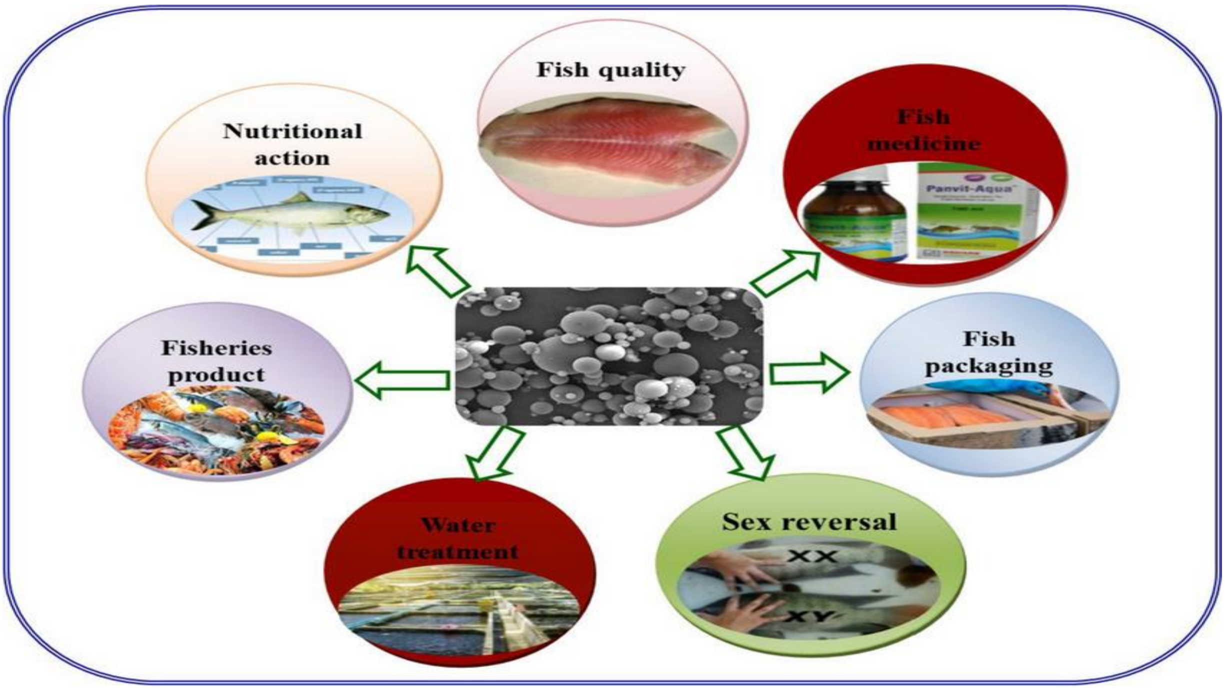
CIARI/training manual/02/2025 Dated: 10/12/2025

TRAINING MANUAL

ON

AWARENESS OF THE USE OF VARIOUS CHEMICALS IN AQUACULTURE



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FOREWORD

Aquaculture continues to hold considerable potential as a sustainable pathway for enhancing food and nutritional security, increasing incomes, and supporting livelihoods in India, particularly in island regions such as the Andaman and Nicobar Islands. As production intensifies, the use of various chemicals for pond-preparation, water and soil treatment, disease control, growth promotion, feed additives, and post-harvest management becomes an increasingly common practice. When applied responsibly and with proper understanding, chemical inputs can increase yields, improve survival rates, stimulate natural food production, and aid in managing disease and water quality, thereby supporting more consistent and productive aquaculture operations.

But there are serious responsibilities as well. Improper or indiscriminate use of chemicals (pesticides, antibiotics, fertilizers, liming agents, algicides, feed additives etc.) can endanger the environment, harm aquatic animals, put workers handling the chemicals at risk and ultimately affect consumers of aquaculture products. Inappropriate dosages, poor timing or lack of proper management can lead to water contamination, ecological imbalance, reduced water quality, development of drug-resistant pathogens and residue accumulation in fish.

This manual focused on promoting awareness of chemical use in aquaculture has been developed as a practical, accessible resource for farmers, hatchery and pond owners, field technicians, extension personnel and students. It provides clear guidance on the wide range of chemicals commonly used in modern aquaculture—their purposes, benefits, risks and safe application practices. The chapters cover essential topics such as pond preparation and safe chemical use, water and soil treatment, use of probiotics, responsible application of fertilizers and growth promoters, disease prevention and treatment and post-harvest chemical handling.

By combining scientific insight with on-ground experience particularly within contexts like Andaman and Nicobar Islands the manual seeks to bridge research and field practice. It aims to support decision-making at the pond-level and encourage adoption of better management strategies. In doing so, it fosters not only higher productivity and profitability, but also environmental sustainability, ecological balance, and safe aquaculture produce.

I express my sincere appreciation to the authors, editors and all contributors whose diligent efforts have made this guide possible. May this work serve as a valuable tool for the aquaculture community in the region and contribute meaningfully to sustainable development, improved livelihoods, and food security.

(Jai Sunder)
ICAR-CIARI, Director (Act.)

Date:
Place:

PREFACE

Aquaculture has become a vital sector for ensuring food security, livelihoods and income especially in coastal, island, and rural regions of India. As fish farming expands and modern practices spread, many farmers now rely on a variety of chemicals for pond preparation, water and soil treatment, disease control, feed enhancement, growth promotion and post-harvest management. Chemical inputs when they are used correctly and thoughtfully, facilitate better survival rates, growth, disease prevention and higher yields, helping aquaculture operations become more productive and reliable. Yet widespread chemical use also brings responsibility. Incorrect doses, unregulated or indiscriminate application, or lack of proper handling can lead to water and soil contamination, harm non-target organisms, degrade water quality, damage pond ecosystems, pose health risks for workers and even create food-safety hazards for consumers.

This manual is a practical, science-based guide designed for a wide range of farmers, hatchery and pond workers, extension staff, field technicians and students. It provides a clear overview of the main categories of chemicals commonly used in aquaculture, from pond preparation (for example liming materials, disinfectants, water conditioners, therapeutants, fertilizers, feed additives, growth promoters and related products) to post-harvest management. It includes guidance on proper handling and safe storage of these chemicals and on the correct dosage, timing and method of application for various aquaculture operations. The manual is written in a clear, accessible style so that both small and medium-scale fish farmers can easily understand and apply it in their routine aquaculture activities. It highlights the importance of observing safe withdrawal periods, proper handling, and environmental protection. Finally, it provides practical alternatives and recommendations for effective pond management and hygiene practices, emphasizing biological and environmental methods while limiting chemical use as a last resort rather than the first option. We hope that this manual will foster a culture of responsibility and awareness, minimize the misuse of chemicals, enhance the sustainability of aquaculture operations and protect the health of aquatic animals, farmers, consumers and the environment.

We would like to thank all authors, researchers, practitioners, extension workers and farmers whose experience, data and insight have contributed to this manual. Their commitment has created a resource that strengthens the bridge between scientific knowledge and field-level practices. May this guide serve as a valuable companion to everyone involved in aquaculture, helping shape a safer, more productive, and environmentally responsible future for the sector.

