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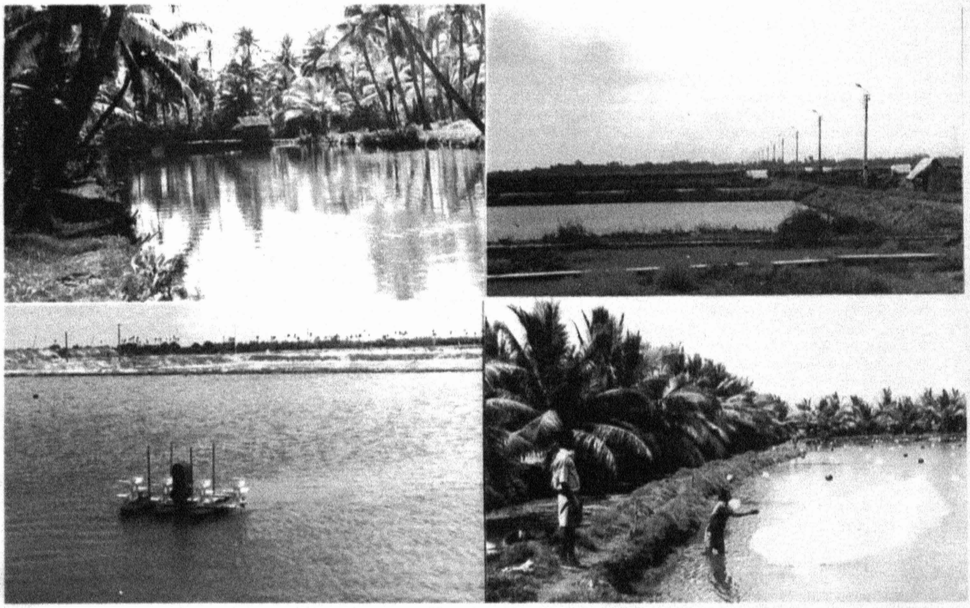
SOIL AND WATER QUALITY MANAGEMENT IN BRACKISHWATER AQUACULTURE



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ICAR

CENTRAL INSTITUTE OF BRACKISHWATER AQUACULTURE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
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AUGUST, 2004

SOIL AND WATER QUALITY MANAGEMENT IN BRACKISHWATER AQUACULTURE

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1. SUITABILITY OF SOILS TO BRACKISHWATER AQUACULTURE

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 result in aquaculture ponds, which cannot 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 – intertidal 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 salts that 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 acquainted 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 microorganisms form the main food for 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 is 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 of nitrogen, phosphorus, potassium, sulfur, calcium and magnesium is maximum. The availability of microelements, iron, manganese, boron, copper, chlorine and zinc is more in the acid range than in neutral or alkaline range. Since the requirement of these microelements 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 arability of pond soil bottom and supplies nutrients. Organic matter helps in reducing the turbidity of pond water and acts as antitoxicants. The microbial activity is entirely dependent on the organic matter.

Though excess amount of readily decomposable organic matter may cause problems, but in brackishwater ponds, a high level 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 productive and above 2% high productive.

1.2.4 $CaCO_3$

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 sulphides 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 more favourable oxygen and carbon reserves. It precipitates suspended or soluble organic materials, 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. Further, 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 the water increase with the increase of 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 O..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 E_h, which indicates whether the water or soil is in reduced condition, or oxidized condition. Negative (-) redox value shows reducing condition. Whereas 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 ponds.

Soils were placed into three classes according to their limitations for excavated ponds, pond levees, 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 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.

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.

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 cannot 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; consequently, 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.

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	>5.5	4.5-5.5	<4.5	Too acid
Clay content (%)	>35 Clayey	18-35 Loamy	<18 Sandy/ silty	Too sandy/ silty; excessive seepage
Slope of terrain (%)	<2	2-5	>5	Slope
Depth to water table (cm)	>75	25-75	<25	Hard to drain; dilution
Frequency of flooding	None	Occasional	Frequent	Flooding
Small stones (%)	<50	50-75	>75	Small stones
Large stones (%)	<25	25-50	>50	Large stones
Decomposed OM (%)				
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

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

Property	Limitation rating			Restrictive feature
	Slight	Moderate	Severe	
Clay content (%)	>35 Clayey	18-35 Loamy	<18 Sandy	Too sandy
Depth to sulfidic or sulfuric material (cm)	>100	50-100	<50	Toxicity; potential acidity
Engineering classes	-	-	All'G' and 'S' classes	Too stony 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

***

2. AQUACULTURE POND SOIL MANAGEMENT

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.

2.1. 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 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.

2.1.1 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.

2.1.2 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.

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.

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 high pressure pump. 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 the mud saturated 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.

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 levelling of pond bottom, repairs of sluice structures and sluice screens are also to be attended.

2.1.3 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.

2.1.4 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 species. 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.

A. Physical method

The most effective method is drying the ponds. Unwanted organisms are removed from the pond by drying of the pond bottom. Direct sunlight helps to disinfect the 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. 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.

B. 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*): 100 - 150 ppm. 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).

2.1.5 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, seashell 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 through 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 inturn 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 carbondioxide
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 application 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 from market 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. Thus, 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. Hence, a fineness guarantee is desirable. 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 limestone 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 percent 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.

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

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 to 8. The recommended levels of lime application during pond preparation are given in Table 1.

2.1.6 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.

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

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.

On application in ponds, a portion of NO_3 leaches down to the reducing zone of the pond soil and gets reduced to nitrite form (NO_2) and ultimately lost to elemental nitrogen by the denitrifying bacteria present in the environment. On the other hand, ammonium (NH_4) carriers are better fertilizers as they are adsorbed 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 ammonia form, it is adsorbed 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 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 phytoplankton 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 limiting 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 the 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.

2.1.7 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 allowed 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 along with 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 100-125 cm. Now the pond is ready for stocking post larvae of shrimps.

Once the pond is filled, nutrients will release into 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.

2.2 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 low pH of bottom sediment indicates unhygienic condition and 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 (E_h) of mud should not exceed -200 mV.

2.2.1 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 has 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, 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 formalin the pond should be filled upto its normal 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 organic 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. 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 aquaculture 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.

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3. WATER QUALITY MANAGEMENT IN BRACKISHWATER AQUACULTURE

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 sulphurous compounds
H.	Lack of proper aeration and water exchange
I.	Over Feeding

3.1 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.

3.1.1 PHYSICAL CHARACTERISTICS

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

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.

2. 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 fluctuate 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.

3. Salinity

The term salinity refers to the total concentration of all dissolved ions in grams contained in 1 kg of seawater. Following major ions mentioned in the table 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)	**Seawater**	**Brackishwater**	**Freshwater**
Chlorides	19000	12090	6
Sodium	10500	7745	8
Sulphate	2700	995	16
Magnesium	1350	125	11
Calcium	400	308	42
Potassium	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.

Shrimp 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.

4. Total Solids

Organic and inorganic, settleable, suspended (TSS) and dissolved matter is 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 led to increased sedimentation of eco-system.

5. 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. It is wrong notion that intake of plankton rich water is good for initial filling. Clear water is best suited. Sometimes, ponds, which develop clear water condition, are repeatedly fertilized with high doses of inorganic fertilizers with the hope to produce bloom. Once the benthic algae develop, it is useless to fertilize the ponds.

