water, is liberated. This iodine is titrated with standardised thiosulphate solution.

**Reagents** :
(a) **Winkler A solution** (Manganous sulphate) : dissolve 480 g $MnSO_4.4H_2O$ or 400 g of $MnSO_4.2H_2O$ or 365 g of $MnSO_4.H_2O$ in distilled water and make up the volume to 1 litre.
(b) **Winkler B solution** (alkaline iodide) : Dissolve 500 g of sodium hydroxide and 300 g of potassium iodide in 900 ml of distilled water and make up the volume to 1 litre.
(c) **Standard thiosulphate solution** (0.025 N): To prepare 0.1 N stock solution of sodium thiosulphate, dissolve 24.82 g of crystalline $Na_2S_2O_3.5H_2O$ and 4.0 g of borax as a preservative in 700 ml of distilled water and make up the volume to 1 litre. Standardise the strength of this solution to exactly 0.1 N by titrating against 0.1 N potassium dichromate. To make 0.025 N thio solution, dilute 125 ml of this standardised stock solution(0.1 N) to 500 ml
(d) **Concentrated sulphuric acid.**
(e) **0.1 N potassium dichromate** : Dissolved 4.904 g of dried and crystalline $K_2Cr_2O_7$ in 1 litre
of distilled water.
(f) **Starch solution(0.2%)** : Add 2.0 g starch and 30 ml 20% NaOH solution in 350 ml of distilled water. Stir until a thick, almost clear solution is obtained. Neutralise the alkali with HCl and acidify with 1 ml of glacial acetic acid. Finally dilute the solution to 1 litre with distilled water.

**Procedure** : Collect the water sample in stoppered BOD bottle and add immediately 1 ml of manganous sulphate reagent with a pipette followed at once by 1.0 ml of alkaline iodide solution. Restopper the bottle immediately and mix the contents thoroughly by shaking to develop a flocculent precipitate. No air bubble should be trapped in the bottle. Add concentrated sulphuric acid (about 1 ml) to dissolve the precipitate. Transfer 50 ml of dissolved solution into a conical flask. Titrate at once with 0.025 N standard thiosulphate solution until a very pale straw colour remains. Add starch(about 5 ml) indicator and continue the titration until the blue colour is just discharged. Solution should remain colourless for at least 20 seconds at the end point.

**Calculation :**

$$DO\ (ppm) = \frac{8000\ N \times V_1}{V_2}$$

$V_1$=volume(in ml) of $Na_2S_2O_3$ of normality N required for titration
$V_2$ = volume of water sample titrated.
If N = 0.025N and $V_2$ = 50 ml then **DO (ppm) = $V_1$ x 4**

**Measurement of DO by DO meter:**
DO can also be measured by DO meter (YSI, USA) in field.

**18.10 Chemical Oxygen Demand**

**Principle** : COD is a measure of organic matter and represents the amount of oxygen required to oxidize the organic matter by strong oxidizing chemicals(potassium dichromate) under acidic condition. The excess dichromate is titrated with standard ferrous ammonium sulphate using ferroin as an indicator. Mercuric sulphate is added to complex the chlorides, thereby effectively eliminating the chlorides interference.

**Reagents :**
(a) **0.05 N Potassium dichromate** : Dissolve 2.452 g dried, crystalline $K_2Cr_2O_7$ in distilled water and make up the volume to 1 litre.
(b) **0.05 N Ferrous ammonium sulphate (FAS)**: Dissolve 19.61 g of $Fe(NH_4)_2(SO_4)_2.6H_2O$ in 800 ml of distilled water containing 1 ml of conc. sulphuric acid. and make up the volume to 1 litre.
(c) **Mercuric sulphate**
(d) **Ferroin indicator** : Dissolve 1.888 g of 1:10 phenanthrolin monohydrate and 0.70 g of $FeSO_4.7H_2O$ in 100 ml of distilled water.

**Procedure** : Pipette out 20 ml of water sample into a 125 ml Erlenmeyer flask. Add exactly 10 ml of 0.05 N $K_2Cr_2O_7$ solution to the flask. Add 200 mg $HgSO_4$ for each 1000 mg per litre of chloride($HgSO_4$ : Cl :: 10 : 1). Swirl until the $HgSO_4$ is dissolved. Add carefully 30 ml of conc. $H_2SO_4$ Cover the flask with watch glass and allow to stand for 30 min. Add 15 ml of distilled water and 3 drops of ferroin indicator and titrate the whole reaction mixture with FAS of same normality. Prepare blank with 20 ml distilled water and repeat the same procedure.

**Calculation :**

$$COD\ mg/l = \frac{(B-S) \times N \times 8000}{V}$$

B = Titre value for Blank in ml
S= Titre value for sample in ml
N = Normality of FAS
V = Volume of sample in ml

## 18.11 Biochemical Oxygen Demand

**Principle** : The sample of water or appropriate dilution is incubated for 5 days at 20°C in the dark. The reduction in DO concentration during the incubation period yields a measure of the BOD.

**Reagents** :

Use all the reagents required for the determination of DO.

