


# AQUACULTURE PRODUCTION MANAGEMENT : MONITORING OF WATER QUALITY

OUTLINE

- Introduction
  - Aquaculture production risk
  - Water quality
  - Water quality parameters
  - Optimum ranges for different water bodies
  - Water quality management
  - BMP
  - Recent findings- Water quality monitoring systems
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# INTRODUCTION

- The common notion that “Water is a free commodity” is no more a reality.
- International Water Management Institute (IWMI) reveals that by 2025 nearly 1/3rd of world’s population would live in the regions of severe water scarcity.
- By 2050, India has to produce about 17.5 million tonnes of fish/year and the 80% of the total production must come from the aquaculture.
- The average fish productivity from ponds and tanks would increase to 4-10 t/ha/year from about 3 t/ha/year.
- Need for Judicious management of this natural resource and to develop strategies for its efficient and multiple uses.

## PRODUCTION RISK

- Adverse environmental conditions inclement weather events (such as drought, excessive rainfall, extreme temperatures)
- Predators
- Biofouling organisms
- Disease
- Invasive species
- Farmers should review the entire operational flow, and consider the potential hazards at each production step.
- **Identify , Record , Monitor , Manage and Ask.**

## Production Flow Chart



# WATER QUALITY

- Water Quality (WQ) plays a very important role to ascertain the quantum of aquatic productivity.
- It determine the ultimate success or failure of an aquaculture operation.
- Water Quality parameters affect respiration, feeding, metabolism, reproduction, and final growth & production.
- The farmers must measure, record, monitor and manage water quality parameters all through the growing season.

# WATER QUALITY PARAMETERS

- Water Quality (WQ) parameters

## PHYSICAL

- ✓ Temperature
- ✓ Turbidity
- ✓ Colour
- ✓ Odour
- ✓ Depth

## CHEMICAL

- ✓ Dissolved oxygen
- ✓ Carbon dioxide
- ✓ Salinity
- ✓ Ammonia
- ✓ Nitrite
- ✓ Hydrogen sulphide
- ✓ Redox potential
- ✓ Total alkalinity
- ✓ Total hardness
- ✓ Iron
- ✓ Chlorine

## BIOLOGICAL

- ✓ Primary productivity
- ✓ Micro-organisms
- ✓ Plankton
- ✓ Algae
- ✓ Bacteria
- ✓ Macro nutrients
- ✓ Micronutrients

# WATER QUALITY MANAGEMENT

1. Analysis of various water parameters.
2. Knowledge of favourable ranges.
3. Quality control technique (chemical, mechanical, biological)

- Chemical Treatment -(liming , coagulation , oxidation ,chlorination , Ozonation )
- Mechanical Control- (mechanical filter, air lift filter, bio-filter, chemical filtration)

# WATER QUALITY PARAMETERS- OPTIMUM RANGES FOR DIFFEERENT WATER

BODIES Sl. No.	Parameter	Freshwater	Brackishwater	Seawater
1	Colour (colour units)	Clear water with greenish hue < 100 colour units	Clear water with greenish hue < 100 colour units	Clear water with greenish hue < 100 colour units
2	Transparency (cm)	20 - 35	26 - 35	26 – 35
3	Clay turbidity (ppm)	< 30	< 30	< 30
4	Solids (mg <sup>l</sup> <sup>-1</sup> )			
	a. Total	< 500	> 500	> 500
	b. Suspended	30 - 200	25 - 200	25 – 200
5.	Temperature (° C)			
	a. Tropical	25 - 32	25 - 32	25 – 32
	b. Temperate	10 - 12	10 - 12	10 - 12
6	pH	7.5 – 9.5	8.0 – 8.7	8.0 – 8.5
7	<b>Hardness (mg<sup>l</sup><sup>-1</sup>)</b>	<b>30 - 180</b>	<b>&gt; 50</b>	<b>&gt; 50</b>
8	<b>Alkalinity (mg<sup>l</sup><sup>-1</sup>)</b>	<b>50 - 300</b>	<b>&gt; 50</b>	<b>&gt; 50</b>
9	<b>Chlorides (mg<sup>l</sup><sup>-1</sup>)</b>	<b>31 - 50</b>	<b>&gt; 500</b>	<b>&gt; 500</b>
10	Salinity (ppt)	< 0.5	10 - 25	> 30