3.1.2 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

1. 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 shrimps 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 come 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 shrimp, 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.

The use 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 gets 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 phytoplankton die-off is greater in ponds with high feeding rate and abundant phytoplankton.

2. 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 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 shrimps. 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 shrimp farms.

3. 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, sometimes it is necessary to remove CO_2 from tanks/containers in which prawn or fish are reared 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.

4. Residual Chlorine

Chlorine in various forms is commonly used in shrimp hatcheries to disinfect seawater. 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.

5. 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 shrimp farms are supplied with 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.

6. 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 aqua culturists. 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 aquatic organisms. The ionic forms however, have 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 shrimps. 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 are less than 0.003 mg/l for shrimps.

3.2 EFFECT 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:

3.2.1 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. TRANS-PARENCY	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

3.2.2 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- 250 ppm)→		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. Waste
			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

3.2.3 GASEOUS FACTORS

GASEOUS	H_2S	Poor Water Quality DO Depletion	Use of Iron Oxide (@ $1 kg/m^2/D$ 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

3.3 EXECESSIVE PHYTOPLANKTON GROWTH

Pond preparation plays 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 disadvantage of various types of algae in shrimp ponds is 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.

3.4 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.

3.5 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 decomposing 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.

3.6 EXCESSIVE ALKALINITY & PHOSPHORUS

High pH in ponds results 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 phenolphthalein alkalinity. But alum treatment does nothing to alter the conditions responsible for excessive high pH so if phytoplankton 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 likelihood 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.

3.7 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 is 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.

3.8 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.

3.9 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 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 affect 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.

3.10 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%. A feed containing moisture more than 10% develop 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 well 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.

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4. IDENTIFICATION AND MANAGEMENT OF ACID SULPHATE SOILS IN SHRIMP FARMS

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 Soils

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.

4.1 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

4.2 INDICATORS OF ASS

There are several indicators of ASS, that is, where the 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, a 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 the pyrite concentration. Organic matter also reacts with peroxide, but the reaction is much less vigorous.

4.3 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 aquaculture 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

4.4 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.

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

(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.

4.5 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 builds 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' as 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.

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5. AQUACULTURE WASTEWATER MANAGEMENT

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.

5.1 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. Comparison 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.

5.2 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. The nutrients and organic matter in shrimp pond wastes of intensive shrimp farming have the potential for the following impacts.

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; Sub lethal 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.

5.3 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.

5.3.1 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.

5.3.2 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 disadvantages 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.

5.4 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 beginning sampling early in the morning and completing the procedure as quickly as possible.

5.5 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.

5.6 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

Sl.No	Parameters	Guidelines by Ministry of Agriculture		General Standards for discharge of environmental pollutants
		Coastal Marine waters		**Marine coastal areas**
1	Ph	6.0-8.5	6.0-8.5	5.5 – 9.0
2.	Suspended solids. mg/l	100	100	100
3.	Dissolved oxygen	not less than 3	Not less than 3	-
4.	Free Ammonia (as NH3-N) mg/l	1.0	0.5	5
5.	Biochemical oxygen Demand-BOD (5 days @ 20^{O} C)	50	20	100
6.	Chemical Oxygen Demand-COD mg/l	100	75	250
7.	Dissolved Phosphate (as P) mg/l max	0.4	0.2	-
8.	Total Nitrogen (as N) mg/l	2.0	2.0	-

5.7 GOOD MANAGEMENT PRACTICES

There are simpler and more cost effective ways of providing environmental protection than to use effluent standards. Good management practices (GMPs) are those demonstrated to provide the most effective practical methods of reducing environmental impact levels to those compatible with resource management goals. The term practice refers to the structural, vegetative, or management activities needed to solve one aspect of a resource management problem. In some situations, a single practice may solve the problem, but usually a collection of practices, or a system of GMPs, is needed to provide effective environmental management. GMPs may be used to supplement effluent discharge standards or other regulations, or they may be the major feature of environmental management systems. As long as a farm complies with the GMPs, it would be allowed to discharge water. Obviously GMPs should be site specific, because different locations and operations will have different requirements for effective effluent management. Nevertheless, it is possible to list some general examples of GMPs that could be used

- Limits on stocking and feeding rates.
- Reduction in nitrogen and phosphorus concentrations in feeds to lowest levels possible without impairing feed quality.
- Prohibit the use of trash fish as feed
- Conservative feeding practices to reduce the amount of wasted feed.
- Limits on water use for water exchange.
- Restrictions on the use of certain chemicals in ponds.
- Specifications for pond and canal construction and aerator placement to minimise erosion and prevent excessive seepage.
- Discharge of effluents, especially the final 25% of pond volume through sedimentation basins.
- Prohibit discharge of brackishwater into common water bodies or onto agricultural land.
- Require sediment disposal be done in an ecologically responsible manner.
- Harvest at the pond out fall without distributing pond sediments.

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6. USE OF PESTICIDES-HEALTH HAZARDS TO AQUATIC ANIMALS

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 and chlordane.

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.

6.1 PERSISTENCE AND BIOACCUMULATION

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 programs. 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.

6.2 TOXICITY AND PERMISSIBLE SAFE LIMIT

Pesticides and their residues are usually very toxic to the aquatic animals. Organochlorines (OCP's) are more toxic than organ phosphorous 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 LC50 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
OCP's				
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
OPP's				
Ethyl parathion	---	< 1000-3300	----	----
Acephate	----	100-1000	----	----
Malathion	-----	1200-9000	82	-----
Ethion	----	500-7600	----	----
Chlorpyrifos	----	2.4-280	---	-----
Phorate	----	6-280	----	----
CARBAMATES				
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.

6.3 DECONTAMINATION OF PESTICIDE RESIDUES FROM AQUATI 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. 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 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. 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.

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.

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7. HEAVY METALS IN AQUATIC ENVIRONMENT

The increasing impairment of coastal water quality resulting from the discharge of domestic, agricultural and industrial waters in coastal waters has affected the aquaculture profitability in certain areas. 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 seawater 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 viewpoint 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 level	**96h LC_{50} value**	**Derived safe level**	**USEPA Safe**
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 floodwater drainage, varying sedimentation rates and non-homogenous distribution of heavy metals in sediment. 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.

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8. ENGINEERING CONSIDERATIONS IN BRACKISHWATER AQUACULTURE

The soil and water quality parameters are the most important factor for the success failure of any coastal aquaculture farm. The various Engineering considerations for better management of soil and water quality in pond systems are discussed here.

8.1 SITE SELECTION

The criterion for selecting site for pond culture mainly depends upon the species to be cultured, the targeted production level and the physiological requirement of the species. Site selection is not only to determine the suitability of site for coastal aquaculture, it is also valuable in determining the modifications required with regard to make the farming possible at a given site. To select the proper site for a coastal aquaculture farm, reconnaissance survey should be conducted at least during two different seasons – summer and monsoon. Nowadays Remote Sensing and Geographical Information System techniques are used to identify potential site for aquaculture.