**Procedure** : Collect three water samples from one site into BOD bottle following the procedure for DO. Determine the DO level in one of these samples, whilst the remaining two samples are firmly stoppered and placed in an incubator at 20° C in the dark for 5 days. At the end of this time, the DO level is determined by the usual Winkler's titration.

**Calculation** :

Initial DO = $D_o$ ppm

Final DO ( after 5 days incubation) = D ppm

BOD ( reduction in DO) = $(D_o - D)$ ppm

In heavily polluted samples, it is necessary to dilute the sample with a known amount of clean, air saturated water, so as to obtain required dilution (almost 50%). Siphon out the mixed sample into two sets of specially designed BOD bottles, one set for incubation and the other for determination of initial DO.

**Calculation** :

Initial DO = $D_o$ ppm

Final DO = D ppm

Reduction in DO = $D_o - D = D_{r1}$ ppm

Dilution water initial DO = $D_1$ ppm

Final DO = $D_2$ ppm

Reduction in DO = $D_1 - D_2 = D_{r2}$ ppm

Therefore reduction due to sample = $D_{r1} - D_{r2}$ ppm = $D_s$

BOD (ppm) = $D_s$ x Dilution factor

## 18.12 Ammonia-N

**Principle** : Water sample is treated in an alkaline citrate medium with sodium hypochlorite and phenol in the presence of sodium nitroprusside which acts as a catalyzer. The blue indophenol colour formed with ammonia is measured spectrophotometrically.

**Reagents**

(a) **De-ionised water**

(b) **Phenol solution** : Dissolve 20 g of analytical grade phenol in 200 ml of 95%v/v ethyl alcohol.

(c) **Sodium nitroprusside solution** : Dissolve 1.0 g of sodium nitroprusside, $Na_2Fe(CN)_5NO.2H_2O$, in 200 ml of de-ionised water. Store in a dark glass bottle. The solution is stable for at least a month.

(d) **Alkaline reagent** : Dissolve 100 g of sodium citrate and 5 g of sodium hydroxide in 500 ml of de-ionised water. The solution is stable indefinitely

(e) **Sodium hypochlorite solution**

(f) **Oxidising solution** : Mix 100 ml of reagent 4 and 25 ml of reagent 5. Prepare fresh every day.

**Procedure** : Add 50 ml of seawater to an Erlenmeyer flask from 50 ml measuring cylinder. Add 2 ml of phenol solution, swirl to mix and then add in sequence 2 ml of nitroprusside 5 ml of oxidizing solution. Mix after each addition by swirling the flasks. Cover the flasks with aluminum foil to lessen the contamination by atmospheric ammonia and allow the flasks to stand at room temperature for 1 hr in dark. The colour is stable for about 24 hr after the reaction period. Read the absorbance at 640 nm in a spectrophotometer against blank or distilled water using 10 cm cell. Carry out the method exactly as described above for blank also using 50 ml of de-ionized water.

**Calculation** : Calculate the ammonia concentration by using calibration curve.

**Standard curve** : Dissolve 0.9433 g of analytical reagent quality ammonium sulphate in 950 ml of distilled water. Add 1 ml of chloroform and make up the volume to 1 litre. Store in refrigerator, sheltered from strong light. This solution contains 200ppm and is stable for many months if well stoppered. Prepare a series of standard solutions from this stock solution and carry out the method exactly as described above. After colour development, measure absorbance at 640 nm and prepare a calibration curve from the absorbance of a series of standards.

18.13 Nitrite-N :

**Principle** : The nitrite in water is allowed to react with sulfanilamide in an acid solution. The resulting diazo compound is reacted with NED and forms a highly coloured azo dye.

**Reagents :**

(a) **Sulfanilamide solution** : Dissolve 5.0 g of sulfanilamide in a mixture of 50 ml of conc. HCl and about 300 ml of distilled water. Dilute to 500 ml with distilled water. The solution is stable for many months.

(b) **NED (N-(1-naphthyl)- ethylene diamine dihydrochloroide solution)** Dissolve 0.5 g of the dihydrochloride in 500 ml of distilled water. Store the solution in a dark bottle. The solution should be renewed once a month or directly a strong brown colouration develops.

(c) **Standard nitrite:** Dissolve 1.064 g anhydrous, analytical grade potassium nitrite. $KNO_2$,(dried at 105 C for 1 hr)in distilled water. Add 1 ml 5 N NaOH and dilute to 250 ml. This solution contains 700 mg/l nitrite-N and should be stored in a dark bottle with 1 ml of chloroform as a preservative in refrigerator. The solution is stable for several months.

**Procedure** : Add 1.0 ml of sulfanilamide solution from a pipette to each 50 ml sample, mix and allow the reagent to react for more than 2 minute but less than 10 min. to assure a complete reaction. Add 1 ml of NED reagent and mix immediately. Leave for 10 minutes and then measure the absorbance(OD) of the samples and standards against a reagent blank at 540 nm. The colour is stable for 2 h. Calculate the nitrite concentration by using callibration curve.

### 18.14 Nitrate

**Principle**: Nitrate in water sample is reduced almost quantitatively to nitrite. The nitrite produced is determined by diazotising with sulfanilamide and coupling with NED to form a highly coloured azo dye which can be measured spectrophotometrically.