Sl. no	Parameter	Freshwater	Brackishwater	Seawater
11	Dissolved Oxygen (mgl <sup>-1</sup> )	5-10	5-10	5-10
12	Total dissolved free carbon dioxide (mgl <sup>-1</sup> )	< 3	< 3	< 3
13	Ammonia Nitrogen (NH <sub>3</sub> <sup>-</sup> N), (mgl <sup>-1</sup> )			
	<b>a. Unionized (NH<sub>3</sub>)</b>	<b>0-0.1</b>	<b>0-0.1</b>	<b>0-0.1</b>
	<b>b. Ionized (NH<sub>4</sub><sup>+</sup>)</b>	<b>0-1.0</b>	<b>0-1.0</b>	<b>0-1.0</b>
14	Nitrite Nitrogen (NO <sub>2</sub> <sup>-</sup> N), (mgl <sup>-1</sup> )	0-0.5	0-0.5	0-0.5
15	Nitrate Nitrogen (NO <sub>3</sub> <sup>-</sup> N),(mgl <sup>-1</sup> )	0-1.3	0-1.3	0-1.3
16	Total Nitrogen (mgl <sup>-1</sup> )	0.5-4.5	0.5-4.5	0.5-4.5
17	Total Phosphorous (mgl <sup>-1</sup> )	0.05-0.4	0.05-0.5	0.05-0.5
18	Potassium (mgl <sup>-1</sup> )	0.5-1.0	>0.5	>0.5
19	Calcium (mgl <sup>-1</sup> )	75-150	>75	>75
20	Magnesium (mgl <sup>-1</sup> )	20-200	200-1350	>1350

21.	Sulphate (mg/l)	20-200	200-885	>885
22.	Silica (mg/l)	4-16	>5	>5
23.	Iron (mg/l)	0.01-0.3	0.01-0.3	0.01-0.3
24.	Manganese (mg/l)	0.001-0.002	0.002-0.02	0.002-0.02
25.	Zinc (mg/l)	0.002-0.01	0.002-0.01	0.002-0.01
26.	Copper (mg/l)	0.003-0.005	0.003-0.005	0.003-0.005
27.	Cobalt (mg/l)	<0.003	<0.003	<0.003
28.	Biochemical Oxygen demand(BOD)	<10	<15	<15
29.	<b>Chemical oxygen demand (COD) (mg/l)</b>	<b>50</b>	<b>70</b>	<b>70</b>
30.	Hydrogen sulphide (mg/l)	<0.002	<0.003	<0.003
31.	Residual chlorine (mg/l)	<0.003	<0.003	<0.003
32.	Primary productivity (mg C/m <sup>3</sup> /day)	1000 - 3000	1000 - 2500	1000 - 2500
33.	Plankton(ml/100 litre)	2	1	1
34.	Chlorophyll-a (µg/l)	20-275	20-250	20-250
35.	Redox-potential(volts)	0.40-0.52	0.40-0.52	0.40-0.52

# WATER QUALITY MANAGEMENT

- **Dissolved Oxygen**

The amount of oxygen consumed by the fish is a function of its size, feeding rate, activity level, temperature, and the type of the fish.

- 5.0 mg/l – optimum for normal growth and reproduction in tropical waters
- mainly consumed by pond sediment (50-70%) and plankton (20-45%) and Only a small portion of dissolved oxygen is consumed by the culture animal (5%).

The amount of oxygen that can be dissolved in water decreases at higher temperatures , but decreases with increases in altitudes and salinities.

- Mechanical aeration

Paddlewheels-proper water circulation and adds oxygen to the pond water

Venturi pumps

Agitators

Liquid oxygen injection

Impellers

Airlift pumps

Air diffusers

- Control plankton density
- Minimizing excess organic substances (uneaten food *etc*).

In indoor water recycling systems, only mechanical means of aeration.

# WATER QUALITY MANAGEMENT

- **Ammonia**
- The total ammonia concentration in water comprises two forms, namely:  $\text{NH}_3\text{-N}$  unionized ammonia (Free ammonia) and  $\text{NH}_4^+$  Ionized ammonia.

The un-ionized ammonia fraction is more toxic to fish and the amount of the total ammonia in this form depends on the pH and temperature of the water.

The higher the pH and temperature, higher is the percentage of the total ammonia present in the toxic un-ionized form.

- 0.02–0.05 mg/l – safe concentration for many tropical fish species;
- 0.05–0.4 mg/l – sub-lethal effects depending on the species; and
- 0.4–2.5 mg/l – lethal to many fish species

**Aeration** will increase the dissolved oxygen concentration and decrease the increasing pH thereby reducing the toxicity.

**Healthy phytoplankton populations** remove ammonia from water. Care should be taken while using fresh manure with high ammonia content. The manure should be dried to allow ammonia gas to escape before application to the pond.