(Authors)

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Chapter 1. Status of fisheries and aquaculture in North & Middle Andaman district

Subam Debroy, Manoj Kumar & V. Damodaran

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Introduction: The Andaman and Nicobar Islands are endowed with diverse aquatic ecosystems, which includes marine (coastal and offshore), brackish-water (mangroves), and freshwater (ponds). Fisheries and Aquaculture both (capture and culture) provides a major livelihood source and contribute substantially to local food security and income for the fishermen community of N&M Andaman district. The presence of rich biodiversity (fish, crustaceans, molluscs, coral, and mangroves) supports the potential for sustainable fisheries and aquaculture.

Status of Capture Fisheries in North & Middle Andaman: The latest comprehensive survey for the islands, the Marine Fisheries Census 2016, covered all marine fishing villages across North, Middle, South Andaman and Nicobar districts. In the broader Andaman region, marine fisheries are largely traditional: fishing crafts include non-mechanized (country crafts), motorized boats, and a few mechanized vessels. Main fishing gears are gill nets, hook-and-line, cast nets, longlines and shore seines/anchor nets. As per a resource assessment study, the overall annual harvestable potential from marine fish in Andaman & Nicobar is estimated around 240,000 tonnes (0.24 million tonnes). However, due to remoteness, dependence on traditional gear/craft, and limited mechanization, exploitation is modest compared to mainland states, and many marine species remain underutilized. Marine fishing continues to support communities in North & Middle Andaman, but remains largely small-scale and traditional. There is sizeable potential for sustainable expansion but it requires better infrastructure, improved fishing craft/gear, and management to avoid overfishing and protect ecosystems.

Inland & Brackish water Aquaculture: Freshwater aquaculture in North and Middle Andaman is largely shaped by the island’s Bengali settler communities, who traditionally value both freshwater and marine fish. Over time, they have constructed more than 1,655 ponds (roughly 121 hectares).Because marine fishing is constrained, freshwater fish farming has become especially important in the region. For many households, pond-based fish culture provides a stable source of food and income. Composite fish culture, raising multiple fish species together in a pond is commonly practiced. This technique optimizes pond productivity by leveraging different feeding habits and ecological niches of the species. Local farmers also often use the Broad Bed and Furrow (BBF) system. In this integrated method, raised beds grow vegetables or fodder while the furrows, filled with water, support fish (or rice + fish) cultivation. This arrangement is well suited for the Andaman’s seasonal water dynamics: during rainy periods, furrows store water for fish/rice, while beds remain dry for crops. Because of these practices, freshwater aquaculture remains the dominant mode of fish production in North and Middle Andaman. It offers a dependable livelihood foundation, especially for settler communities, and contributes to food security. At the same time, there is untapped potential. Brackish-water aquaculture and marine cage culture have not yet been developed fully but these represent real opportunities for future growth. If advanced carefully, with attention to ecological balance, equitable resource use and social justice, such expansion could diversify production, increase income and reduce pressure on natural fish stocks.

Major Practical Constraints for Fish Production in North & Middle Andaman:

Water scarcity and seasonal shortage: Freshwater aquaculture in Andaman faces serious water-supply problems during dry months (roughly January to May). Many ponds depend on rainfall or natural water sources that may not be reliable every season, making consistent fish rearing difficult. Because of this, productivity is uneven: some ponds may perform well when water is available, others may fail or yield poor output, which undermines the reliability of fish production as a livelihood.

Lack of access to quality inputs: Many farmers struggle to get good quality fingerlings (juvenile fish) at the right time and in required numbers. Delays or shortages force them to use lower-quality seed from mainland India (Unauthorized Hatchery) or postpone stocking, which affects yield. Feeding and pond-management practices are often sub-optimal due to lack of knowledge regarding proper feeding, feeding frequency, and water-quality monitoring or disease prevention. There is limited capacity among farmers to adopt more advanced or scientific aquaculture methods (for instance recirculatory systems, systematic water-quality monitoring, improved species or polyculture practices etc.).

Risk of disease and poor water-quality management: Aquatic animal diseases pose a severe and systemic threat to successful fish farming in North & Middle Andaman, with surveillance confirming that both freshwater and brackish-water operations are afflicted by a range of pathogens, including parasites, bacteria, fungi, and viruses. The primary catalyst for these outbreaks is poor water quality; when crucial parameters like oxygen, ammonia, and pH levels are not properly maintained, fish become severely stressed and immune-compromised. In many small-scale settings, the lack of regular monitoring equipment and limited technical expertise means these critical water fluctuations often go unnoticed, especially after heavy rains or during dry periods. This significantly raises the risk of sudden, catastrophic mortality or chronic disease that can wipe out entire stock before harvest. Furthermore, poor farm hygiene, failure to quarantine new stock, and overstocking exacerbate stress and accelerate pathogen transmission among the fish.

Poor infrastructure and market: Successful fish production is often undermined by significant post-harvest and market challenges faced by small-scale producers. Due to the perishable nature of fish, immediate and reliable handling is critical. Unfortunately, many producers lack essential infrastructure, including cold-storage and processing facilities, and struggle with inadequate transport and weak market linkages. This deficiency in the cold chain and logistics results in substantial post-harvest losses and compels producers to accept low returns for their product.

Limited access to Lab: Limited access to diagnostic labs and aquatic-animal health services (especially on remote islands) means disease outbreaks are often detected late or remain unreported; this leads to bigger losses and discourages farmers from investing in improved aquaculture practices.

Potential Solution:

- Ensure ponds have adequate water-holding capacity (sufficient depth and volume) so they don’t rely only on rainfall or seasonal flows.

- Regularly monitor water-quality parameters (dissolved oxygen, ammonia/nitrite, pH, temperature and Transparency) to detect stress conditions early.
- Maintain good pond hygiene: remove waste/uneaten feed and dead fish quickly and avoid overcrowding or excessive stocking.
- Stock fingerlings from reliable, certified hatcheries rather than risk inferior stock from unverified sources.
- Provide training and extension support to farmers so they learn better feeding schedules, pond management, and water-quality maintenance and disease-prevention practices.
- Explore improved or alternative aquaculture methods such as recirculating water systems, bio-floc, or integrated fish-crop farming, which help stabilize water quality and improve sustainability.
- Invest in post-harvest infrastructure: cold-storage, hygienic handling, and transport facilities, so fish quality and value are preserved after harvest rather than lost due to spoilage or poor logistics.
- Strengthen access to diagnostic support or aquatic-animal health services (lab support, disease surveillance) to enable early detection and management of disease outbreaks.

Chapter 2. Importance of Chemical Awareness for Aquaculture in North & Middle Andaman district

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Introduction: Chemical management is a critical component of intensive and semi-intensive aquaculture systems. In the North and Middle Andaman district, aquaculture relies on freshwater ponds, brackish-water systems, and integrated farms, where water quality and animal health are highly sensitive to environmental and anthropogenic factors. Chemicals such as disinfectants, lime, probiotics, and feed additives are commonly used to improve growth, maintain pond health, and prevent disease outbreaks. However, inappropriate chemical application can lead to toxicity, eutrophication, residual contamination in aquatic products, and environmental degradation. Chemical awareness among aquaculture practitioners is therefore essential to ensure judicious, efficient, and safe application of chemicals, thereby improving productivity, product quality, and sustainability.