**Reagents**

(a) **Phenol solutions** : 23 g phenol in 500 ml of distilled water.
(b) **NaOH** : 1.25 g in 500 ml of distilled water.
(c) **Buffer reagent** : Mix equal volume of phenol solution and NaOH solution.
(d) **Copper sulphate solution** : 0.1 g in 1 litre distilled water.
(e) **Hydrazine sulphate** : 3.625 g in 500 ml of distilled water.
(f) **Reducing agent** . 5 ml of copper sulphate solution to 5 ml of hydrazine sulphate.
(g) **Acetone**
(h) **Sulfanilamide** ; Dissolve 5.0 g in 50 ml of conc. HCl and make up the volume to 500 ml.
(i) **NED** : Dissolve 0.5 g of NED in 500 ml of distilled water
(j) **Nitrate standard solutions** : Dissolve 0.36119 g potassium nitrate, $KNO_3$ (AR dried at 105°C) in 250 ml distilled water. Dilute 100 ml of this solution to 1 litre with distilled water. This final solution contains 2 ppm $NO_3^-$.

**Procedure** : Take 10 ml of sample and add 0.4 ml of buffer and mix and then add 0.2 ml reducing agent and keep the tube in dark for 24 hours. Then add 0.4 ml of acetone and after 2 minutes add 0.2 ml of sulphanilamide. After 3 minutes, add 0.2 ml of NED solution and after 10 minutes, measure the absorbance at 540 nm in a spectrophotometer.

### 18.15 Total P and Dissolved reactive phosphorous

**Principle** : Ammonium molybdate and potassium antimony tartarate react in acid medium with orthophosphate to form a heteropoly acid- phosphomolybdic acid that is reduced to intensely coloured molybdenum blue by ascorbic acid.

**Reagents**

(a) **Sulphuric acid:** 5N : Dilutre 70 ml conc sulphuric acid to 500 ml.
(b) **Pottassium antimony tartarate**: Dissolve 1.3715 gm K(SbO)C4H4O6.1/2 H2O in 500 ml of distilled water.
(c) **Ammonium molybdate solution** : Dissolve 20 gm (NH4)6 Mo7O24.4H2O in 500 ml of distilled water.
(d) **Ascorbic acid: 0.01M:** Dissolve 1.76 gm ascorbic acid in 100 ml of distillede water. stable for 1 week at 4oC.
(e) **Combined reagent:** Mix 50 ml of 5N H2SO4 + 5 ml Potassium antimony tartarate+ 15 ml ammonium molybdate reagents+ 30 ml ascorbic acid. If turbidity, shake until turbidity disappears. Stable for 4 hours.

(f) **Stock phosphate solution**: Dissolve 219.5 mg anhydrous potassium di-hydrogen phosphate in distilled water and dilute to 100 ml. **1ml = 50 ug $PO_4^{-}$ -P**

**Standard solutions**: Dilute 50 ml of stock solution to 1000 ml with distilled water.

**1 ml = 2.5 ug $PO_4^{-}$ -P**

**Procedure** : To 50 ml water sample in Erlenmeyer flask, add 0.05 ml (1 drop) phenolphthaliene. If red colour appears, add 5 N sulphuric acid to discharge the colour. Add 8 ml combined reagent and mix thoroughly. After 10 minutes to 30 minute, measure absorbance of sample at 880 nm using reagent blank as the reference solution.

**Total P**

1. Add 8 ml of potassium persulfate solution into a 100 ml conical flask containing 40 ml of sample.
2. Mix well and cover the mouth of the flask with aluminium foil.
3. Place the conical flask in a autoclave for 15 minutes under a presence of 15 lbs.
4. After that, remove the flask, cool the contents and make up the volume to 60 ml with distilled water.
5. Then, follow the same procedure as mentioned above for inorganic phosphates.
6. Calculate the organic- P by deducting inorganic- P from total- P.

## 18.16 Hardness

**Principle** : Calcium and magnesium ions are titrated with the complexing agent ethylene diamine tetra acetic acid disodium salt(EDTA) to form the stable complexes. The end point of the titration is signalled with an indicator called Erichrom black-T.

**Reagents :**

(a) **Buffer solution** : Disolve 67.5 g of ammonium chloride in 570 ml of conc. ammonium hydroxide. Dilute to 1000 ml with distilled water.

(b) **Erichrome black-T** (EBT): Dissolve 4.5 g of hydroxyl amine hydrochloride and 0.5 g of Erichrome black-T in 100 ml of 70 % ethanol.

(c) **Standard calcium solution** : Transfer 1.0 g of anhydrous calcium carbonate to a 1 litre beaker. Add 1:1 HCl slowly to dissolve the calcium carbonate and dilute to about 200 ml with distilled water. Boil for 5 to 10 minutes to expel carbon dioxide, cool and adjust to pH 7.0 as determined with a pH meter, with 3N $NH_4OH$. Transfer to a 1000 ml volumetric flask and dilute to volume with distilled water.