Factors to be considered in site selection

In order to identify the best possible site for a coastal aquaculture farm, major factors to be considered are

- Water source and drainage,
- Soil Quality
- Topography
- Environmental factors
- Accessibility
- Occurrence of flood and storms
- Power Source
- Social and Political factors and
- Marketing and other facilities

Water Source

An ideal site must have clean and pollution free fresh water and seawater sources to get the desired salinity. The sea is main source of water supply to brackish water ponds. Besides sufficient water supply, perfect draining of wastewater from the pond and proper drying of the pond bottom are of prime importance to maintain the stable production. As long as the coastal plain is not muddy, a site close to the coastline is better than those far from the sea. Preferably, a site should be within 3 km from the sea to have good access to seawater

Topography

Rectangular or square shaped flat areas located near the sea and other natural ways such as rivers, streams etc, with average natural ground elevation of 1 to 3m above the mean sea level having minimum vegetation on it and slight sloping in one or two directions are ideal for coastal pond development. Sites with excessive undulating topography should be avoided.

8.2 LAYOUT AND DESIGN OF THE PONDS

Layout of the farm mainly depends upon topography and shape of the area. A proper layout of the farm significantly reduces the cost of construction and ensures smooth and trouble free operation of the various facilities and structures allowing proper management of production activities few major considerations in the planning of the farm layout are as follows.

- The pond orientation should take into account the direction of prevailing wind. The longer sides of rectangular ponds should be oriented parallel to the prevailing wind direction to increase the pond water aeration
- Water intake system should be located at place which is well protected against the natural calamities
- Location of the seawater intake system should be decided taking into consideration the sea current direction with respect to the farm discharge outlets and other sources of pollutants.
- The water distribution system should be as straight and short as possible. If bends cannot be avoided, they should be as smooth as possible.
- Effluent discharge outlets should be located at downstream of the river water intake system to ensure that it is not recycled back to the ponds.
- The farm layout and design should permit complete drainage of the ponds at any given time during the production process and specially during the rainy season

Pond geometry

Pond geometry i.e. its shape and size mainly depends upon the species to be cultured, purpose of the ponds (Nursery, rearing, grow out), culture system to be employed, soil characteristics and topography of the area .For intensive farming smaller size ponds are constructed especially circular and square shapes are commonly used. The larger ponds, on the other hand are usually constructed in rectangular shape as it facilitates better pond management

Pond bed

The pond bottom is provided a slope between 1000:1 to 1000:5 towards the drain to facilitate the water flow during harvest and drainage. The pond bottom should be designed so as to remain above the ground water table.

Pond depth

The pond is normally designed for a water depth of 1to 1.5 m depth.

Pond dyke

An aquaculture pond generally has main or peripheral dyke and partition or secondary dyke. Side slope is necessary for stability of dyke. The outer slope and inner slope of dyke depend upon soil texture and prevailing site condition. The pond dyke should be strong and should be protected against erosion. The top width of the dyke depends upon the height of the dyke and its purpose. The base width of the dyke depends upon the depth of water and the top width of the dyke and type of the soil.

8.3 WATER DISTRIBUTION STRUCTURES:

- Water is conveyed to the ponds by gravity through feeder channels, which is lined or unlined. . The channels should be constructed with most economic section. Water supplied should be of free from dust and hence filtration of the water is advisable.

- A drainage channel network is necessary to facilitate the proper drainage of wastewater from the pond and to ensure that the used culture water does not find its way back into the farm. If intensive culture is being undertaken it is better to have effluent treatment and then discharge to the sea. Through drainage channel .the drainage channels should designed for the most economic section.

8.4 WATER CONTROL STRUCTURES:

Gates are part of water distribution system in an aquaculture farm and the gates used in a farm can be classified into the main gate, secondary gates, pond inlet gates and pond outlet gates or water exchange structures.

8.5 POND CONSTRUCTION:

Pond can be of embankment type or Excavated type.

Construction of pond system is normally performed in following order.

- Cleaning the site
- Contour survey and preparation of farm layout
- Demarcation of lines for construction of pond dykes, channels etc.
- Preparation of dyke foundation
- Excavation of drainage canals
- Construction of main/peripheral dikes and compaction
- Excavation of pits for construction of sluices (gates).
- Leveling and compaction of pond bottom, providing pond bed slope towards outlets.
- Construction of various sluices (i.e.) main sluice, pond outlets etc. and refilling the pits.
- Construction of feeder channels
- Construction of pond inlets and secondary gated
- Dykes protection works.

8.6 SEEPAGE CONTROL IN PONDS:

Excessive seepage often results from improper site selection, therefore, soil properties should be clearly investigated and identified during site selection. Situation does arise where no satisfactory site is available and, in those cases, we must deal with poor soils. The various methods to control seepage are enumerated here.

Compaction

Pond seepage can be generally reduced by compaction, provided that bottom soil material contains particle sizes that range from small gravel or coarse sand to fine sand, with at least 10% clay. For aquatic ponds with a normal average water depth of less than 1.5 m (5 feet), about 20 cm (8 inches) of compacted layer is required to provide a good seal. First, clear the pond area of all vegetation and fill all stump holds and other cracks with imperious material. Scarify the surface to a depth of 20 to 30 cm (8 to 10 inches) with a disk or roto tiller. Remove all rocks and tree roots. Roll the soil under optimum moisture conditions to a dense, tight layer with four to six passes with a sheepsfoot roller.

Clay blankets

If the soil material at the site contains a high percentage of coarse grained particles, but not enough clay to produce a compaction layer one of the alternatives is to blanket the seepage area with a well graded material containing atleast 20% clay. For aquatic ponds, a depth of 30 cm (12 inches) is recommended. Protect clay blankets against cracking caused by drying, by spreading a cover of gravel 30 to 45 cm (12 to 18 inches) thick over the blanket, below the anticipated high water mark.

Bentonite

Bentonite can reduce seepage in coarse soil. Bentonite is a fine-textured colloidal clay. When wet, it absorbs several times its own weight of water, and at complete saturation, swells as much a 8 to 20 times its original volume, when mixed in correct proportions with well-graded, coarse-grained material, then thoroughly compacted and saturated, the particles of Bentonite swell until they fill the pores to the point that the mixture becomes impervious to water. Bentonite, applications generally range from 2 to 5 kg/m^{2,} Soil moisture level is very important with Bentonite applications, therefore, following application, the treated area must be prevented from drying.

Chemical additives

If fine-grained clay particles are arranged at random with end-to-plate or end-to-end contacts, they will form an open, porous, or honeycombed structure said to be "aggregated". Small applications of sodium polyphosphate (such as tetra sodium pyrophosphate, Sodium tripolyphosphate or technical grade soda ash) or 99 to 100% sodium carbonate may collapse the open structure and rearrange the clay particles thereby reducing soil permeability. For effective chemical treatment the soil should have more than 50% fine-grained material (silt and clay), and at least 15% clay. Sodium polyphosphates are usually applied at a rate of 0.25 to 0.50 kg/m^2, and sodium chloride at 1.0 to 1.6 kg/m^2. Soda ash is applied at 0.5 to 1.0 kg/m^2. Soil and chemical mixture 15cm (6 inches) thick is recommended for aquatic ponds.