Role of Chemicals in Aquaculture Systems:

Chemicals in aquaculture serve specific purposes:

- **Water Quality Management:** Chemicals like quicklime (CaO), hydrated lime ($Ca(OH)_2$), and potassium permanganate ($KMnO_4$), zeolite and probiotics are routinely used to adjust pond pH and alkalinity, oxidize organic load and reduce ammonia and nitrite toxicity, control pathogenic microorganisms, and suppress excessive algal blooms in pond water.
- **Disease Control and Therapeutics:** Antibiotics (strictly under veterinary prescription) are used to treat bacterial infections in pond animals. Fungicides and parasiticides help control infestations by fungi, protozoa or external parasites. When treatments are applied early based on diagnostic testing, disease spread can often be stopped before it expands drastically. Such timely, precisely targeted intervention helps prevent large-scale outbreaks in aquaculture ponds.
- **Feed and Growth Enhancement:** Feed additives such as enzymes, probiotics, and immunostimulants improve feed conversion ratio (FCR), growth rates, and disease resistance. But overuse or indiscriminate supplementation can lead to water deterioration and residues in fish tissue.
- **Post-Harvest and Preservation:** Only approved disinfectants, ice treatments, and food-grade preservatives should be used to reduce bacterial load and extend the shelf life of fish and fish products during storage.

Risks Associated with Improper Chemical Use:

Excessive or inappropriate chemical usage in aquaculture leads to:

- **Acute or chronic toxicity in cultured species**: Overdosing lime, $KMnO_4$, or antibiotics can cause gill necrosis, reduced feed intake, and finally mass mortality will occur.

- **Accumulation of chemical residues** in pond sediment and fish tissue, creating food-safety hazards.
- **Water quality degradation**: Overuse of chemicals may alter pH, reduce dissolved oxygen (DO), and increase total dissolved solids (TDS), negatively affecting growth and survival of aquatic animals.
- **Antibiotic resistance**: Improper therapeutic application can lead to resistant bacterial strains, complicating disease management.
- **Economic losses**: Fish mortality, reduced growth and rejection in markets reduce farm profitability.

Importance of Chemical Awareness: Chemical awareness is essential for achieving productive, sustainable, and safe aquaculture. In the North and Middle Andaman district, judicious and regulated use of chemicals supports optimal growth performance, stable pond ecology, safe and residue-free aquatic products, and compliance with national food-safety and environmental standards. Farmers who integrate chemical stewardship with systematic water-quality monitoring, science-based disease prevention, and best pond management practices can enhance production efficiency, minimize mortality-related losses, improve market acceptance, and ensure long-term environmental sustainability.

Recommendations for North & Middle Andaman district:

- Avoid unnecessary chemical applications; when required, consult specialists to select environmentally safe, approved products and to know the correct dosage and method of application in the pond.
- Purchase chemicals only from certified suppliers and avoid unverified or substandard materials.
- Apply chemicals only based on water-quality assessments or diagnostic results**.**
- Maintain detailed pond records on chemical use, water-quality parameters, and animal health, and integrate these records with good management practices such as balanced feeding, proper aeration, and optimal stocking density.
- Invest in post-harvest facilities, including hygienic handling and cold storage, to prevent residue contamination.

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Chapter 3. Overview of chemicals and their roles in modern aquaculture

Subam Debroy, V. Damodaran

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Introduction: Aquaculture is much more than simply putting fish or shrimp in water and feeding them. The water-itself its chemistry, quality, balance is the foundation on which healthy, productive aquaculture depends. In essence, water serves as the living medium for cultured organisms, providing oxygen, nutrients, a substrate for plankton and microbial life, and the environment in which fish and shellfish grow, reproduce, breathe, feed and excrete. The chemical composition of that medium influences nearly every aspect of the animals' physiology, behaviour, health and growth. Proper management of water chemistry enables aquaculture to achieve high yields, good survival, efficient growth, and overall robust production, often on a scale suitable for commercial farming. But when chemistry is ignored or poorly managed, water may become toxic or stressful: dissolved wastes build up, oxygen drops, pH swings occur, and harmful compounds accumulate. These conditions can impair growth, reduce feed conversion efficiency, weaken immunity, provoke disease, or even cause mass mortalities. Because of this, modern aquaculture relies heavily on carefully selected and applied chemicals or chemical-based products. These are not "unnatural extras" but essential tools — used to condition water and soil, manage pH and alkalinity, neutralize toxins, stimulate natural food (plankton) growth, disinfect ponds or hatchery systems, treat diseases or parasites, and maintain stable, healthy conditions through the growth cycle.

Major Chemical Categories & Their Roles:

pH regulators / liming agents: Substances such as lime (calcium oxide CaO, slaked lime $Ca(OH)_2$, or limestone ($CaCO_3$) are used to adjust and stabilize the pH of pond water or soil. This helps create a favourable environment for plankton bloom, supports healthy biological activity in pond bottom soil, and reduces harmful acidity or alkalinity.

Soil conditioners / adsorbents: Compounds like zeolite, porous alumino-silicate, and similar minerals help "clean" the pond and they absorb ammonia, hydrogen sulfide, carbon dioxide, and other harmful waste products. This helps maintain water clarity and reduces toxic build-up.

Fertilizers / nutrients: To promote natural productivity (e.g. plankton growth), organic (Raw cow dung, cattle dung, poultry droppings and Vermicompost) and inorganic fertilizers (urea, ammonium phosphate/sulfate, or triple superphosphate) may be used. This helps create a basal food supply (phytoplankton → zooplankton → fish) before stocking.

Disinfectants / sanitizers: These include chlorine-based compounds (e.g. sodium hypochlorite, calcium hypochlorite), hydrogen peroxide, quaternary ammonium compounds (QACs such as benzalkonium chloride), formalin, and other agents. Their purpose is to kill or inactivate bacteria, viruses, fungi, and parasites — either in the water, on equipment, in hatcheries, or on eggs.

External therapeutants: External therapeutants like potassium permanganate ($KMnO_4$) are commonly used to control external parasites, fungal infections, and some bacterial issues in fish. The compound works by oxidizing and removing disease-causing organisms from the skin and gills. Accurate dosing is essential because excessive application can harm or even kill the fish.

Algaecides / piscicides / weed / predator control chemicals: In some systems, especially before stocking, unwanted fish (predators), aquatic weeds or undesirable algae may be removed using piscicides or herbicides. These chemicals help to protect the cultured species and maintain ecological balance in the pond.

Antibiotics and antimicrobials: They are used to treat and control bacterial diseases in fish and shrimp. Products such as oxytetracycline, tetracyclines, sulfonamides, and others (depending on regional approval) may be administered, often through feed, after a confirmed diagnosis. Their use should always be based on expert guidance to ensure proper dosage, duration, and responsible application

Growth promoters, feed additives, and probiotics: They are used not only to prevent disease but also to improve growth, feed efficiency, and overall health in cultured species. Probiotics, which consist of beneficial microorganisms, can support digestion, enhance gut function, and help suppress harmful pathogens, contributing to better survival and performance.

Challenges: Using chemicals in aquaculture carries both benefits and risks. Some key concerns are listed below:

Many disinfectants, pesticides, antibiotics, or external therapeutants can be harmful not only to pathogens but also to fish, non-target organisms, and even farm workers.

Overuse or improper dosing may lead to the accumulation of toxic residues in water, soil, or fish/shrimp tissues. This can affect ecosystem balance and human health through consumption.