(d) **Standard EDTA solution** : Dissolve 4.0 g EDTA disodium salt and 100 mg of $MgCl_2.6H_2O$ in distilled water and dilute to 1 litre. The solution must be standardized against the standard calcium solution. Pipette 10 ml of the standard calcium solution into a 250 ml beaker and add 90 ml of distilled water. Titrate the calcium solution with EDTA solution according to the procedure given below. Compare the molarity of the EDTA solution with the equation : $NV = N'V'$

**Procedure** : Measure 100 ml of water sample into a 250 ml Erlenmeyer flask. Add 2 ml of the buffer solution and mix. Add 8 drops of EBT indicator and titrate with the EDTA solution. At the end point, the solution will change from wine red to pure blue.

**Calculation** :

$$\text{Total hardness ( mg/l as } CaCO_3) = \frac{T \cdot M \cdot 100000}{S}$$

Where, T = Volume in ml of EDTA solution
M = Molarity of EDTA solution
S = Volume in ml of sample

**18.17 Hydrogen sulphide**

**Reagents**

*(a)* **Hydrochloric acid,** ***HCL, 6N.***

(b) **Standard iodine solution, 0.0250N**: Dissolve 20 to 25 g KI in a little water and add 3.2 g iodine. After iodine has dissolved, dilute to 1000 ml and stadardize against 0.0250 *N* $Na_2S_2O_3$, using starch solution as indicator.

*(c)* **Standard sodium thiosulfate solution**, 0.0250N: Dissolve 6.205 g Na2S2O3.5H2O in distilled water. Add 1.5 ml 6N NaOH or 0.4 g solid NaOH and dilute to 100 ml

(d) **Starch Solution**: Dissolve 2 g starch + 0.2 g salicylic acid as a preservative in 100 ml hot distilled water.

**Procedure** : Measure from a burette into a 500-ml flask an amount of iodine solution estimated to be an excess over the amount of sulfide present. Add distilled water, if necessary, to bring volume to about 20 ml. Add 2 ml 6N HCL. Pipet 200 ml sample into flask, discharging sample under solution surface. If iodine color disappears, add more iodine so that color remains. Back titrate with $Na_2S_2O_3$ solution as end point is approached, and continuing until blue color disappears.

**Calculaltion**

ml of 0.0250*N* iodine solution reacts with 0.4 mg $S^{--}$

$$\text{mg } S^{2-}/L = \frac{[(A \times B)-(C \times D)] \times 16000}{\text{ml sample}}$$

Where:

A = ml iodine solution,
B = normality of iodine solution,
C = ml $Na_2S_2O_3$ solution, and
D = normality of $Na_2S_2O_3$ solution.

**18.18 Residual Chlorine (Free, combined and total)**

**Principle**: N, N-diethyl-p-phenylenediamine (DPD) is used as an indicator in the titrimetric procedure with ferrous ammonium sulfate (FAS). Where complete differentiation of chlorine species is not required, the procedure may be simplified to give only free and combined chlorine or total chlorine. In the absence of iodide ions, free chlorine reacts instantly with DPD indicator to produce a red colour. Subsequent addition of iodide ions acts catalytically to cause chloramines(mono & di) to produce colour.

**Reagents**

(a) **Phosphate buffer solution:** Dissolve 24 g anhydrous $Na_2HPO_4$ and 46 g anhydrous $KH_2PO_4$ in distilled water. Combine with 100 ml distilled water in which 800 mg disodium ethylenediamine tetraacetate dihydrate (EDTA) have been dissolved. Dilute to 1 L with distilled water and add 20 mg $HgCl_2$ to prevent mold growth and interference in the free chlorine test caused by any trace amounts of iodide in the reagents. (CAUTION: *$HgCl_2$ is toxic – take care to avoid ingestion*).

(b) **N, N-Diethyl-phenylenediamine** (DPD) indicator solution: Dissolve 1 g DPD oxalate, * or 1.5 g DPD sulfate pentahydate, or 1.1 g anhydrous DPD sulfate in chlorine-free distilled water containing 8 ml(1 + 3)$H_2SO_4$ and 200 mg disodium EDTA. Make up to 1 L, store in a brown glass-stoppered bottle in the dark, and discard when discolored. Periodically check solution blank for absorbance and discard when absorbance at 515 nm exceeds 0.002/ cm. CAUTION: *The oxalate is toxic – take care to avoid ingestion.*

(c) **Standard ferrous ammonium sulfate** (FAS) titrant: Dissolve 1.106 g $Fe(NH_4)_2(SO_4)_2 . 6H_2O$ in distilled water containing 1 ml 1 + 3 $H_2SO_4$ and make up to 1 litre with freshly boiled and cooled distilled water. This standard may be used for 1 month, and the titer checked by potassium dichromate. For this purpose add 10 ml 1 + 5 $H_2SO_4$, 5 ml conc. $H_3PO_4$, and 2 ml 0.1% barium diphenylamine sulfonate indicator to a 100-ml sample of FAS and titrate with 0.100 N primary standard potassium dichromate to a violet end point that persists for 30 s. The FAS titrant is equivalent to 100 µg Cl as $Cl_2$/ 1.00 ml.

**Procedure :** Mix 5 ml each of buffer reagent and DPD indicator in a conical flask. Then, add 100 ml of sample (upto 5 ppm, if > 5 ppm use diluted sample) and mix and titrate rapidly with standard ferrous ammonium sulphate titrant until red colour is discharged (titre value A). For combined chlorine, add about 1 gm of KI, mix and then continue titrating until red colour is discharged again.(titre value B).