**Biological filters**

**High quality feed and over-feeding should be avoided.**

**Excessive liming should be avoided** as it raises pH and high pH favours ammonia toxicity to aquatic animals.

# WATER QUALITY MANAGEMENT

- **Temperature**

- Temperature sets the pace of metabolism and biochemical reaction rates.
- The optimum temperature range for many cold water and warm water fishes are **14–18°C and 24–30°C**, respectively
- Operation of aerator** during calm and warm afternoon helps to break thermal stratification.
- Planting of trees on pond banks** to give shade will reduce stratification but at the same time, reduces the beneficial effects of **wind mixing and restricts solar energy for photosynthesis.**

- **Turbidity**

- Optimum secchi disk visibility in fish pond is **40–60 cm**. Turbidity resulting from plankton is generally desirable.
- Pond waters turbid with suspended soil particles can be controlled by application of **500–1000kg/ha organic manure, 250–500 kg/ha gypsum or 25–50 kg/ha alum.**

# WATER QUALITY MANAGEMENT

- **Hydrogen sulphide**

- Hydrogen sulphide is produced by chemical reduction of organic matter that accumulates and forms a thick layer of organic deposit at the bottom.

Unionised hydrogen sulphide is toxic to fish, but the ions resulting from its dissociation are not very toxic.

- **0.01–0.5 mg/l** – lethal to fish and any detectable concentration of hydrogen sulphide in water creates stress to fish;
- **0.1–0.2 mg/l** – prawn lose their equilibrium and create sub-lethal stress;
- **3 mg/l** – prawn die instantly.

- water exchange

- liming, the toxicity of hydrogen sulphide decreases.

- Potassium permanganate (6.2 mg/l) can be used to remove hydrogen sulphide (1mg/l) from water.

# WATER QUALITY MANAGEMENT

- **pH**
- It affects metabolism and physiological process of fish and it exerts considerable influence on toxicity of ammonia and hydrogen sulphide as well as solubility of nutrients and thereby water fertility.

pH	Effect
4	Acid death point
4-6	Slow growth
6-9	Best for growth
9-11	Slow growth ,lethal to fish over long period of time
11	Alkaline death point

# WATER QUALITY MANAGEMENT

## ☐ Alkalinity

- 20–300 mg/l – ideal for fish;

## ☐ Total Hardness

- 20 mg/l – satisfactory for pond productivity and helps protect fish against harmful effects of pH fluctuations and metal ions

## Rectification measures:

- Ponds with low alkalinity and low hardness can be treated with lime for rectification.

## ☐ Carbon Dioxide

- 12–50 mg/l – sub-lethal effects include respiratory stress and development of kidney stones (nephro calcinosis)

## Repeated aeration of water;

- **hydrated lime** can control high carbon-dioxide concentration- **1.0 mg/l of hydrated lime** can remove **1.68 mg/l of free CO<sub>2</sub>**

- Phytoplankton population and the organic loading in a water body should be regulated by correct stocking, feeding and fertilization.



# LIMING

- Improve water quality and neutralizes acidity of soil
- creates a buffer system
- precipitates colloidal matters such as clay
- kills pathogen and promotes bacterial breakdown of organic matter
- helps phosphorus fixation in ponds
- supplies calcium – bone formation and plankton growth.

$\text{CaCO}_3$ , Lime stone

$\text{CaO}$ , Quick lime

$\text{Ca(OH)}_2$ , Hydrated or slaked lime

Alkalinity or hardness more than 20 mg/l needs lime @ 5 mg/l

Should not exceed more than 10mg/l

# CHLORINATION AND DECHLORINATION

## Chlorine

- Various forms, used for disinfecting shrimp and fish hatcheries.
- Widely used as water disinfectant
- Used to disinfect equipment, tanks, countertops, and nets at 10 ppm for 24 hours or 200 ppm for 30 to 60 minutes.
- Common commercial chlorine compounds are available in 3 forms : Chlorine gas( $\text{Cl}_2$ ), Sodium hypochlorite( $\text{NaOCl}$ ) and Calcium hypochlorite( $\text{CaOCl}_2$ )
- For aqua hatchery practices, bleach liquor or chlorine bleach(sodium hypochlorite) are used.
- For culture practices, water in bulk quantity can be chlorinated with bleaching powder ( $\text{CaOCl}_2$ ) which contain 30-33% chlorine approx.

## Dechlorination

Most effective method of chlorine removal- air stripping the chlorinated water for overnight or treatment with Sodium thiosulphate .

Sodium thiosulfate ,Sodium bisulphate, Potassium permanganate, Activated carbon and Sulphur dioxide etc. can be used to reduce free and combine chlorine residual.

- **Chlorine must be removed from hatchery/culture water as it is toxic to rearing or culturable organisms if it exceeds more than 0.003 ppm or 3 ug/litre.**
- **$2\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O} + \text{Cl}_2 = \text{Na}_2\text{S}_4\text{O}_6 + 2\text{NaCl} + 5\text{H}_2\text{O}$**
- **Molecular weight ratio= 496.2 :70.9**

**Chlorine demand ratio= 7 : 1**

For the removal of 1ppm of chlorine,7 ppm of Sodium thiosulphate is required△

- **Ozonation**

Ozone is an allotropic form of oxygen produced by passing dry oxygen or air into it through an electrical discharge(5000-20,000V).