Frequent or indiscriminate use of antibiotics can lead to resistant bacterial strains, reducing the effectiveness of treatments over time. It also poses public health concerns.

Survey-based studies report that many farmers lack proper training about correct doses, contact times, side effects, or safe handling of chemicals. This often results in inefficient use, wastage, or harmful consequences.

Therefore, chemical use must always follow recommended guidelines: correct concentration, proper contact time, safe handling (gloves, ventilation, clear labeling), and careful storage.

Best Management Practices (BMPs):

- **Plan pond preparation carefully before stocking fish**: Apply lime or other pH stabilizers, soil conditioners such as zeolite, and fertilizers to support good water quality and a healthy plankton base.
- **Disinfectants and sanitizers:** Use disinfectants and sanitizers during site preparation and routine maintenance, especially in hatcheries or when introducing new stock. Clean equipment, treat water and pond bottoms, and disinfect eggs if required.

- **Monitor water quality on a regular schedule**: Check pH, dissolved oxygen, ammonia, nitrite and organic load. When oxygen levels are low, consider aeration, water exchange or approved oxygen-releasing products.
- **Limit and manage the use of therapeutics and antibiotics**: Use them only when truly needed, not as a routine. Keep proper records and follow the withdrawal period before harvest. Whenever possible, choose safer alternatives such as probiotics and good management practices.
- **Follow safety and environmental guidelines**: Use protective gear when handling chemicals. Label containers clearly, prevent cross-contamination, dispose of waste safely, avoid overdosing and remain aware of long-term environmental and health risks.
- Adopt an integrated health management approach by combining strong pond management, effective water quality control, biosecurity, good nutrition and minimal but careful use of chemicals. Explore non-chemical options such as probiotics, improved sanitation and aeration whenever feasible.

Conclusion: Chemicals are an important tool in aquaculture when they are used correctly. They help maintain clean water and soil, support plankton growth, control diseases and parasites, improve oxygen levels, and promote healthy growth of fish and shrimp. But if chemicals are misused, overused, or used without guidance, they can cause serious problems like toxic effects, antibiotic resistance, environmental pollution, and risks to human health. The key principle is to use chemicals only when they are truly necessary, in the correct dose, and with proper handling. Always combine chemical use with good pond management, hygiene, and strong biosecurity to achieve safe and sustainable production.

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Chapter 4. Pond Preparation and Safe Use of Chemicals

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Introduction: Proper pond preparation is one of the most important steps in successful aquaculture. Well-prepared ponds provide a clean, healthy, and favourable environment for fish or shrimp growth. It supports good water quality, reduces disease risk, improves survival, and ensures better production. Along with preparation, safe and responsible use of chemicals is essential for maintaining a balanced ecosystem without harming the cultured species, the environment, or human consumers. Different types of ponds such as nursery, rearing, and grow-out ponds require specific management practices based on culture stages and stocking density.

Pond Preparation Steps and Chemicals Used:

Pond Drying and Cleaning: After harvesting, the pond should be completely drained and allowed to dry under sunlight. Sun-drying helps destroy harmful organisms, parasites and bacteria present in the pond bottom. During this stage, accumulated sludge, leftover feed, weed roots and debris should be removed. Drying also reduces harmful gases such as ammonia and hydrogen sulfide, controls unwanted organisms and improves the overall soil quality, creating a healthier environment for the next culture cycle.

Weed and Predator Control: Weeds can be removed manually or using mechanical tools to ensure clean water circulation and better light penetration. If predators such as unwanted fish species are present, approved piscicides may be applied carefully before filling the pond. Commonly, mahua oil cake is used at a dose of 200 to 250 ppm to eliminate predatory fish. For limited weed control, copper sulfate ($CuSO_4$) can be used at 0.5 to 1 ppm depending on the alkalinity of water. All chemical applications should follow recommended guidelines to avoid harmful side effects.

Liming: Liming is a key step in pond preparation because it helps correct soil pH, acts as a disinfectant and supports the growth of plankton. By stabilizing the soil environment, lime improves nutrient availability and overall water quality, creating better conditions for fish or shrimp culture. Commonly used materials include agricultural lime (calcium carbonate, $CaCO_3$) applied at 200 to 500 kg per hectare for pH correction, quick lime (calcium oxide, CaO) applied at 200 to 300 kg per hectare for disinfection, and slaked lime (calcium hydroxide, $Ca(OH)_2$) applied at 150 to 250 kg per hectare for both pH adjustment and disinfection. The actual dose depends on the soil's acidity level and should be based on proper testing. Lime should be spread evenly over the dry pond bottom, or dissolved in water and sprayed uniformly when applied to ponds that already contain water.

Fertilization to Promote Plankton Growth: Fertilizers are applied in the pond to promote the growth of plankton, which serves as natural food and improves the survival of fry and fingerlings. Organic fertilizers like cow dung are commonly used at a rate of 10000 to 20000 kilograms per hectare, while inorganic fertilizers such as urea and single super phosphate (SSP) are applied at 25 to 30 kilograms per hectare and 30 to 40 kilograms per hectare respectively. After applying fertilizers, the pond should be filled gradually and allowed time for plankton to develop. The pond is ready for stocking when the water turns light green, indicating a healthy plankton population.

Water Quality Conditioning: During pond preparation, different soil and water conditioners are applied for specific purposes. Zeolite at 20 to 40 kilograms per hectare improves soil and water quality by removing ammonia and other harmful gases. Potassium permanganate at 2 to 4 parts per million is used for disinfection and parasite control. Alum at 10 to 25 kilograms per hectare helps stabilize water and reduce turbidity. For chlorination and pathogen removal in a dry pond bottom, bleaching powder (calcium hypochlorite) is applied at 30 to 40 kilograms per hectare. These treatments help create a clean and safe pond environment before stocking.

Safe Use of Chemicals in Aquaculture: Chemicals support healthy production, but incorrect use can be dangerous. Farmers must follow safety guidelines.

Guidelines

- Use chemicals only when required, not routinely.
- Apply recommended doses; never estimate or overdose.
- Do not mix unknown chemicals together.
- Store chemicals in labeled and sealed containers.
- Use protective gloves, mask and avoid direct contact.
- Maintain records of doses, dates and purpose.
- Follow withdrawal periods before harvest.
- Prefer safe alternatives like probiotics, good aeration and better hygiene.

Integrated Pond Health Management: Integrated pond health management focuses on maintaining a balanced and healthy environment rather than relying only on chemicals. Regular monitoring of key water quality parameters such as pH, dissolved oxygen, ammonia and nitrite is essential to detect problems early. Adequate aeration using paddle wheels or diffusers helps maintain sufficient oxygen levels for healthy growth. Strong biosecurity measures, including restricting visitors and avoiding the exchange of equipment between farms, reduce the risk of disease transfer. Proper feeding practices are important; avoiding overfeeding helps prevent excess sludge and water pollution. Stocking healthy seed from reliable hatcheries improves survival and growth performance. Periodic pond cleaning, such as removing accumulated sludge and inspecting pond dikes, inlets and outlets, helps maintain good pond hygiene and ensures smooth operation throughout the culture period.