**Calculation**

For a 100-ml sample, 1.00 ml standard FAS titrant = 1.00 mg Cl as $Cl_2$/L.

A = Free chlorine
B = Combined chlorine (mono-chloramines and di-chloramines)
C = (A+B) = Total chlorine

# 19. APPLICATION OF MOLECULAR TECHNIQUES FOR FOOD SAFETY

K.K.Krishnani

The pollution of soil and water with xenobiotics is widespread in the environment and is creating major health problems. Heavy metals which are discharged from electroplating industry, metal finishing, leather tanning and chrome preparation has got adverse impact on the aquatic species as they are among the conservative pollutants which are not subject to bacterial attack or other breakdown and are permanent additions to the marine environment. Pesticides that are primarily of agricultural origin may contaminate aquatic ecosystem. Persistent organic pollutants (POP) and other persistent bio-accumulative toxicants (PBT's) pose a serious environmental hazard because of their persistence, toxicity and lipophilic nature. The utilization of microorganisms to clean up xenobiotics from a polluted environment represents a potential solution to such environmental problems.

Knowledge and monitoring of microbial ecology is required to predict nutrient fluxes and to analyze the fate of pollutant, which helps to optimize bioremediation performance. The biochemical importance of bioremediators indicates a need for development of reliable methods for identification of these organisms in nature. Molecular detection systems, which do not rely on traditional cultivation appear to be promising alternatives for examining microbial diversity and functional genes. Molecular methods detect the presence of functional genes directly involved in the chemical process of interest. Nucleic acid methods based on sequencing of clone libraries provide sequence and the phylogenetic information of individual clone. In addition, identifying functional genes directly involved in the chemical process of interest could complement 16S rRNA gene based approaches.

An understanding of microbial populations in the system is very important since biodiversity may play a major role in enhancing biostimulation and indigenous bioaugmentation predictability and reliability. In addition, study on better knowledge of the microbial structure in their natural habitats is useful for a more accurate understanding and modeling of the nitrogen fluxes.

### 19.1 Molecular biological characterization of chemolithoautotrophs

Nitrogen fixing bacteria play an important role in conversion of atmospheric nitrogen into ammonia, which oxidized to nitrite and nitrate by nitrifying bacteria. Denitrifying bacteria converts nitrate into atmospheric nitrogen through the formation of nitrogenous metabolites. Chemolithoautotrophic sulfur oxidizing bacteria (SOB) makes an important contribution in oxidation of reduced sulfur compounds such as sulfide, elemental sulfur, polythionates and thiosulfate in coastal aquaculture.

A better knowledge of the structure of the nitrifying and denitrifying communities in their natural habitats is required for a more accurate understanding and modeling of the nitrogen fluxes. Molecular detection systems which do not rely on traditional cultivation appear to be promising alternatives. Most of the molecular studies on the ecology of microbes are based on the functional genes, which are exploited for developing probes or primers. In this connection, molecular methods based on DNA sequencing of clone libraries provide novel sequence information and the phylogenetic identification of individual clones.

Recently, molecular techniques have been used to study microbial populations in Indian coastal aquaculture water / wastewater systems. Chemolithoautotrophic bacteria have been characterized, for which functional genes were targeted. The nucleotide sequences of functional genes determined have been deposited in the GenBank database. This has a potential to shed light on the ecology of uncultured organisms responsible for ammonia and sulfide oxidation and for making bioremediation strategy in coastal shrimp aquaculture. This study will have impact on the modeling of nutrient flux from coastal soil.

The molecular methods shed light on the ecology of the uncultured organisms and their population changes in aquaculture environment. An understanding of microbial populations in the system is very important since biodiversity may play a major role in enhancing indigenous bioaugmentation predictability and reliability.

### 19.2 Real-time PCR

Soils are estimated to harbor up to $10^{10}$ bacteria of about $10^4$ different ribotypes per gram, of which more than 95% can not be cultured by present methods. Cultivation-dependent analysis of diversity of environmental ammonia oxidizing bacteria is difficult and extremely tedious due to the slow growth rates, long incubation period and the small size of the colonies. Both MPN and plating methods have qualitative and quantitative biases. Overgrowth of other organisms occur during the long incubation of 1-4 months. Micro colonies formed do not have distinguishing features and therefore it is difficult to recognize nitrifier colonies among contaminated colonies. Moreover, the MPN method underestimates the nitrifier population by 10 to 100 times because of media selectivity, particulate matter and clumping, whereas cultivation-independent molecular techniques helps to recover the entire diversity.

The value of molecular techniques for addressing problems in marine biology has only recently begun to be cherished. Microarray for the detection of nitrifying bacteria, has drawback of less sensitivity. In the case of FISH technique for quantification of nitrifying bacteria, there is uncertainty about the reliability of the quantification data. Conversely, real time PCR has shown much higher sensitivity for the detection of nitrifying bacteria. The real-time PCR technique is based on continuously monitoring fluorescence throughout the reaction. This is made possible by adding a dually labeled fluorescent probe that hybridizes to the template in each cycle. The fluorescent emission from one of the dyes, the reporter dye, is quenched by the emission from the other dye-called quencher. Due to free resonance energy transfer (FRET) and 5'-to -3' nuclease activity of the polymerase, probe gets cleaved, which in turns, increases the emission from the reporter dye. Quantification of DNA by real-time PCR is based on measurements obtained during the early exponential phase, when amplification of the PCR product is first detected and the amount of the amplified product is proportional to the concentration of the template DNA.