Water proofing linings

Polyethylene, vinyl, butyl rubber, and asphalt-sealed fabric liners are slowly gaining acceptance as linings for small aquatic ponds. The main problems with plastic linings are cost and the potential for puncture and breakage. Black polyethylene is less expensive and has better aging properties than vinyl, which is more resistant to damage and can be easily repaired with a solvent cement. Plastic membranes must be protected against puncture with a layer of soil and gravel no less than 15 cm (6 inches) thick. Butyl rubber and asphalt-sealed fabrics are more resistant to puncture, and special protective measures are generally not required. Before installing vinyl lining, the ground should be sterilized, cleaned smoothed and covered with a cushion layer of fine-textured material to serve as a base for the lining. Butyl rubber and vinyl linings should be laid down smoothly but with some slack; polyethylene linings require 10% slack. Anchor the top of the lining by burying it in a trench 20 to 25 cm (8 to 10 inches) deep and about 30 cm (12 inches) wide, dug completely around the pond.

Biocrete technology

A Dutch company developed a system christened as Borate system and applied with success in waste sandy tracks in the southern part of west Java. The technology takes its inspiration from Ferro cement technology. Instead of iron, non-corrosive natural materials such as bamboo frames and natural fibers are used for reinforcement. The system enables the use of locally available construction materials of natural origin as far as possible and it is found to be economically feasible. In essence, Biocrete is a mixture of cement, sand and natural fibres including bamboo frames used for paving sides

8.7 AERATION IN BRACKISHWATER PONDS

Dissolved Oxygen (DO) is considered to be one of the most critical water parameter in aquaculture affecting growth, feed efficiency, susceptibility to disease and ultimately production of fish. Aeration is necessary to supplement natural resources of DO in culture system especially in intensive and semi intensive systems.

Types of aeration devices

Aeration devices or aerator increases the rate at which oxygen enters water. There are two types of aeration devices.

- Splasher or surface aerators where in water is splashed into the air, and
- Bubbler, wherein bubbles of air are released into the water.

Paddle wheel aerator, vertical pump and pump sprayer are splasher aerators. Among them, paddle wheel aerators are most commonly used aeration devices for aeration in aquaculture ponds. They splash water into the air as the paddle wheel rotates. In terms of efficiency in circulating pond water, oxygen transfer to pond water, reliability, easiness in operation and power requirements, these aerators are for better than any other type of aerators. The average oxygen transfer efficiency of these aerators is 2.13 Kg O_2/Kw-hr. The power requirement of these aerators varies with paddle wheel speed, and paddle depth. Usually, the paddle wheel requires approximately 1 kW of power for each 50 cm of Paddle wheel length for a speed of 80 – 90 rpm and paddle depth of 10 to 15 cm.

Diffuser aerators and propeller aspirator pumps.

In a diffused air system, the air from an air blower or air compressor is released through air diffusers placed at the pond bottom or suspended in the water. Here the aeration efficiency depends on the bubble diameter and depth of submergence of the diffuser. Oxygen transfer is maximized by producing possible diameter. However, the average oxygen transfer efficiency of such aeration devices is 0.97 kg O_2/kw-hr.

The Propeller-aspirator-pump aerators consist of an uncased impeller mounted at the end of a hollow shaft and housing. This impeller rotates at a high speed by an electric motor mounted above the shaft. This results in flowing of air down the shaft by the venturi principle, which is released into the water in fine bubbles. The average oxygen transfer efficiency of such aerators is 1.58 kg O_2/kw-hr.

Position of aerators in ponds

Proper placement of aerators in ponds plays an important role in efficient mixing of water throughout ponds. In a rectangular pond, the best position is to place the aerator at the middle of one of the long sides of the pond directing water parallel to the short side of the pond. Placement of aerator in the corner of the pond to direct water diagonally across the pond should be avoided. Depending upon the size and shape of the pond, the placement pattern of the aerators aimed to achieve the best water circulation will vary.

Estimation of the aeration requirement

For estimating the aeration requirement in an aquaculture pond the total oxygen demand of the pond should be calculated. It can be broadly classified into three categories.

- Oxygen demand of the cultured animals i.e. fish / shrimp grown in the pond water
- Oxygen demand of the planktons, and
- Oxygen demand of the benthos i.e. organisms in sediment & mud

The oxygen demand due to shrimp respiration varies with temperature and salinity of the pond water. At a temperature and salinity of the pond water. At a temperature of 30°C this demand can be computed using the following equation

$R = 0.487 * w^{0.881}$
Where,
R = oxygen consumption of shrimp (mg/hr)
w = weight of the shrimp (gram)

The average oxygen demand in pond water for respiration of plankton can be taken as 0.134 mg/l/hr for 1m deep ponds. The oxygen demand for benthos (sediment) respiration can be taken as 0.473 mg/l/hr for extensive ponds. For well-prepared pond bottom of semi-intensive ponds, this value may be taken as 0.061 mg/l/hr.

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9.REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN AQUACULTURE

Aquaculture has grown rapidly in recent years, and is probably the fastest growing food industry in the world. Aquaculture has become more remunerative than agriculture due to high profit, economic viability of the industry and low labour requirement. Its fast growth has invited some of the environmental issues like conversion of agricultural lands and mangroves, salinisation of agricultural lands and drinking water resources and conflicts with other users. This resulted in the enforcement of coastal regulation zone (CRZ) rules and development of aquaculture authority by Government of India.

Aquaculture has gained global attention due to its role in strengthening the economy of the country and also by the sudden collapse the industry registered in the recent past. Environmental awareness has increased in the last few decades and the need for systematic monitoring and management is well understood. Planning is most important factor in aquaculture development. In addition to the variable precision of source data, reliable analytical processes for proper planning have until now been a major constraint. A systematic approach to data acquisition and analysis is required which is able to cope with a wide range of source data types and origins.

9.1 REMOTE SENSING

Evolution of man's ability to observe in regions of electro magnetic spectrum even beyond the range of human vision and photographic sensitivity demanded the introduction of a new term "remote sensing " to encompass the total observational process from remote platforms. It is acquiring information about material objects from measurements made at a distance without coming into physical contact with the objects. The unique capabilities of satellite based remote sensors in providing a wide spectrum of information available through electro magnetic spectrum in a repetitive coverage over inaccessible and large areas in frequent intervals made the remote sensing technology an effective tool in the sustainable development and management of our environment and resources Various data can be collected using remote sensing technique are inventorying of wetland categories, identification of plant community, bio mass estimation, shore line changes, delineation of coastal land forms, and total boundary etc. The remote sensing data that appear in the form of images are characterized by various features like vegetation, soil, water bodies etc Satellite data can be obtained from Space Application Centre, Ahmedabad or National Remote Sensing Agency, Hyderabad on a payment basis by giving path and row, date of the pass of the satellite with latitude and longitude of the area.

9.2 GEOGRAPHIC INFORMATION SYSTEM

For the users of remote sensing. It is not sufficient to display only the results obtained from image processing. For example, to detect land cover change in an area is not enough, because the final goal would be to analyse the cause of change or to evaluate the impact of change. Therefore, the results should be overlaid on maps of different themes. In order to promote the integration of remote sensing and geographic data, Geographic Information System should be established in which both the image and graphic data are stored in a digital form, retrieved conditionally, overlaid on each other and evaluated with the use of a model. GIS is a powerful tool for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. GIS can handle any type of data, with one constraint; the data has to have a location.