Conclusion: Effective pond preparation and careful chemical use play a vital role in the success of aquaculture. A properly prepared pond provides stable water quality, reduces stress, limits disease outbreaks, and supports uniform growth and survival rates. Using chemicals only when necessary and in the correct dosage protects fish health, safeguards the environment, and ensures consumer safety. When combined with routine monitoring and good management practices, farmers can maintain a clean and productive culture system. Strong preparation at the start creates a reliable foundation for sustainable and profitable fish farming.

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Chapter 5. Safe Use of Chemicals in Integrated Farming Systems

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Introduction

Integrated Farming Systems (IFS) represent a holistic approach where aquaculture, agriculture, livestock, and crops coexist in a single framework. This integration promotes efficient resource utilization, enhances farm productivity, and strengthens ecological balance by recycling nutrients and reducing waste. However, the use of agro-chemicals—such as fertilizers, pesticides, herbicides, and disinfectants—within these systems requires careful management.

Improper or excessive chemical application can disrupt the delicate interactions among farm components: fish and aquatic organisms may be poisoned, livestock can suffer from contaminated feed or water, soil fertility may decline, and human health can be endangered through exposure or food residues. Moreover, careless chemical use threatens ecosystem integrity, undermining the sustainability that integrated systems are designed to achieve.

Therefore, this module emphasizes the **safe and responsible use of agro-chemicals**. The aim is to protect all elements of integrated farms—water bodies, aquatic life, crops, soil, livestock, and humans—while ensuring that productivity and ecological balance are maintained. By adopting best practices, farmers can harness the benefits of chemicals without compromising health, environment, or long-term sustainability.

When and What Chemicals to Use

When to Use Chemicals

Threshold-Based Application: Apply pesticides or herbicides only when pest or weed populations exceed economic thresholds. Preventive spraying without evidence of infestation is discouraged. Chemicals should be used only when essential. Prioritize non-chemical methods first (manual weed/pest control, biological controls, sanitation, cultural practices) wherever possible. This minimizes environmental and health hazards.

Seasonal Timing: Fertilizers should be applied at crop growth stages when nutrient demand is highest (e.g., nitrogen during vegetative growth, phosphorus during root development).

Aquaculture Safety: Disinfectants or water treatments should be used only when disease risk is confirmed, and never in excess to avoid harming fish. If chemicals are required, use only those approved for agriculture or aquaculture, and avoid banned or highly toxic substances. In many integrated systems (for example a rice-fish system), pesticide use is discouraged because of risk to the fish.

Livestock Management: Use disinfectants for housing or equipment cleaning at regular intervals, but avoid contaminating feed or water.

What Chemicals to Use

Fertilizers
Nitrogen (Urea, Ammonium Sulfate): For leafy growth.
Phosphorus (DAP, SSP): For root and flower development.
Potassium (MOP, SOP): For fruiting and stress tolerance.
Micronutrients (Zinc, Boron, and Iron): Correct specific deficiencies.
Pesticides
Insecticides (e.g., neem-based, pyrethroids): For insect infestations.
Fungicides (e.g., copper oxychloride, carbendazim): For fungal diseases.
Rodenticides: For rodent control in storage areas.
Herbicides
Pre-emergence (e.g., pendimethalin): Applied before weeds germinate.
Post-emergence (e.g., glyphosate, 2, 4-D): Applied after weeds appear.
Disinfectants (Aquaculture & Livestock)
Lime or bleaching powder: For pond disinfection.
Iodine or formalin (controlled use): For livestock housing sanitation.

Risks and Precautions
Overuse leads to residues in food, water, and soil.
Non-target effects: Chemicals may harm fish, beneficial insects, or soil microbes.
Resistance development: Continuous use of the same pesticide fosters resistant pests.
Human health hazards: Exposure without PPE can cause poisoning or chronic illness.

Best Practices
Rotate chemicals to avoid resistance.
Use biological alternatives (e.g., neem oil, Trichoderma fungi) whenever possible.
Apply chemicals with calibrated equipment to ensure correct dosage.
Maintain buffer zones around ponds and livestock areas to prevent contamination.
Keep records of chemical use for traceability and monitoring.

Proper Application and Handling

- Always read and follow the instructions on the chemical label or Safety Data Sheet (SDS). Use correct dosages — avoid “guesswork” or “over-dosing.” Measure and mix properly.
- Use personal protective equipment (PPE): gloves, masks or respirators where needed, long sleeves/trousers, boots, protective eyewear if spraying. Avoid eating, drinking or smoking during application; wash hands and exposed skin afterward.
- To ensure chemicals are applied safely and effectively.
- To protect crops, livestock, aquaculture, soil, water, and human health.
- To minimize waste, contamination, and environmental damage.
- Avoid spraying when wind or drift can carry chemicals into water bodies or nearby ponds. Do not dispose leftover sprays or wash water near ponds, irrigation channels, or drains.

Storage and Disposal

- Store all chemicals only in their original, labeled containers. Never transfer to unlabeled bottles or reuse empty pesticide containers for water, food, feed or domestic use.
- Keep the storage area locked, dry, well-ventilated, and away from animal shelters, water bodies, dwelling places, and food/feed storage areas.
- Dispose empty containers, unwanted or obsolete chemicals properly: triple-rinse containers before disposing; never burn or bury them where chemicals may leach into soil or water. Prefer handing them over to authorized disposal facilities if available.

Integration Considerations — Protecting Aquaculture Components

In systems where aquaculture is combined with agriculture or livestock:

• Avoid using chemicals in crop fields that drain into fish ponds or water bodies. Persistent or toxic chemicals may accumulate and harm aquatic life.

• Maintain good water quality. Chemical runoff, pesticide residues or improper disposal can degrade water quality, reduce dissolved oxygen or cause toxicity — harming fish, other aquatic organisms, or livestock that depend on the water.

• Use integrated pest management (cultural, biological, mechanical methods) rather than relying solely on chemicals; this aligns with sustainable practices and reduces environmental risk.

Record-Keeping, Traceability, Accountability

- Maintain a chemical register: record name of chemical, date of purchase, batch/lot number, date of application, dosage used, field/pond treated, and reason for application. This helps track use and ensures traceability. A chemical-use log supports safety audits, compliance with regulations, and rapid response in case of contamination.
- Keep SDS or manufacturer labels accessible. Note expiry dates: do not use expired products. Keep track of leftover or unused chemicals to plan safe disposal.

7. Training & Awareness for Farm Workers

All personnel involved in handling chemicals — farmers, labourers, caretakers, fishery workers — should be trained on:

- Reading and interpreting labels and SDSs;
- Proper mixing, dosage measurement, application methods;
- PPE use; safe handling, transportation, storage;
- Proper disposal methods; risks of misuse; and alternate pest-control practices;
- Recognizing signs of chemical exposure or toxicity in humans, livestock, or aquatic animals; and emergency response measures.

Regular refreshers or demonstration sessions help reinforce good practices and prevent accidents or misuse.