In real-time PCR analyses, quantification is based on the threshold cycle Ct, which is inversely proportional to the logarithm of the initial gene copy number. Real-time PCR for estimation of ammonia oxidizing bacteria, was found to be several order magnitude higher than culture dependent methods. Simultaneous quantification of phylogenetic and functional genes can be achieved by Real time PCR, which has the advantages of microarrays and quantitative PCR.

### 19.3 Summary

Molecular methods detect the presence of the genes responsible for the degradation of capability, when the molecular pathway is known. A better knowledge of these functional genes is required to develop molecular approaches for environmental studies on the ecology of microbial population. One classical molecular approach is targeting the ribosomal gene. In addition, identifying genes directly involved in the chemical process of interest could complement 16S rRNA gene based approaches. These molecular techniques are proved to be most effective in detection of low copy numbers of target genes.

# 20. PRECISION AND ACCURACY IN ANALYSIS

**M.Muralidhar**

Precision refers to agreement of two or more replicate determinations of a given value. Accuracy refers to the closeness with which a measured value approaches the true value. To illustrate precision and accuracy, consider the determinations of salinity by four students. The instructor determined that the sample had a salinity of 25.2 ppt (considered to be the true value). The results are given in Table 1.

**Table 1. Illustration of precision and accuracy in salinity measurement**

| Student | Replicate | | | | | Standard |
|---|---|---|---|---|---|---|
| | a | b | c | d | Mean | deviation |
| 1 | 25.1 | 25.2 | 24.9 | 25.2 | 25.1 | 0.14 |
| 2 | 23.1 | 23.2 | 23.0 | 23.1 | 23.1 | 0.08 |
| 3 | 22.1 | 20.1 | 23.2 | 19.1 | 21.1 | 1.86 |
| 4 | 22.2 | 23.2 | 28.7 | 25.1 | 24.8 | 2.86 |

Student 1 obtained both high precision (low standard deviation) and accuracy. While Student 2 achieved good precision, accuracy was poor. Student 3 obtained low accuracy and low precision. Student 4 obtained good accuracy in spite of low precision. Obviously, the most desirable results were those of Student 1.

Relative accuracy may be expressed as:

$$\text{Percent relative error} = \frac{\text{True value} - \text{measured value}}{\text{True value}} \times 100.$$

## 20.1 Precision and Accuracy Checks

Once an analyst has accepted a certain method of analysis, obtained the necessary reagents and equipment, and learned to perform the analysis, precision of the measurements should be estimated. Precision can be determined on standard solutions of the substance to be measured, but a better procedure is to obtain real water samples and make the precision estimates on them. An acceptable procedure is to obtain three water samples: one low, one intermediate, and one high in concentration of the substance to be measured. The analyst then makes a number of repetitive measurements on each sample and calculates the mean and standard deviation or confidence interval for individual measurements. The results (Table 2) of total suspended solids analysis indicate that waters with a high concentration of total suspended solids can be analyzed with slightly better precision than waters with a lower concentration of total suspended solids.

The accuracy of procedures can be checked by adding a known amount of the substance to be measured to distilled water, analyzing the resulting standard solution, and determining how close the measured value approaches the true value (represented by the concentration of the standard solution). It is again more desirable to determine the accuracy of a method by measurements involving natural water. This can be achieved by determining the concentration of the substance in natural water and then adding a known amount of the substance to the natural water and determining the percentage recovery. This technique, called spike recovery, is illustrated for the determination of total ammonia nitrogen. A water had a measured total ammonia nitrogen concentration of 1.51 mg/ liter. An ammonia nitrogen spike of 1.0 mg/L was added to the sample to provide a concentration of 2.51 mg/L of total ammonia nitrogen. Replicate determinations were made and the obtained were given in Table 3.

**Table 2. Illustration of evaluation of precision of total suspended solids analysis.**

| Replicate | Total Suspended Solids | | |
|---|---|---|---|
| | Sample A | Sample B | Sample C |
| 1 | 18.0 | 65.6 | 155.6 |
| 2 | 16.8 | 64.4 | 152.0 |
| 3 | 17.8 | 64.5 | 159.1 |
| 4 | 18.0 | 63.1 | 155.8 |
| 5 | 17.5 | 64.1 | 157.2 |
| 6 | 18.8 | 66.9 | 150.3 |
| 7 | 19.0 | 63.0 | 160.5 |
| Mean | 18.0 | 64.5 | 155.8 |
| Standard deviation | 0.75 | 1.38 | 3.64 |
| 95% confidence interval | 1.83 | 3.36 | 8.92 |
| Coefficient of variation (%) | 4.17 | 2.13 | 2.34 |

**Table 3. Illustration of evaluation of accuracy of total ammonia nitrogen analysis.**

| Replicate | Total ammonia nitrogen (mg/liter) |
|---|---|
| 1 | 2.50 |
| 2 | 2.39 |
| 3 | 2.35 |
| 4 | 2.45 |
| 5 | 2.53 |
| 6 | 2.40 |
| 7 | 2.51 |
| Mean | 2.45 |

$$\text{Recovery} = \frac{2.45}{1.51 + 1.00} \times 100 = 97.6\%$$

We may state that for a water containing 2.51 mg/liter total ammonia nitrogen, the recovery was 97.6% . The percent recovery is a good approximation of accuracy, but the true concentration of substance can never be known with absolute certainly.