9.3 USE OF REMOTE SENSING IN GIS FOR AQUACULTURE

Remote sensing and GIS have the potential to contribute for aquaculture management because of its ability to collect information for large areas at a specific time, to handle much larger data bases and to integrate, synthesize data from a much wider range of relevant criteria, and to model and compare alternative management scenario. Sustainable development of aquaculture can be achieved by properly selecting sites leaving ecologically sensitive areas, following the coastal regulation rules and avoiding intensive aquaculture.

The important parameters have to be considered for aquaculture are identification of soil types, occurrence of wetland categories, distance from shoreline, general topography of the coastal area, shoreline erosion and cyclone prone areas, coastal pollution due to industrial activities and presence of salt pans and any important eco systems. Most of the important parameters can be sensed in visible and near infrared region. Remote sensing data after geometric correction can be overlaid on other geographic data in a raster form. In GIS, there are two uses of remote sensing data, as a classified data and as image data.

a. Use of classified data

Remote sensing data or vegetation maps classified from remote sensing data can be overlaid on to other geographic data, which enables analysis for monitoring the aquaculture development.

b. Use of image data.

Remote sensing data will be classified or analysed with other geographic data to obtain a higher accuracy of classification. If ground height and slope gradient are given as map data, aquaculture farms can be checked and located or sites can be selected for the development. A GIS sees each aqua farm at a given location as a point or polygon. In addition to its location it can have a number of attributes (e.g. design details, soil type and water quality) to it that reside in a database. GIS is especially useful in circumstances where many diverse factors have to be considered to reach a decision, where the factors differ in importance and where the factors themselves are quite variable spatially.

Base map

The base map prepared from the Survey of India toposheets received from Soil survey and land use organization gives the idea about land water boundary, low and high water line, location of coastal villages and major towns, transport network, important cultural features, major rivers, water spread areas, reserve forest boundary and coastal bathymetry contours and serves as the basis for the preparation of thematic maps. The various wetland categories like beach, mudflat, agricultural lands, mangroves, degraded mangroves, agricultural plantation and aquaculture can be identified from the remote sensing data based on the base map and image interpretation keys. These categories plays main role in identifying and monitoring aquaculture farms.

Visual interpretation

Visual interpretation is the process whereby an image is studied and habitats identified by eye. It involves overlay of base map on satellite imagery using light table and it is based on the information such as tone, texture, color, pattern, location, size, shape and association. The various wetland categories like beach, mudflat, agricultural lands, mangroves, degraded mangroves, agricultural plantation and aquaculture can be identified and the low water line, forest boundary and village location can be transferred from the survey of India toposheet. Table 1 gives the keys developed by SAC for identifying the coastal wetland classes.

Table 1. Image Characteristics of Coastal Wetland Classes

Category	Tone	Texture	Remarks
Estuary	Dark	Smooth	Semi enclosed body. Part of the lower river course that is affected by mixing of salt water with fresh water
Creek	Blue	Smooth	Intricate network of narrow inlets of sea water in tidal flats
Forest plantation	Dark red	Coarse	Slightly rough pattern
Mudflat	Grayish	Medium	Usually clayey & silty, Vegetation may be present, Slightly rough pattern
Water Logged	Light to Dark blue	Smooth to medium	Dispersed, Continuous
Aquaculture	Dark blue, light blue	Smooth	Slightly rough pattern
Crop land	Bright red	Medium to Smooth	Continuous to Non continuous pattern
Agricultural plantation	Dark red to red	Coarse to Medium	Dispersed, Continuous
Fallow	Yellow to Greenish blue	Medium to Smooth	Dispersed, Continuous
Sand/Beach	White/Half white	Fine	Smooth Pattern
Mangrove Dense Degraded	 Dark red Light red	 Medium Coarse	Smooth pattern, Occurs with coastal elements categories such as mud/tidal flats, water ways, beach sand, etc

Data input and editing

The validation of the information derived from remote sensing data should be checked by ground truth information. Field checks should be made in doubtful areas and the necessary corrections should be made in the interpreted maps. If the remote sensing data is visually interpreted, ARCINFO can be used to digitise the visually interpreted map using the digitiser. If the data is digital, ERDAS Imagine can be used for enhancement, rectification and classification of data. The thematic maps can be projected and transformed to geographic coordinates to make use the map for analysis. The labels can be assigned to each polygon for a specific land use class using vector attribute editor module. The final spatial information in the form of a layout with the corrected and completed maps can be created using ARC VIEW.

The accuracy of geometrically corrected image is usually checked by overlaying the rectified toposheet on the digital imager and swiped vertically or horizontally to check any shift in corresponding categories. The shifts in the image corresponding to the toposheet are again resembled with additional ground control points. The vector layer can be created with false colour composite (FCC) as the background image by digitising various features available on the imagery.

Spatial analysis

Spatial analysis is used to produce additional geographic information using existing information or to enhance the spatial structure or relationship between geographic information. Many techniques have been proposed

a. Overlaying

Various geographic data comprised of multiple layers are overlaid with logical operations including Different year data can be overlaid to fond the change in the land use due to aquaculture development. Thematic maps of different categories like land use, water quality, soil quality, drainage pattern, topography can be prepared from remote sensing data. Spatial characteristics are apparent because of the difference in the spatial characteristics of various materials that the sensor is looking for. Presence or changes of important ecosystems, extent of agricultural lands, industries, topography of the area, soil and water quality, distance from shoreline, etc can be obtained from overlaying the thematic maps. These maps can be overlaid using ARCINFO to identify sites for aquaculture or monitor the sites under aquaculture. The suitability will be decided based on the ranks assigned from GIS analysis.

b. Buffering

RS and GIS could be an integral part of the successful management of aquaculture because it has facility for regular updating with newly available information. Seasonal changes under major land use and land cover types can be derived by spatial intersection of land use maps. The changes occurred from one class to other class like agriculture, mangroves etc to aquaculture can be identified with area statistics and these changes will be useful in policy decision-making process. GIS and remote sensing technology can be combined to provide accurate information, which will be useful for development, monitoring, management of aquaculture.

With the data displayed in two-dimensional array, we can interpret the spatial features in the data such as shape, size and texture. In many advanced studies, remote sensing data has become an essential component as the aerial extent, type, condition and other parameters of land and water features can be studied effectively using remote sensing. Once the features are identified, it can be processed using Geographic Information System (GIS). GIS provides a well-structured approach to the analysis of geographic data important for any activity, and can be used to spatially link and to conceptually integrate the complex data needed for aquaculture development and monitoring.

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10. ENVIRONMENTAL MANAGEMENT OF AQUACULTURE FARMS

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 evolving 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 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 20th March, 1997.

10.1 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.

10.2 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 wastewater 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.

10.3 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 programs. 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 are 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.

10.4 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 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

- 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. 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 aqua farmer.
- 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.

10.5 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. All people have a right of access to drinking water in quantity and quality equal to their basic needs. 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.

10.5.1 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.

10.5.2 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.

10.5.3 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 bore well 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 Buckingham 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.