Monitoring and Environment / Health Safety

- Monitor water quality (pH, dissolved oxygen, clarity) especially after chemical applications or after rains/runoff. Ensure there is no unintended chemical entry into ponds or water bodies.
- If chemical contamination is suspected, avoid harvesting aquatic animals or using water for drinking/irrigation until water quality is restored.
- Where possible, combine integrated pest-management (IPM) and organic/farm-waste-based fertilization instead of synthetic chemicals to reduce chemical load in the

Farmer's Checklist: Safe Agrochemical Use in IFS

DOs

- Use chemicals only when necessary (economic threshold exceeded).
- Follow label instructions & Safety Data Sheets (SDS).
- Apply fertilizers at the right crop stage (N for vegetative, P for roots, K for fruiting).
- Wear PPE: gloves, masks, boots, long sleeves, protective eyewear.
- Store chemicals in original labeled containers, locked & ventilated.
- Dispose containers safely: triple-rinse, don't reuse, hand over to disposal facilities.
- Keep records/logs: chemical name, batch, date, dosage, location, reason.
- Maintain buffer zones around ponds/livestock areas.
- Train workers regularly on safe handling, PPE, and emergency response.

DON'Ts

- Don't spray near ponds or water bodies.
- Don't dump leftover sprays/washings into drains or ponds.
- Don't transfer chemicals into unlabeled or reused containers.
- Don't burn or bury containers (risk of soil/water contamination).
- Don't use expired or unapproved chemicals.
- Don't apply pesticides preventively without infestation evidence.

Risks to Watch

- Residues in food, soil, water.
- Non-target harm (fish, beneficial insects, and microbes).
- Resistance from repeated use of same pesticide.
- Human health hazards without PPE.

Safer Alternatives

- Biological controls (neem oil, Trichoderma fungi).
- Cultural practices (crop rotation, sanitation).
- Mechanical/manual weed/pest control.
- Integrated Pest Management (IPM).

Integrated Farming Systems (IFS) rely on the careful and responsible use of agrochemicals to sustain productivity while protecting crops, livestock, aquaculture, soil, water, and human health. Chemicals should only be applied when necessary, following label instructions and Safety Data Sheets, at the right crop stage, and with proper personal protective equipment. Safe storage in original labeled containers, correct disposal through triple-rinsing and authorized facilities, and accurate record-keeping are essential to prevent contamination. Farmers must avoid spraying near ponds, dumping leftovers into drains, reusing or burning containers, and using expired or unapproved products. Overuse or misuse can leave harmful residues, damage non-target organisms, foster pest resistance, and pose health risks. To reduce dependence on chemicals, safer alternatives such as biological controls, cultural practices, manual methods, and integrated pest management should be prioritized. Overall, responsible chemical management ensures ecological balance, long-term sustainability, and safety across all components of integrated farms.

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Chapter 6. Disease Prevention & Treatment in Aquaculture by Responsible Use of Chemicals

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Introduction: Aquaculture has, over recent decades, become a central pillar of global food production. Once merely a minor supplement to wild fisheries, it has transformed into one of the fastest-growing food-production systems worldwide. This dramatic growth is driven by deep and growing global needs. With a rising human population and increasing demand for affordable, high-quality protein, the pressure on wild fish stocks has intensified. In this context, aquaculture offers a scalable, efficient way to supply seafood, often more sustainably than many land-based animal-protein systems. Beyond its role in feeding growing populations, aquaculture provides valuable economic and social benefits. It supports livelihoods and incomes, especially in rural and coastal communities, by providing job opportunities, enabling trade, and contributing to food security. At the same time, this expansion brings new challenges. As aquaculture becomes more intensive, with higher stocking densities, more frequent production cycles, and reliance on confined ponds or tanks, the vulnerability of cultured aquatic animals to disease increases sharply. Disease outbreaks in aquaculture are not just a biological issue. They can cause severe economic losses, compromise food safety, threaten the livelihoods of producers, and undermine consumer confidence in farmed seafood. Given this backdrop, maintaining the health and well-being of farmed aquatic animals is not optional — it is fundamental to ensuring that aquaculture remains sustainable, productive, and responsible. In this context, chemicals (such as therapeutants, disinfectants, sanitizers, and water-treatment agents) are important tools for disease prevention and control. However, their use must be balanced with caution, sound judgment, and good practices.

Common Diseases in Aquaculture:

Columnaris disease: Columnaris disease generally caused by *Flavobacterium columnare*, is a common and often severe bacterial infection in freshwater aquaculture. Infected fish frequently show white or grey patches on their skin, fins, or gills — patches that can be mistaken for fungal growth — along with fin erosion, ulcers, or necrosis of gill tissue. Stressful conditions such as warm water, poor water quality, overcrowding, or low dissolved oxygen dramatically increase the likelihood of outbreaks. Because the bacterium is common in natural water and pond environments, prevention is usually more effective than cure. Keeping water clean and well-oxygenated, avoiding overcrowding, promptly removing dead or sick fish, and disinfecting equipment are key measures to minimize risk.

Fin & Tail Rot: Often a secondary infection — fin/tail tissue becomes frayed, eroded; fish may show lethargy or loss of appetite. Common when water quality is poor or fish are stressed.

Motile Aeromonas septicemia / Aeromoniasis: Motile Aeromonas Septicemia (MAS), caused by *A. hydrophila*, is one of the most common bacterial diseases in freshwater fish. Under stress conditions such as poor water quality, overcrowding, or low oxygen, the fish's resistance weakens and these bacteria may invade, leading to rapid disease outbreaks. Affected fish often show external signs such as reddening of the skin, hemorrhages, ulcers, and fin or tail rot, and may develop internal septicemia — sometimes dying rapidly with little warning. Because these bacteria are naturally present in pond water and sediment, prevention is often more effective than cure. Maintaining good water quality, proper oxygenation, moderate stocking densities, and minimal stress greatly reduces disease risk. When infection does occur, diagnosis should ideally be confirmed in a laboratory before treatment is applied. Indiscriminate use of antibiotics can lead to resistance and may not succeed if conditions remain poor.

Saprolegniasis: Caused by fungi (water-molds) such as *Saprolegnia parasitica* (and related species). It is among the most frequent fungal problems in freshwater aquaculture, especially in fish with damaged skin, injured fins, eggs or during handling or transport stress.

Branchiomycosis (gill rot): A fungal (or fungus-like) infection targeting gill tissue, often affecting fish reared in poor water conditions or crowded systems.

Epizootic Ulcerative Syndrome (EUS): Caused by fungus/water-mold species such as *Aphanomyces invadans* and leads to skin lesions that may turn into ulcers, and can affect internal organs in severe cases.

Ich (White Spot Disease): It is caused by the protozoan *Ichthyophthirius multifiliis*, is a common parasitic infection in freshwater fish. Infected fish develop tiny white spots on the skin, fins, and gills. As the parasites invade the gills, respiratory distress occurs. Affected fish often scratch against surfaces and display abnormal behaviour.

Gill or skin fluke infestations / monogenean parasites: Parasites such as Gyrodactylus attach to skin or gills; heavy infestations damage gill tissue or skin, impairing respiration or causing ulcers.

Koi Herpesvirus Disease (KHV): Caused by *Cyprinid herpesvirus-3*, affects common carp and koi carp. It is recognized as one of the most serious viral diseases in freshwater aquaculture. Infected fish often develop severe gill lesions and necrosis of gill tissue, which lead to impaired respiration. These internal changes compromise the fish's ability to survive even under otherwise favourable conditions. Externally, signs may include skin hemorrhages, sunken eyes, abnormal mucus production, and lethargy. Behavioural changes such as gasping at the surface or erratic swimming are also common indicators of infection. When conditions are favourable (typically in warm water) the disease can spread rapidly through a pond or farm. Outbreaks often result in very high mortality rates, frequently between 80% and 100%.