It disinfect,deodourises,decolorises and deoxidises the raw water or waste water in aquafarms, aquahatchery and fish processing unit.

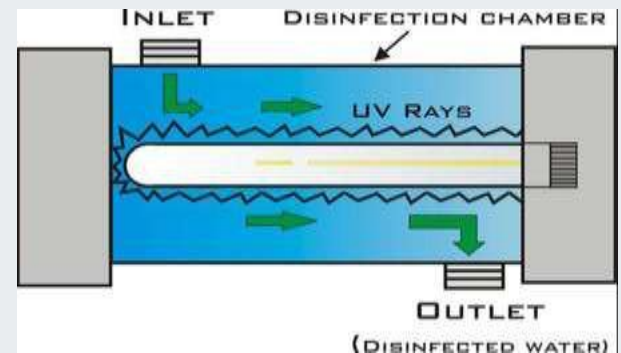
The unutilized organic materials in the form of feed and manure , which cannot be removed by normal filtering or by settling tanks are removed effectively by ozonation by neutralization and oxidation.

Concentration – 0.6-1.0 mg/l (contact time – 1 -3 minutes)

- **Coagulating agent** – Alum (commercial alum,  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ +  $\text{Al}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ )
- **Oxygenation/Aeration**

## UV RADIATION

- Natural and artificial UV light (wavelength of **190–400 nm**) may damage microorganisms by directly and indirectly altering nucleic acids.
- UV irradiation units are commonly installed in aquaculture farms for sea and freshwater disinfection.
- UV applications in **highly turbid water** will be **totally ineffective** since the **transmission** is **very minor**.
- **Bacteria** and pathogenic **protozoa** are **inactivated readily at low UV doses** with **higher doses required for virus** inactivation
- However, it does not remove colour and does not leave a residual in treated water



# WATER TREATMENT IN RAS

- Increasing costs for make-up water, waste-water discharge, temperature control and separation of waste streams are driving RAS production more and more towards intensification of water re-use.
- The increase in applied feed load per water volume results in more concentrated waste levels in the system making an effective water treatment and waste management to essential key factors in modern RAS technology more than ever.
- Ozone as an effective disinfecting agent, itself decays relatively fast in aquacultural waters, minimizing the risk of toxic ozone residuals impairing cultured organisms and biofilter bacteria in freshwater.
- However, **during ozonation of saline waters highly toxic and persistent by-products are formed, as ozone reacts rapidly with selected halogen ions such as iodide and mainly bromide to different secondary oxidants summed up as ozone-produced oxidants (OPO) .**
- It has been shown that **brominated oxidants** such as hypobromous acid/hypobromite, bromamines and further bromine species represent the dominant species in ozonated saline waters (Heeb et al., 2014 ).
- the impact of OPO on different marine aquaculture species showed impairment of health and animal welfare at concentrations as low as  $\geq 0.10$  mg/l chlorine equivalent (Reiser et al., 2010).

**WATER QUALITY PARAMETERS REQUIRED FOR MAXIMUM FEED EFFICIENCY AND  
MAXIMUM GROWTH OF *PENAEUS MONODON***

<b>Water Parameters</b>	<b>Optimum level</b>
Dissolved Oxygen	3.5-4 ppm
Salinity	10-25 ppt
Water Temperature	26-32 (°C)
pH	6.8-8.7
Total nitrite nitrogen	1.0 ppm
Total ammonia (less than)	1.0 ppm
Biological Oxygen Demand (BOD)	10 ppm
Chemical Oxygen Demand (COD)	70 ppm
Transparency	35 cm
Carbon dioxide (less than)	10 ppm
Sulphide (less than)	0.003 ppm