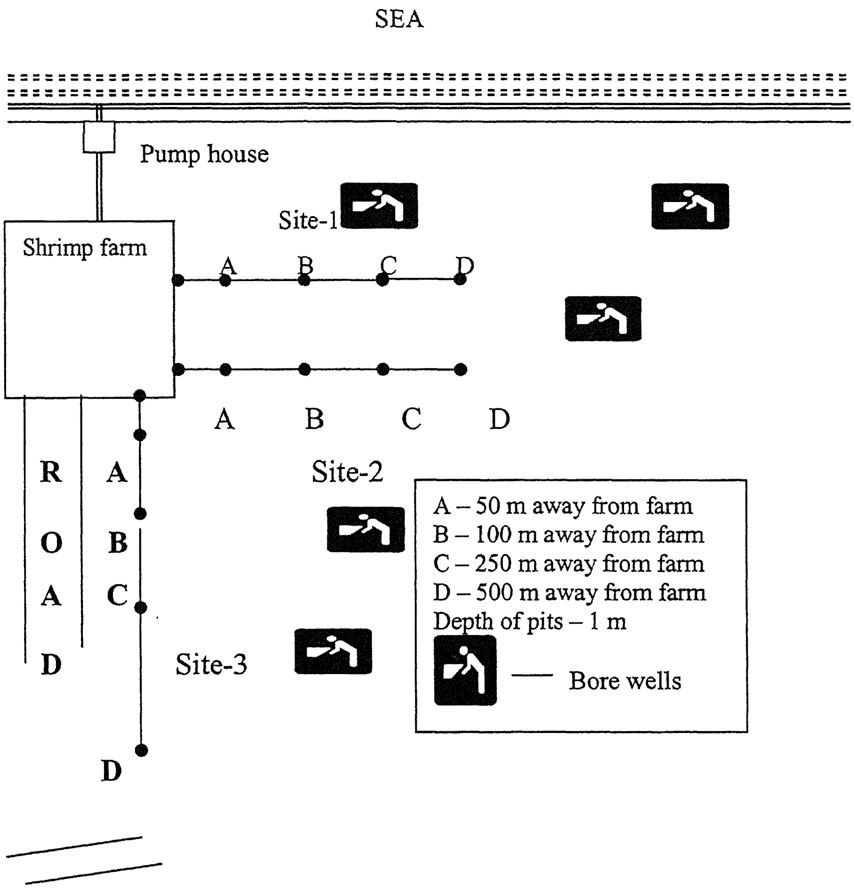

Fig. 1. Sampling points for land and drinking water salinisation study around shrimp farms

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11. BRACKISHWATER POND SOIL ANALYSIS

11.1 COLLECTION OF SOIL SAMPLES

Collection of representative soil sample for different analyses merits greater attention since, error at the time of sampling cannot 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 zigzag 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, posthole 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 posthole 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.

11. 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 liter.

(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 liter.

(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 that 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) :

11. 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 liter. 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

11. 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 cannot 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 ammonium sulphate solution using diphenylamine 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 liter.

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

(c) 85% orthophosphoric acid : 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 of 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 minutes with intermittent shaking. After digestion about 100 ml of distilled water is added followed by 5-10 ml of orthophosphoric acid. 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 also 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

11.5 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:

$(NH_4)_2SO_4 + 2NaOH$ --> $Na_2SO_4 + 2NH_4OH$

$2NH_4OH + H_3BO_3$ --> $(NH_4)_2B_4O_7 + H_2O(NH_4)_2B_4O_7 + H_2SO_4 + 5H_2O$ --> $(NH_4)_2SO_4 + 4H_3BO_3$

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 liter.

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

(c) liquid paraffin: Commercially available.

(d) 0.02 N sulphuric acid : Dilute 30 ml of Conc. H_2SO_4 to 1 liter 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 liter.

(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 liter 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 = $2.24 \times 10^6 \times 0.000028 \times y = 62.72\,y$

11.6 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.

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 SnCl2, 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 liter 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 liter. 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 liter.

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

11.7 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 liter. 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 liter 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 liter.

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).

11.8 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, erosion, 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 supernatant 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, adds 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)

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12. ANALYSIS OF BRACKISHWATER

12.1 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 of chloroform per 1l water. 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 of 2M H_2SO_4 per 1l water
PO_4-P	Add 5 ml of chloroform or 2M H_2SO_4 per 1l water

12.2 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.

12.3 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 liter with distilled water to get approximately 1N stock solution. To make 0.02N H2SO4, take 20 ml of this stock solution and dilute to 1 liter 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 liter 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 taint orange.

Calculation

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

12.4 TURBIDITY

Principle (Nephelometric method): Turbidity can be caused either by planktonic organisms or by suspended soil particles. Turbidity due to suspended soil particles is 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 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 25°C. 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.

12.5 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.

12.6 TOTAL SETTLEABLE SOLIDS

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

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

12.7 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 103°C to 105°C. 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.

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

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.

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

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

12.8 SALINITY

Principle : The salinity of seawater 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)

12.9 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 revert 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 liter.

(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 liter.

(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 liter. 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 liter 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 liter 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 :

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

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.

12.10 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 liter.
(b) **0.05 N Ferrous ammonium sulphate** : 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 liter.
(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 chloride per liter of water. Swirl until the mercuric sulphate is dissolved. Add carefully 30 ml of conc. sulphuric acid. Cover the flask with watch glass and allow to stand for 30 minutes. Add 15 ml of distilled water and 3 drops of ferroin indicator and titrate the whole reaction mixture with ferrous ammonium sulphate of same normality. Prepare blank with 20 ml distilled water and repeat the same procedure.

Calculation :

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

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

12.11 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

12. 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 catalyser. 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 (d) and 25 ml of reagent (e). 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 liter. Store in refrigerator, sheltered from strong light. This solution contains 100ppm 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.

12.13 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 calibration curve.

12.14 NITRATE - N

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 liter 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 gives 200 ppm. Dilute 100 ml of this solution to 1 liter with distilled water. This final solution contains 20 ppm N.

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.

12.15 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 : Dilute 70 ml conc. sulphuric acid to 500 ml.
(b) **Pottassium antimony tartarate**: Dissolve 1.3715 gm $K(SbO)C_4H_4O_6.1/2\ H_2O$ in 500 ml of distilled water.
(c) **Ammonium molybdate solution** : Dissolve 20 gm $(NH_4)_6\ Mo_7O_{24}.4H_2O$ 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 4°C.
(e) **Combined reagent:** Mix 50 ml of 5N H_2SO_4 + 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 an 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.

12.16 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 signaled 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** : 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 liter 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 liter. 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 a 100 ml of water sample into a 250 ml Erlenmeyer flask. Add 2 ml of the buffer solution and mix. Add 8 drops of Erichrome black-T indicator and titrate with the EDTA solution. At the end point, the solution will change from wine red to pure blue.

Calculation :

$$\textbf{Total hardness (mg/l as CaCO}_3\textbf{)} = \frac{\mathbf{T\,.\,M\,.\,10000}}{\mathbf{S}}$$

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

12. 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 $Na_2S_2O_3.5H_2O$ 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. Pipette 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.