Spring Viremia of Carp (SVC): Spring Viremia of Carp (SVC) is a serious viral disease that primarily affects carp species, including grass carp, silver carp, and common carp, as well as other cyprinids. It is considered one of the most significant viral threats in freshwater aquaculture. Infected fish often exhibit external signs such as hemorrhages on the skin, pale gills, and abdominal swelling (ascites). These symptoms reflect the systemic nature of the infection and the damage it causes to multiple organs. Under favourable conditions, outbreaks of SVC can result in sudden mass die-offs within affected populations. Mortality rates are frequently high, making prevention and early detection critical for managing the disease in aquaculture systems.

Lymphocystis disease: Lymphocystis disease is caused by Lymphocystis disease virus (genus Lymphocystivirus, family Iridoviridae), and it can affect many species of both freshwater and marine fishes. Infected fish develop small, wart-like nodules or growths on the skin, fins, or gills and often described as white, cream or gray cauliflower-like lumps. Though these growths are unsightly, the disease is generally chronic and non-fatal; many fish survive and may even outgrow the lesions. Because there is no specific cure, management focuses on good water quality, reducing stress, and isolating affected fish; often, under favourable conditions, the nodules regress over time.

Treatment and precautionary measures:

Disinfect water, pond bottom and equipment before stocking: Before introducing new fish stock, pond/tank disinfection helps reduce pathogens lingering in water, sediment or on equipment. Chemicals such as burnt lime or chlorinated lime are often used to sanitize pond bottom or empty culture units before refilling.

Treat water or fish with disinfectants /oxidizing agents: Agents like Potassium permanganate ($KMnO_4$) are used as external bactericide, fungicide, and parasiticide — to "burn off" external pathogens from fish surfaces or disinfect water. When used in correct concentration and under proper conditions, such treatments reduce external infections and lower disease risk.

Use approved therapeutic drugs when necessary under expert guidance: Certified antibiotics, copper sulfate, formalin or other approved therapeutics may be used only after proper diagnosis and professional advice. Indiscriminate or repeated use leads to drug resistance, residues in fish flesh and environmental harm. Dose calculation should consider pond area, water volume and biomass.

Ensure adequate aeration and water quality during treatment: Good water quality reduces stress and strengthens the immune system, improving treatment success. Maintain dissolved oxygen levels during chemical use and avoid chemical application when DO is low or during hot afternoons.

Follow correct application procedures and safety precautions: Dissolve chemicals fully before broadcasting to prevent localized toxicity. Stop feeding for 4 to 6 hours after treatment. Do not mix chemicals unless advised by specialists. Always use protective gloves, masks and avoid direct skin contact.

Maintain proper records and environmental responsibility: Document every treatment, including purpose, dose, date and results. Store chemicals safely and dispose containers responsibly to prevent pollution. Use chemicals only when necessary and avoid exceeding recommended limits to protect natural water bodies.

Recommendations:

- Maintain good water quality by monitoring pH, alkalinity, ammonia, and nitrite and dissolved oxygen regularly.
- Stock healthy seed from certified hatcheries and avoid overcrowding.
- Quarantine new fish before adding them to the main culture pond.

- Clean and disinfect ponds, tanks, nets and equipment before stocking.
- Manage feeding properly and avoid overfeeding to reduce waste accumulation.
- Use chemicals and therapeutic agents only when necessary and at recommended doses.
- Strengthen fish immunity by maintaining stable environmental conditions and reducing stress.
- Observe fish daily for early signs of abnormal behaviour or disease symptoms.
- Remove dead or sick fish promptly and dispose safely.
- Maintain strict biosecurity measures to prevent pathogens from entering the farm.
- Seek expert advice and diagnostic support for persistent disease issues.
- Keep detailed records of treatments, water quality and fish health status.

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Chapter 7. Water Quality Management in Aquaculture

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Introduction: Proper monitoring and assessment of water quality are essential to ensure a healthy and productive aquaculture pond. Water quality directly affects fish growth, survival, and overall pond productivity. Systematic monitoring allows farmers to identify problems early, take corrective measures, and maintain an optimal pond environment.

Objectives of Monitoring

The main objectives of water quality monitoring are:

*Assess pond health***:** Determine whether the physical, chemical, and biological conditions are suitable for fish production or not.

Detect changes: Identify harmful fluctuations in water parameters before they cause stress or mortality.

Guide management practices: Provide information for feeding, fertilization, aeration, and water exchange decisions.

Ensure sustainability: Maintain a balanced ecosystem that supports natural food production and long-term pond productivity.

Key Parameters to Monitor

Monitoring should include physical, chemical, and biological parameters.

Physical parameters & Their Management:

Depth: The depth of a pond significantly influences both the physical and chemical characteristics of water. It affects temperature distribution, water circulation patterns, and the extent of photosynthetic activity. In shallow ponds, sunlight can penetrate to the bottom, warming the water and enhancing productivity. However, ponds shallower than one meter may overheat during tropical summers, which can adversely affect the survival of fish and other aquatic organisms. For optimal biological productivity, a pond depth of approximately two meters is generally considered ideal.

Temperature: Water temperature is primarily influenced by climate, sunlight, and pond depth. Seasonal and diurnal fluctuations significantly affect pond productivity, with temperatures generally lowest in the early morning and highest in the afternoon. Tropical ponds often support higher fish yields than temperate ones due to greater heat availability. Temperature also plays a critical role in physiological processes, including breeding, and affects chemical dynamics in water and soil, such as dissolved oxygen levels, which decrease as temperature rises. Fish exhibit varying temperature tolerances, with Indian major carps being eurythermal, capable of surviving across a wide temperature range.

Remedies/correction: Thermal stratification in ponds during summer can be minimized through regular water exchange and by providing shade, either with planted trees or artificial coverings, while mechanical aeration can be used simultaneously to ensure proper oxygen circulation.

Turbidity: Turbidity in water bodies arises from suspended inorganic particles, such as silt and clay, as well as planktonic organisms. Its intensity depends on the nature of the pond basin and the sediments entering the system. Ponds with clayey bottoms typically exhibit higher turbidity, which limits light penetration, reduces photosynthetic activity, and consequently restricts overall biological productivity. Managing turbidity is therefore essential for maintaining optimal pond performance.

Remedies/correction: Turbidity in the pond can be reduced by adding fresh water or applying lime (CaO), alum at a rate of 20 mg/L, or spreading gypsum over the entire pond at a rate of 200 kg per 1,000 m^3 of water.

Light: Light is a critical physical factor influencing pond productivity. The availability of light energy affects photosynthesis and overall biological activity in the pond. Light penetration is largely determined by turbidity, which reflects the combined effects of suspended clay and silt particles as well as the density and distribution of planktonic organisms. Accurate assessment of light penetration is essential for evaluating and managing pond productivity.

Chemical parameters:

pH: The pH of water is measured as the negative logarithm of the hydrogen ion concentration. The presence of carbon dioxide, an acidic gas, significantly influences the pH of natural water bodies (Boyd, 1979). The normal blood pH of fish is around 7.4, but a slightly broader range of 7.0 to 8.5 is considered ideal for optimal growth and reproduction. Fish may experience stress in water with a pH of 4.0 to 6.5 or 9.0 to 11.0, and mortality becomes likely if the pH falls below 4.0 or exceeds 11.0.