# BMP

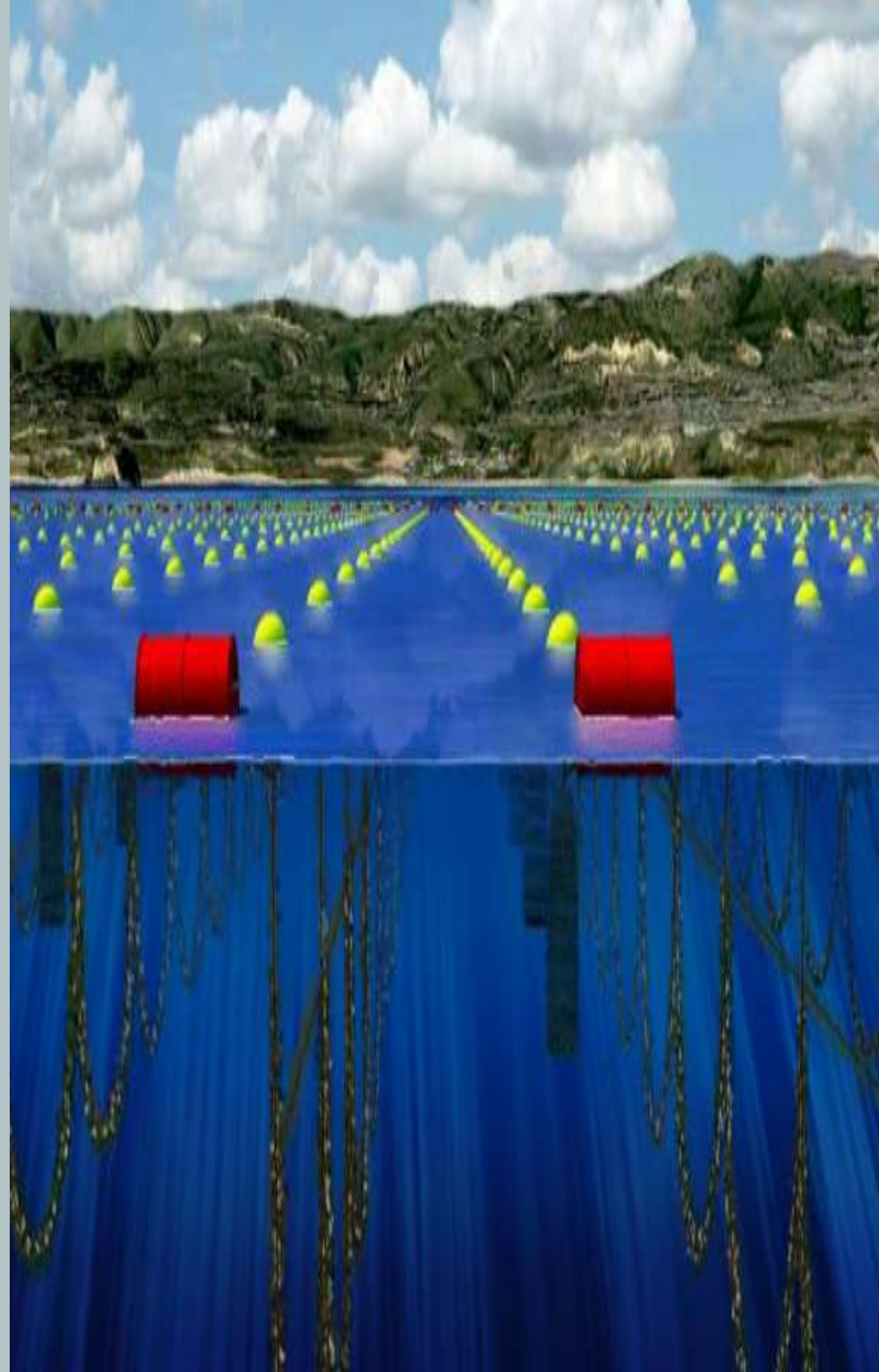
- Use fertilizers as needed to maintain phytoplankton blooms
- Select optimum stocking and feeding rate
- High quality water stable feed with N and P within limit
- Avoid overfeeding
- Apply enough mechanical aeration in intensive culture
- Provide storage volume for heavy rainfall to minimize overflow
- Seining of the pond than draining for harvest
- Discharge effluent through a settling basin
- Reuse water wherever possible



**Wastewater Standards at final discharge point from the aquaculture farms, hatcheries, feed mills and processing units**

Sl. No.	Parameters	Final discharge point	
		Coastal Marine Waters	Creek or estuarine courses when the same inland water courses are used as water source and disposal point
(1)	pH	6.0 – 8.5	6.0 – 8.5
(2)	Suspended solids mg/1	100	100
(3)	Dissolved oxygen mg/1	Not less than 3	Not less than 3
(4)	Free Ammonia (as NH <sub>3</sub> -N) mg/1	1.0	0.5
(5)	Biochemical Oxygen Demand-BOD (5 days @ 20 c) Max mg/1	50	20
(6)	Chemical Oxygen Demand-COD mg/1 Max	100	75
(7)	Dissolved Phosphate (as P) mg/1 Max	0.4	0.2
(8)	Total Nitrogen (as N) mg/1	2.0	2.0

- **Filter-feeding bivalve shellfish** – oysters, mussels, clams and scallops – are successfully farmed across the globe as **a sustainable food source** while also **enhancing the marine environment**.
- An adult shellfish can filter up **to 50 gallons of water a day** removing suspended solids from surrounding waters and form the foundations of the **marine food chain to flourish**.
- Beds of bivalve shellfish provide ecosystem services by naturally filtering silt and also removing bacteria, viruses and nutrients from the water.
- **Scientists calculate** that bacteria in sediment around bivalve beds biologically remove at least 20 percent of the nitrogen in wastes through the same process used in modern wastewater treatment plants.