12.18 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 tetra acetate 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 $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ in distilled water containing 1 ml 1 + 3 H_2SO_4 and make up to 1 liter 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

***

13. ANALYSIS OF POLLUTANTS IN AQUATIC ENVIRONMENT

13.1 PESTICIDE RESIDUES

The pesticides in water may be present in dissolved, precipitated (when present in excess) and suspended forms (when adsorbed on suspended particles). The solubility of pesticides in water besides their chemical structure (polarity), depend on pH, temperature, salt concentration, organic matter and biotic activity. As far as the solubility of these pesticides in water is concerned, the organochlorine pesticides being almost non polar, dissolve in water to a very low extent and in general the solubility of organochlorines in water range between 0.001 mg/l for DDT to 10 mg/l for y-BHC. On the other hand, the organo-phosphorous pesticides largely vary in their polar nature from almost non-polar to highly polar ones and subsequently, from sparingly soluble to highly soluble in water they are. In general, the solubility range of organo-phosphorus pesticides may be from 24 mg/l for parathion to 25 mg/l for dimethoate.

In the case of pesticides susceptible to degradation or some transformations, it is inadequate to measure concentration of parent compound only. In such cases it is essential to assay the possible metabolites and degradation products of a particular pesticide under the known environmental conditions and sum them up in order to ascertain their levels in water.

Most of the organo-chlorine pesticides are very stable and their metabolites and isomers are well known and are also quite stable for long periods in water and therefore, their actual residue level is represented by the parent compound along with its metabolites and/or isomers. It may be noted that pesticides, which are non-polar or less polar, dissolve in water excess to a very low extent (organo-chlorines) and therefore, in water excess of these pesticides tends to remain adsorbed on the suspended solids. On the other hand the organo-phosphorus pesticides are very unstable in aqueous media and transformed products need to be ascertained to represent their actual levels. For analysis of pesticide residues in water, the sequence of operations is discussed below:

1. Sampling and storage

The most important step in water quality monitoring is sampling part which includes selection of sampling site, types of sample (grab, mixed or composite), sample container, volume, sample handling (transportation), preservation and storage.

At least one liter of water is collected into 1.2-liter glass container and is transported to the analytical laboratory under standard conditions (4°C) using icebox. Preserve the sample in refrigerator until analysis.

2. Sample processing

The water samples stored or brought directly from the sampling site can not be analysed directly on instruments as the aqueous phase is not acceptable to instrument (GLC) and the pesticides to be analysed are extracted from some moisture free organic solvent and is subjected to clean up in order to remove the interfering co-extractives.

i. Extraction:

Pesticides can be extracted from water using Liquid Liquid Extraction method (LLE). Pour 1 liter of homogenised water sample into 2 liter separatory funnel and shake it with 60 ml of mixture of hexane and diethyl ether (85:15) vigorously for 2-3 minutes with releasing pressure repeatedly in between by inverting the funnel and opening the stop cock so that liquid does not come out at all. Allow it to stand for about 20 minutes in order to allow the layers (aqueous and organic layers) to separate distinctly. After clear separation, drain out the aqueous (lower) layer again in to other separatory funnel for second extraction and collect the organic layer in 250 ml round bottom flask. Rinse the just used separatory funnel with hexane (2-3 ml) for 2-3 times and collect the washings in the flask containing extract. Shake aqueous phase separated in the first extraction, with another 60 ml of solvent mixture in a similar way. Discard the aqueous layer and combine the organic fractions.

ii. Drying-Demoisturing and clean up

During liquid liquid extraction of water samples, some traces of water or moisture may obviously go along with the organic solvent (extract), which must be removed before moving to the next step of concentration. The brackish waters carrying agricultural run off, industrial and urban effluents often contain many other chemical compounds such as polychlorinated biphenyls (PCB's), organosulphur and phosphor-lipids etc. During extraction of pesticide residues from water samples such compounds present in environmental samples also get extracted and are known as co-extractives and due to being similar and identical in many of their physico-chemical characteristics with those to be analysed, these co-extractives usually interfere with end analysis. So the extracts are cleaned up before end analysis. Moisture and co-extractives can be removed by passing the extract though chromatographic column containing florisil sandwiched between two anhydrous sodium sulphate layers.

iii. Concentration

Pesticide residues extracted in organic solvent dried as above may not be injected into GLC as their low concentration levels may not be detected by the instrument in diluted forms. Therefore, after having dried the extract, it is concentrated to 5 or 10 ml volume. Open evaporation of extracts on water bath at boiling point of solvent may cause severe losses due to thermal degradation of some of the pesticides. Therefore, this can be achieved at reduced pressure through rotary evaporator or K.D. evaporator.

After the volume of extract has been reduced to about 1-2 ml, it should be transferred to a volumetric flask of 5 to 10 ml carefully with several small washings of the evaporatory flask to ensure complete transfer and finally make up the volume to the mark with hexane (HPLC grade).

3. End analysis (Instrumental analysis)

Gas chromatography is a technique used to separate volatile organic compounds. Gas chromatography - specifically gas-liquid chromatography involves a sample being vapourised and injected onto the head of the chromatographic column. The sample is transported through the column by the flow of inert gaseous mobile phase. The column itself contains a liquid stationary phase which is adsorbed onto the surface of an inert solid. The basic structure of the instrument is shown in the figure.

$$C\ (\mathrm{ug/l})\ (\mathrm{ppb}) = \frac{A_{sam} \times W_{std} \times V_{ext}}{A_{std} \times V_{inj} \times V_{sam}}$$

A_{sam} = Area of sample
W_{std} = Nanogram of standard
V_{ext} = Final concentrated volume of sample prior to injection (ml)
A_{std} = Area of standard
V_{inj} = Volume of sample injected (ul)
V_{sam} = Volume of water sample (in litre) extracted

SOIL

Weigh 10g undried soil, sieved through 2 mm sieve and mixed thoroughly into 250 ml Erlenmeyer flask. Add 7 ml 0.2M ammonium chloride solution (10.7 g/l) and let stand 15 minutes. Add 100 ml hexane-acetone (1+1), stopper tightly and shake overnight on shaker. Carefully pour supernatant, avoiding aqueous clay phase through 2-3 cm column (22 mm id) of florisil and collect elute in 1-liter separator. Rinse flask and soil with two 25 ml portions of mixtures of hexane + acetone and decant through column. Rinse column with 10 ml solvent mixtures. Add 200 ml water to separator and shake gently about 1 minute. Drain aqueous phase into second separator and extract with 50 ml hexane. Combine hexane layers in first separator and wash with 100 ml water. Drain and discard water. Pour hexane through 2 cm column anhydrous sodium sulphate. Concentrate to 100 ml using rotary or K.D. evaporator. Make preliminary injection of 5-10 ul into gas chromatograph. To calculate to dry basis, dry separate sample of 10 g about 16 hour at 105oC to obtain % solids.

Analysis of pesticide residues in tissue

Samples meant for pesticide analysis should be stored in stainless steel containers or wrapped in aluminium foil during transport and storage.

Mince the tissue to get a representative sample. Weigh 25g of the sample to the nearest 0.1 g. Add 100 g of anhydrous sodium sulphate and homogenize till free flowing. Then take it into a one litre flask and add 150ml of petroleum ether and shake for 15 min on an orbital shaker. Decant the supernatant ether layer through anhydrous sodium sulphate through a filtering device into a previously weighed round bottomed flask. The residue is extracted two more times in the similar manner. Evaporate the contents in the flask to get the weight of fat.