Obviously, an analyst cannot afford to make a large number of repetitive measurements, conduct a spike recovery for each sample, or analyze a standard solution with each sample. The analyst can and should make periodic checks of precision and accuracy. For example, about 5 to 10% of the samples should be analyzed in duplicate. If the duplicate measurements do not agree with the known precision of the method, the results are not reliable and the problem in the technique must be located and corrected. Similarly, periodic checks of accuracy should be made with spike recovery tests or by analyses of standard solutions.

For colorimetric methods, calibration graphs must be prepared by measuring the absorbance of known concentrations of the substance being measured and plotting the results. These graphs should be verified frequently by analyzing known concentrations of the substance in question. It is important to understand that the common practice of making duplicate or triplicate analyses of all samples is essentially worthless. Analysts should not waste time and reagents on checking every sample, and duplicate analyses provide no estimate of accuracy.

**20.2 Quality Control Charts**

A more refined quality control procedure involves use of quality control charts, and use of quality control charts is highly recommended for monitoring programs. Charts for maintaining quality control were originally developed for manufacturing, but they can be adapted for use by laboratories that conduct water analyses. A quality control chart consists of a graph on which the vertical scale represents the results and the horizontal scale indicates the sequence of the results (time). Warning and control limits and the averages of the statistical measures under consideration are indicated on the graph. The results are plotted over time and from these plots it can be ascertained if precision and accuracy are acceptable. The most commonly used quality control charts are range charts to reveal the control of precision and means charts to reveal the control of accuracy. The greatest value of quality control charts is that trends of change in precision and accuracy over time may be detected.

**20.2.1 Range Control Charts**

A range control chart for replicate measurements is made by calculating a mean range ($\overline{R}$), a warning limit (WL), and a control limit (CL). A minimum of 20 range values (difference between the lowest and highest values in replicate analyses of a sample) is used to make the chart. The factors for computing control and warning limits on range control charts are as follow:

| Number of replicates (n) | Factors for control limits ($D_4$) |
|---|---|
| 2 | 3.27 |
| 3 | 2.58 |
| 4 | 2.28 |
| 5 | 2.12 |
| 6 | 2.00 |

The range values should be obtained during normal laboratory operation over a period of several days. For water quality monitoring, it is sufficient to base the chart on duplicate analyses (n = 2; $D_4$ = 3.27). An example of a set of duplicate analyses of 25 total ammonia nitrogen samples is provided in Table 3. Calculations of R, CL, and WL are provided below:

The necessary equations are:

$$\overline{R} = \Sigma R/n$$

$$CL = D_4(\overline{R})$$

$$WL = 0.67(\overline{D_4 R} - \overline{R}) + \overline{R}$$

The analyst should measure about 10% of samples in duplicate. The range is determined for each of the duplicate analyses and plotted on the range chart. If the ranges for the duplicates remain below WL, the analysis is in control of precision. A single value above WL suggests a problem, and steps should be taken to determine if a problem exists. Of course, range values above the control limit should be a signal to stop the analyses and find the source of the problem. All data collected for quality control should be plotted on the chart and the chart updated as necessary.

**Table 4. Results of duplicate total ammonia nitrogen analyses used to prepare a quality control chart for precision.**

| Date | Total ammonia nitrogen (mg/liter) Result 1 | Result 2 | Range |
|---|---|---|---|
| July 2 | 0.51 | 0.47 | 0.04 |
| July 3 | 0.25 | 0.20 | 0.05 |
| July 4 | 0.11 | 0.09 | 0.02 |
| July 5 | 1.05 | 0.92 | 0.13 |
| July 6 | 0.82 | 0.95 | 0.13 |
| July 9 | 0.75 | 0.74 | 0.01 |
| July 10 | 0.44 | 0.44 | 0.00 |
| July 11 | 0.36 | 0.38 | 0.02 |
| July 12 | 2.13 | 2.05 | 0.08 |
| July 13 | 1.50 | 1.55 | 0.05 |
| July 16 | 0.09 | 0.06 | 0.03 |
| July 17 | 0.35 | 0.37 | 0.02 |
| July 18 | 0.50 | 0.54 | 0.04 |
| July 19 | 0.62 | 0.58 | 0.04 |
| July 22 | 1.00 | 0.92 | 0.08 |
| July 23 | 0.78 | 0.71 | 0.07 |
| July 24 | 0.98 | 0.92 | 0.06 |
| July 25 | 0.68 | 0.72 | 0.04 |
| July 26 | 1.25 | 1.31 | 0.06 |
| July 29 | 0.05 | 0.05 | 0.00 |
| July 30 | 1.33 | 1.25 | 0.08 |
| July 31 | 1.62 | 1.74 | 0.12 |
| August 3 | 0.45 | 0.42 | 0.03 |
| August 4 | 0.62 | 0.66 | 0.04 |
| August 5 | 0.80 | 0.75 | 0.05 |

$$\bar{R} = 1.29 \div 25 = 0.052 \text{ mg/L}$$

$$CL = (3.27)(0.052) = 0.17 \text{ mg/L}$$

$$WL = (0.67)[(3.27)(0.052) - 0.052] + 0.052 = 0.131 \text{ mg/L}$$

The values for R, CL, and WL are plotted on a chart ( Fig.1).