# BIOREMEDIATION : WATER AND SOIL QUALITY MANAGEMENT

- *Bacillus sp.*, *Paracoccus sp.*, *Thiobacillus sp.* - added directly to the water involve the modulation of the microbiology profile in ponds, degradation of undesirable waste compounds (ammonia, nitrite, hydrogen sulfide), enhanced mineralization of organic matter, decreased anaerobic conditions in pond soil and reduced sludge accumulation.

Table 1. Summary of pond interactions with and without the addition of beneficial bacteria.

Effect on	Without beneficial bacteria	With beneficial bacteria
Feed waste, faeces and organic matter	Accumulation	Reduction
Ammonia (NH <sub>3</sub> ), Nitrogen dioxide (NO <sub>2</sub> ), Hydrogen sulphide (H <sub>2</sub> S)	▲ Increase	▼ Decrease
Oxygen (O <sub>2</sub> )	▼ Decrease	▲ Increase
Eutrophication	▲ Increase Contaminated pond, water and bottom	▼ Decrease Improved pond, water and bottom
Pathogen and disease	▲ Increase	▼ Decrease
Shrimp growth and crop	▼ Decrease	▲ Increase



# PROBIOTICS AND THEIR ROLES

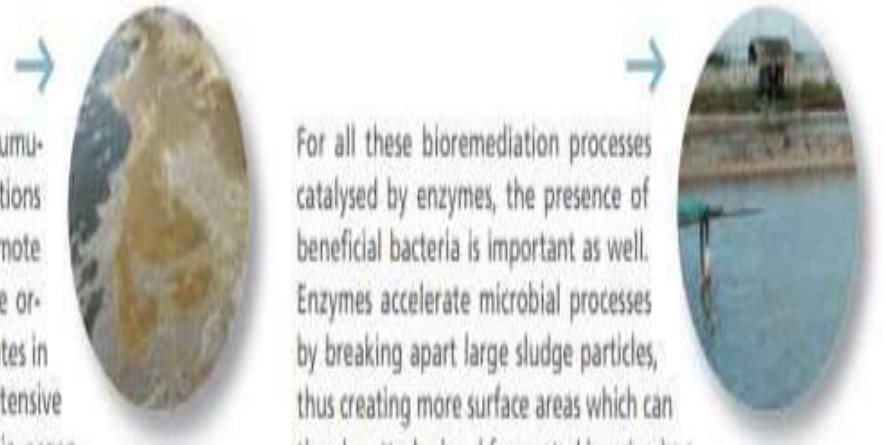
<i>Bacillus</i> sp.	→	Mineralization and Breakage of proteins
<i>Nitrosomonas</i> sp.	→	Oxidation of ammonia
<i>Nitrobacter</i> sp.	→	Oxidation of nitrites
<i>Aerobacter</i> sp.	→	Reduction of organic matter
<i>Cellulomonas</i> sp.	→	Breakage of plant material

- Regulate the micro-flora of the aquaculture water.
- Control pathogenic microorganisms.
- Enhance decomposition of the undesirable organic substances in the water and improve the ecological environment by minimizing the toxic gases like ammonia, nitrite, hydrogen sulfide, methane etc.
- Increase the population of food organisms.
- Improves the nutrition level and immunity of the cultured animals to pathogenic microorganisms and prevent the frequent outbreak of diseases.

**Table 2.** A diverse range of enzymes used as bioremediation agents in aquaculture.

Enzyme	Substrate
Amylase	Starch
$\beta$ -Glucosidase	$\beta$ -Glucoside
Cellulase	Cellulose
Lipase	Lipids and fat
Protease	Protein
Xylanase	Xylan, Hemicellulose
Pectinase	Pectin

Enzymes reduce sludge accumulation and anaerobic conditions in pond bottoms. They promote a faster degradation of the organic matter that accumulates in ponds, especially under intensive production conditions. This organic matter comprises uneaten feed, dead plankton, mineral soils, faeces and pathogenic micro-organisms in the soil where conditions are often anaerobic.



For all these bioremediation processes catalysed by enzymes, the presence of beneficial bacteria is important as well. Enzymes accelerate microbial processes by breaking apart large sludge particles, thus creating more surface areas which can then be attacked and fermented by microbes. This reduction of sludge and dead organic matter can be seen visually not only with better water quality, but also better soil quality.



ponds using bacterial strains and enzymes showed better soil conditions (yellow soil) and enhanced shrimp performance, while the soil of ponds without the treatment showed an accumulation of dead organic matter (black soil).