Dissolve the fat in 15ml of petroleum ether and completely transfer into a 125ml separating funnel. (If the weight of fat is >3g it must be dissolved in petroleum ether and a volume containing < 3g of fat must be taken).Add 30 ml of acetonitrile saturated with petroleum ether and shake vigorously for 1 min. Let the layers separate and add the acetonitrile layer into a 1litre separator containing 650ml water,40 ml saturated sodium chloride and 100 ml petroleum ether. Extract the ether layer two more times with acetonitrile saturated with petroleum ether and combine the acetonitrile layers into the 1litre separator. Mix the contents of the separating funnel for 30 seconds and let the layers separate. Collect the petroleum ether extract into another 1 litre separator and extract the aqueous layer again with petroleum ether and combine. The combined petroleum extract is washed twice with water and collect the petroleum ether extract through anhydrous sodium sulphate.Rinse the separating funnel with 10 ml portions of petroleum ether and evaporate the combined extract to 5 – 10 ml.

Add 25g of florisil into a 20 mm id glass column. Top the column with 2 inches of anhydrous sodium sulphate. Wash the column with 50 ml of petroleum ether. Add the sample from above to the column. Elute the column with (i) 200 ml of 6% diethyl ether in petroleum ether and (ii) 200 ml of 15 % diethyl ether in petroleum ether at a rate of 5 ml / min. Evaporate the eluents to 1 ml and inject in GC.

Computation

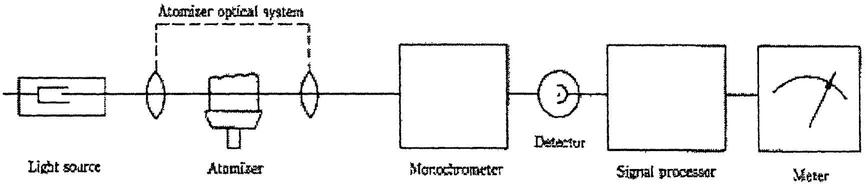
$$\textbf{Pesticide (ug/g)} = \frac{\textbf{As x Wstd x Vsam}}{\textbf{Astd x Vinj x W}}$$

As = Area of sample
Wstd = ug amount of standard pesticide
Vsam = final volume of sample (ml)
Astd = Area of standard
Vinj = Volume of sample injected(ul)
W = Weight of tissues(g)

13.2 HEAVY METALS

Analysis of heavy metals by AAS

Atomic absorption spectrophotometry utilizes the phenomenon that atoms absorb radiation of particular wavelength. The basic structure of the instrument is shown in the figure.



It consists of 4 basic structural elements; a light source (hollow cathode lamp), an atomizer section for atomizing the sample (burner for flame, graphite furnace for electro thermal atomization), a monochromator for selecting the analysis wavelength of the target element, and a detector for converting the light into an electrical signal.

Analysis of heavy metals in tisssue.

Samples meant for heavy metal analysis should be stored only in plastic/glass containers. All glass apparatus to be used should be cleaned and then rinsed with 1:10 nitric acid and finally washed with double distilled water.

Weigh 10 – 15 g of minced tissue (to the nearest 0.1g) into a 250 ml RB flask. Add 20 ml concentrated nitric acid. Swirl and allow to stand overnight. Add 20 ml concentrated sulphuric acid and digest under reflux using a water condenser for 6 – 8 hours till fumes of nitrogen dioxide ceases. Cool and add 25 ml of water down the condenser and reflux for 30 minutes. If yellow colour remains in the solution add 1 ml more of sulphuric acid and complete the digestion. After completion of digestion cool the contents of the RB flask, wash down the condenser and make up quantitatively to 100ml in a standard flask. Estimate by atomic absorption spectrophotometer using appropriate hollow cathode lamp.

Analysis of heavy metals in water.

The quantity of water sample to be analysed depends upon the amount of heavy metals.

Metal concentration	**Sample volume**
< 0.1ppm	1000 ml
0.1 – 10 ppm	100 ml
10 – 100 ppm	10 ml

Water should be collected in bottles that have been leached with 1: 1 nitric acid. Take appropriate sample volume in a suitable beaker. Add 5 ml of concentrated nitric acid and cover with a watch glass. Heat slowly and concentrate to 15 – 20 ml. Add 5 ml concentrated nitric acid followed by 10 ml concentrated sulphuric acid. Evaporate till white fumes appear. If solution is not clear add an additional 1 ml and evaporate. Cool and if any undissolved salts are present add 25 ml of double distilled water and heat slowly till clear. Cool and quantitatively make up to 100 ml. Estimate by AAS.

Analysis of heavy metals in soil.

Take 10 g of wet soil (or 1 g of dry soil) in a round bottomed flask. Add 20 ml of concentrated nitric acid and 20 ml of concentrated sulphuric acid and reflux using a water condenser for 6 hours. Cool and add 5ml of perchloric acid (in some cases hydrofluoric acid may be used) and reflux for 2 more hours or till clear. Cool and add 25 ml of double distilled water and heat slowly to dissolve any undissolved salts. Cool and transfer quantitatively and make up to 100ml. Estimate by AAS.

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14. PRECISION AND ACCURACY IN ANALYSIS

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 deviation**
	a	**b**	**c**	**d**	**Mean**	
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:

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

14.1 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 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.

14.2 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.

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; $D_4 = 3.27$). Calculations of R, CL, and WL are provided below:

The necessary equations are:

$$\begin{aligned} R &= \sum R/n \\ CL &= D_4\,(\underline{R}) \\ WL &= 0.67\,(D_4\overline{R} - \overline{R}) + \overline{R} \end{aligned}$$

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

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. 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, analyse 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.

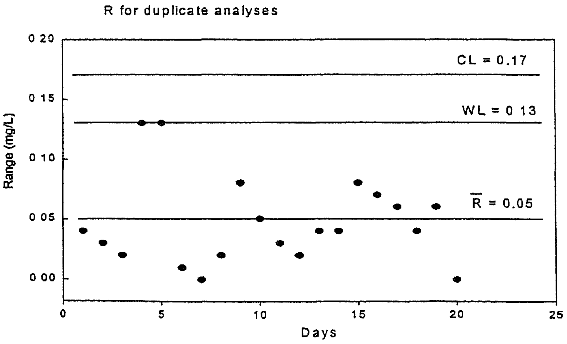

Fig 1. Range chart for control of precision in total ammonia nitrogen analysis

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15. LIST OF EQUIPMENTS FOR SOIL AND WATER ANALYSIS

	Instrument	Make	Approximate Cost (Rs./-)
1.	PH	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	5,500
2.	Spectrophotometer – Indigenous	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	26,000
	Imported	Shimadzu, Hitachi	4,00,000
3.	Conductivity meter	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	8,000
4.	Water Quality Analyzer	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	19,000 (pH, TDS, DO, Cond. ORP, Temp)
5.	Flame Photometer	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	25,000
6.	Nephelo turbidity meter	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	10,000
7.	Gas Chromatography	Chemito	5,00,000
8.	TDS meter	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	8,000
9.	DO meter	M/S ELICO LTD, M/S Systronics Ltd, M/SW EI-Deep Vision	10,000

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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