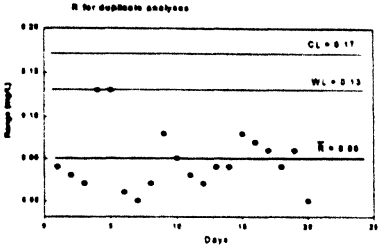


Fig 1. Range chart for control of precision in total ammonia nitrogen analysis

### 20.2.2 Means Control Chart

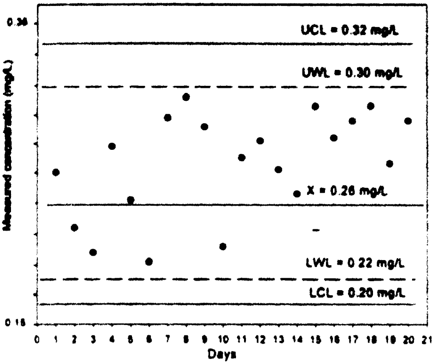
A means control chart allows evaluation of control on accuracy. A common way of making means control charts is to make about 20 measurements on a standard solution of the variable of interest over a period of several days during normal laboratory operation. The mean and standard deviation of these measurements is determined, and the upper and lower warning and control limits are taken as ± 2 standard deviations and ± 3 standard deviations, respectively. For example, suppose that twenty measured values for a total phosphorus standard have an average of 0.26 mg/L with a standard deviation of ± 0.02 mg/L. A plot of the limits is shown in Fig 2. The limits will be as follows:

| | |
|---|---|
| Upper control limit | 0.32 mg/L |
| Upper warning limit | 0.30 mg/L |
| Mean | 0.26 mg/L |
| Lower warning limit | 0.22 mg/L |
| Lower control limit | 0.20 mg/L |

Alternatively, percentage recovery values can be used to make a means control chart. Suppose that percentage recovery values for total ammonia nitrogen averaged 95.0 with a standard deviation of ± 2.5. The limits would be as follows:

| | |
|---|---|
| Upper control limit | 102.5 % |
| Upper warning limit | 100.0 % |
| Mean | 95.0 % |
| Lower warning limit | 90.0 % |
| Lower control limit | 87.5 % |

The analyst should, at intervals, analyze a standard solution or conduct a percentage recovery trial. The results of these analyses or trials should then be plotted on the mean control chart. Interpretation of the means control chart is the same as explained above for use of the range control chart.




Days

Fig. 2. Means control chart for the control of accuracy of total phosphorus analyses based on analyses of a standard solution.

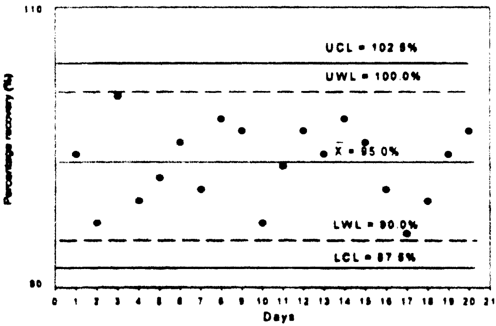



Fig. 3. Means control chart for the control of accuracy of total ammonia nitrogen analyses based on spike recovery trials.

## 21. LIST OF EQUIPMENTS FOR SOIL AND WATER ANALYSIS

| | Instruments | Make | Approximate Cost (Rs.) |
|---|---|---|---|
| 1. | pH meter | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | Digital: 7,500/<br>Microprocessor: 20,000/- |
| 2. | Spectrophotometer<br>Indigeneous<br><br>Imported | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision<br>Shimadzu, Hitachi | 45,000/-<br><br><br>3,50,000 |
| 3. | Conductivity meter | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 8,000/- |
| 4. | Water Quality Analyzer | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 45,000/-<br>(pH,TDS,DO,Cond.ORP,<br>Temp) |
| 5. | Flame Photometer | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 55,000/- |
| 6. | Nephelo turbidity meter | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 12,000/- |
| 7. | Gas Chromatograph<br>(Imported) | Chemito | 4,00,000/- |
| 8. | TDS meter | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 8,000/- |
| 9. | DO meter (Imported) | M/S ELICO LTD,<br>M/S Systronics Ltd,<br>M/SW El-Deep Vision | 30,000/- |

M/S ELICO LTD,
263, Pantheon Road,
Egmore, Chennai-600 008.

M/S Systronics Ltd.,
Raja Annamalaipuram,
Chennai.

M/S. Ei-Deep Vision,
20/6 Jennis Road,
Saidapet, Chennai – 600 015.

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