# RECENT FINDINGS – water quality monitoring

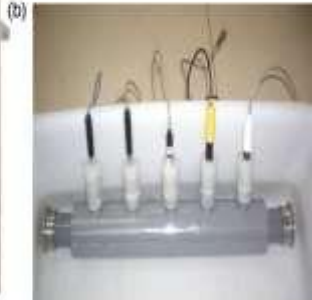
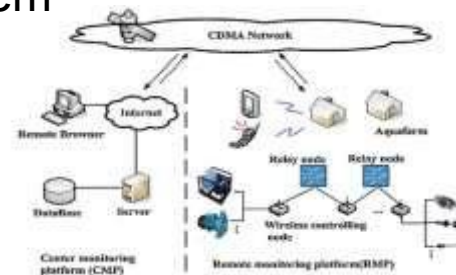
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ΚΕΦΑΛΑΙΟ ΠΡΩΤΟ – ΜΕΤΡΑ

- Farmer ought to measure variables to know the status of fish pond waters and comply with the standards for aquaculture effluents, and the *more variables that were measured, the higher the cost.*
- Concentrations of settle-able solids (Set), turbidity (Tur), total suspended solids (TSS), particulate organic matter (POM), chlorophyll-a (Chl), 5-day biochemical oxygen demand (BOD), total phosphorus (TP), and total nitrogen (TN) were measured in 50 fish ponds.
- Use of POM as a surrogate for the other analyses measured in this study could result in a savings of both time and money.
- The study conducted in Auburn, Alabama, USA collected the raw data by measurements , expanding model choices by construction of different regression models, enabling the models to be used widely by testing them with the data from the literature, and reducing the number of water quality variables by comparing the MdAPEs (median of absolute percentage error).

# A remote wireless system for water quality online monitoring in intensive fish culture

- Online water quality monitoring system for intensive fish culture in China, which combined **web-server-embedded telecommunication technology**



- Based on historical data, this system is designed to **forecast water quality** with artificial neural networks (ANNs) and **control the water quality** in time to reduce catastrophic losses.
- The forecasting model for dissolved oxygen half an hour ahead has been validated with experimental data.
- The results demonstrate that multi-parametric, long-distance and online monitoring for water quality



information can be accurately acquired and predicted

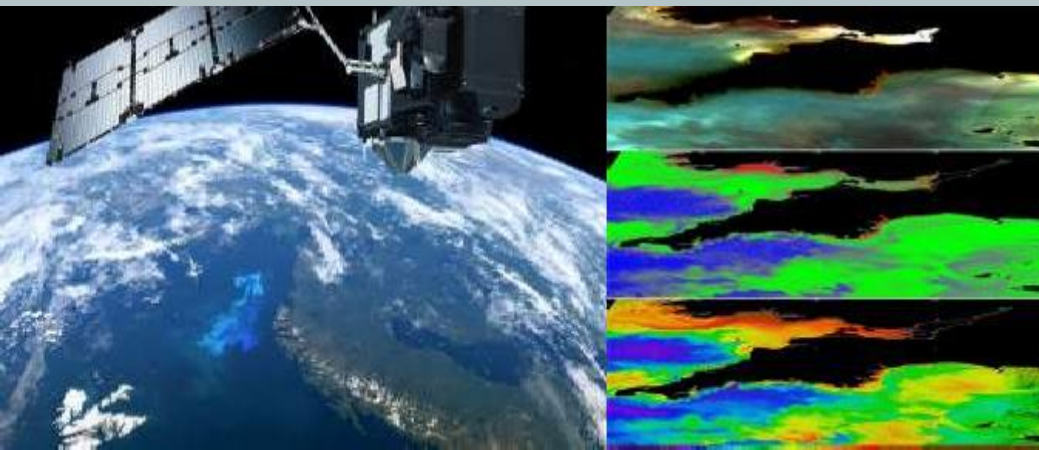
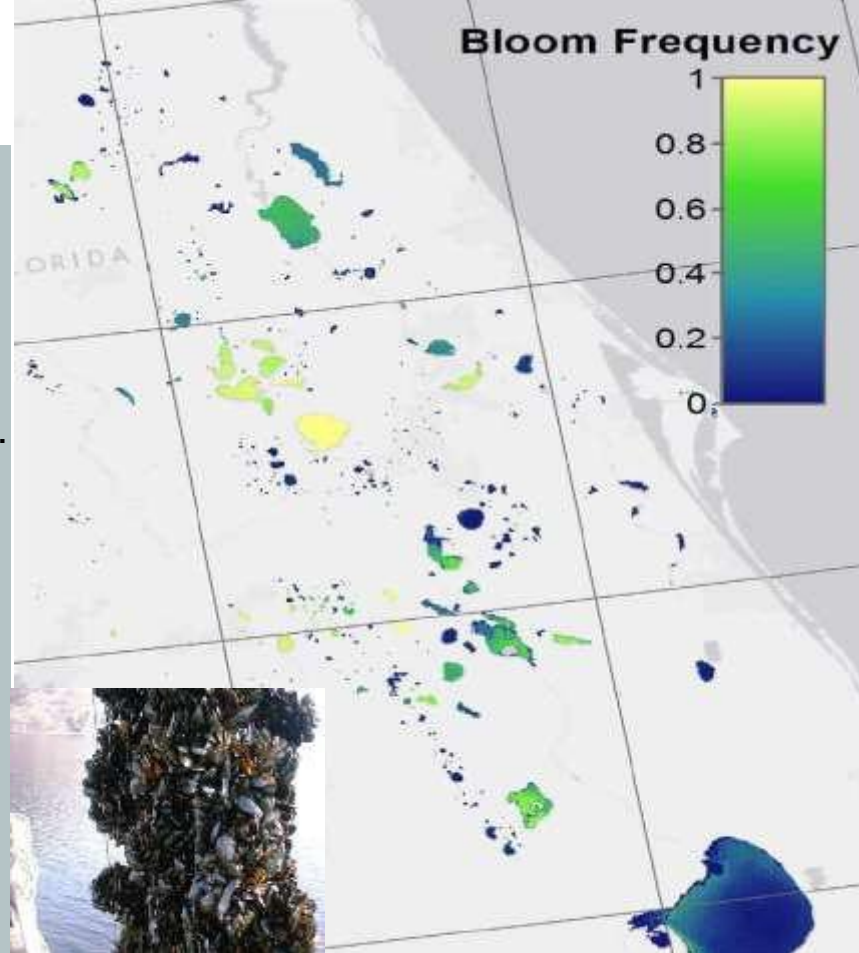


Remote monitoring platform

(a) installation of each module in, RMP case, (b) sensors, and (c) a remote monitoring platform deployed in an

# SATELLITE SENSOR TECHNOLOGY

- A joint collaboration between EPA, NOAA, NASA, and USGS (2017) scientists has demonstrated that **satellite imagery** can be used to **track the location and frequency of harmful algal blooms**. The satellites can accomplish this by measuring certain **algal pigments** in the water.
- **ShellEye project**, (UK,2016) seeks to help shellfish farmers manage threats from harmful algal blooms and *E. coli* bacteria.
- Lakes, reservoirs, seas, *etc.*

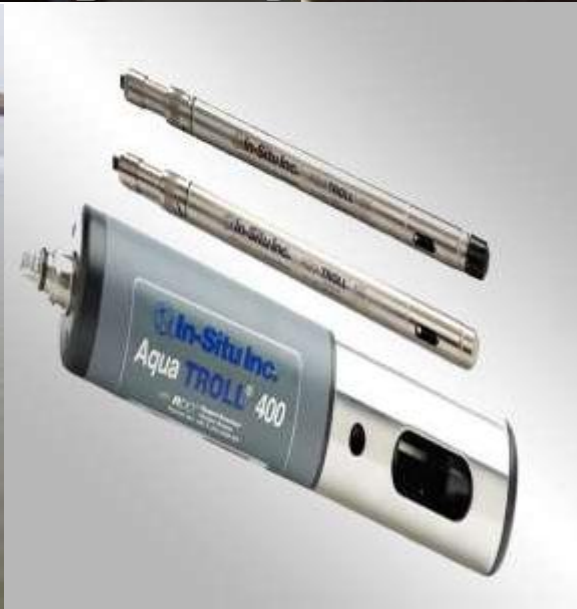


cyanoHAB occurrence above the World Health Organization (WHO) high threshold for risk of 100,000 cells per milliliter (cells mL<sup>-1</sup>) in central Florida lakes from 2008 through 2011

A value of 1 indicates that the pixel was observed to have cyanoHABs above the WHO threshold in all observations, and a



# Autonomous robotic fish designed to monitor water quality



**Wireless Sensor Network**

**Aqua TROLL**

**Floating Sensorised Networked Robots**

# STRATEGIES TO IMPROVE WATER QUALITY MANAGEMENT & MONITORING

## ➤ **Culture Systems**

- RAS
  - Biofloc
  - Aquaponics
  - Integrated aquaculture farming system
  - IMTA
  - Cage culture based Aquageoponics
  - Organic aquaculture
  - Sewage aquaculture
- Water quality is obviously a major concern of any aquaculture facility, and elimination of antibiotics, pesticides, and fertilizers will help alleviate one of the major contributing factors leading to water quality declines during production.
- Improved feeds and feeding regimes are also important considerations in water quality control, as is regular careful monitoring and assessment of the internal pond environment..
- BMP
- Bioremediation

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