Remedies/correction: To lower high pH levels in a pond, gypsum ($CaSO_4$), organic materials such as cow dung or poultry droppings can be applied. Conversely, quicklime (CaO) can be used to raise the pH if it is too low in the aquatic environment.

Dissolved oxygen (DO): Dissolved oxygen (DO) refers to the amount of oxygen gas present in water that is available for aquatic organisms. It is a critical factor for fish survival, growth, and metabolic processes. Fish extract oxygen from water through their gills, and inadequate oxygen levels can lead to stress, reduced feeding, slower growth, and even mortality. For most freshwater species, the optimal DO concentration ranges from 5 to 9 mg/L, supporting healthy growth and physiological functions. When DO levels drop below 3 mg/L, fish begin to experience stress, and their normal metabolic activities are affected. At critically low levels, below 1 to 2 mg/L, the risk of mass fish mortality becomes high, making the maintenance of adequate dissolved oxygen essential in aquaculture systems. The concentration of dissolved oxygen in water is influenced by several factors. Temperature plays a key role, as colder water can hold more oxygen than warmer water. Photosynthetic activity by aquatic plants and algae also contributes to oxygen levels, releasing oxygen during daylight hours. Conversely, respiration by fish and microorganisms, as well as the decomposition of organic matter, consumes oxygen and can reduce its concentration. Water movement, such as currents, waterfalls, or artificial aeration, helps increase oxygen levels by promoting gas exchange between the water and the atmosphere.

Remedies/correction: To maintain optimal water quality in aquaculture ponds, it is important to limit the use of fertilizers and organic manures to prevent oxygen depletion. Aquatic plants should be controlled physically, and phytoplankton growth managed to maintain balanced dissolved oxygen (DO) levels. Recycling pond water and using aerators can improve circulation and oxygenation, while manual or mechanical stirring of the water further enhances oxygen distribution. Overstocking of fish should be avoided to reduce stress and maintain healthy water conditions. Additionally, if DO levels become excessively high, warm water can be gradually introduced through pipes to stabilize the pond environment.

Carbon dioxide: The primary source of carbon in aquatic ecosystems is free carbon dioxide, a highly soluble gas in water. It is produced mainly through the respiratory activities of animals and can exist in water in the form of bicarbonates or carbonates, derived from natural sources such as the earth's crust, limestone, and coral reefs. When carbon dioxide dissolves in water, it forms carbonic acid, which lowers the pH of the system, particularly in waters with low buffering capacity. This reduction in pH can be harmful to aquatic organisms, affecting their growth, reproduction, and overall health.

Remedies/correction: Proper aeration is an effective method to release excess dissolved gases from pond water. This helps prevent gas-related stress in fish and maintains a healthy aquatic environment. Chemical additives such as lime ($CaCO_3$) or sodium bicarbonate ($NaHCO_3$) can be applied to stabilize pH levels and improve overall pond conditions, ensuring a suitable environment for fish growth.

***Salinity*:** Salinity is a vital chemical parameter in aquaculture, as it significantly influences the health, growth, and survival of aquatic organisms. Different species have specific tolerance ranges to salinity, making it essential to maintain suitable conditions depending on the type of aquaculture system. For instance, freshwater species such as tilapia, catfish, and carp thrive in water with very low salinity typically less than 0.5 ppt. These environments include rivers, lakes, ponds, reservoirs, and other inland water bodies. In contrast, coastal or brackish water systems have moderate salinity levels, ranging from 0.5 to 30 ppt. These areas such as estuaries, mangroves, and tidal zones represent a mix of freshwater and seawater, supporting species like shrimp, milkfish, and various mangrove-associated organisms. Brackish water aquaculture is common in these regions due to the adaptability of certain species to fluctuating salinity levels. Marine water environments, such as oceans and seas, have high salinity usually around 35 ppt. These systems are home to marine species like sea bass, grouper, and marine algae, which are well adapted to salty conditions. Marine aquaculture in these waters is used for fish farming, shellfish cultivation, and even salt production. Maintaining optimal salinity is crucial for the osmoregulation of aquatic organisms, which affects their metabolism, immune function, and overall well-being. Rapid or extreme changes in salinity, often caused by evaporation, rainfall, or improper water exchange practices, can stress aquatic species and lead to reduced growth or mortality.

Remedies/correction: Salinity in the pond can be managed by either increasing it or diluting it through the replenishment of fresh water, depending on the requirements of the cultured species. In addition, aeration is essential to evenly distribute salinity throughout the water column, ensuring a balanced environment and reducing stress on the fish.

Alkalinity: Alkalinity is the measure of water's ability to resist changes in pH, acting as a natural buffer that helps maintain stable water conditions. It is mainly made up of dissolved substances such as carbonates, bicarbonates, hydroxides, phosphates, borates, calcium, and magnesium. In aquaculture, proper alkalinity is crucial for fish health, as it prevents sudden pH fluctuations that can stress or harm aquatic organisms. The ideal alkalinity range for fish culture is 50–300 mg/L. If alkalinity is too low, even a small amount of acid can significantly lower the pH, leading to an unstable environment. Alkalinity can increase naturally through lime leaching from concrete ponds or rocks, plant photosynthesis, and processes like denitrification and sulphate reduction. It can decrease due to respiration, nitrification, and sulphide oxidation. Small increases may also result from evaporation and organic matter decomposition. Regular monitoring and management of alkalinity help maintain water quality, ensuring a healthy and productive aquaculture system.

Remedies/correction: Alkalinity can be increased using calcium carbonate, concrete blocks, oyster shells, limestone, or eggshells, depending on soil pH and buffering capacity.

Hardness: Hardness is an important chemical parameter of water quality, especially in aquaculture and freshwater systems. It refers to the concentration of divalent metal ions in the water, mainly calcium (Ca^{2+}) and magnesium (Mg^{2+}). These minerals are naturally present in rocks and soil and dissolve into water as it moves through the environment. Hardness is typically measured in milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$). Based on concentration, water is classified as: Soft: 0–75 mg/L, moderately hard: 75–150 mg/L, Hard: 150–300 mg/L and Very hard: >300 mg/L.

In aquaculture, the ideal hardness range is 75–250 mg/L. Calcium and magnesium are essential for fish physiology, including bone development, enzyme activity, and osmoregulation. Proper hardness also supports the health of crustaceans like shrimp, which need calcium for shell formation.

Remedies/correction: Quicklime, alum, or a combination of both increases water hardness, whereas the addition of zeolite helps reduce it in the pond.

Ammonia: Ammonia is a crucial water quality parameter in aquaculture and aquatic environments because it directly affects the health of aquatic organisms. It primarily originates from fish excretion, the breakdown of uneaten feed, and decomposing organic matter. In water, ammonia exists in two forms: un-ionized ammonia (NH_3), which is highly toxic to fish, and ionized ammonia (NH_4^+), which is much less harmful. The total amount of both forms is known as Total Ammonia Nitrogen (TAN). The proportion of toxic un-ionized ammonia increases with higher pH and temperature, making water conditions more dangerous for fish. For healthy aquaculture practices, the concentration of un-ionized ammonia should be kept below 0.02 mg/L to prevent harmful effects such as gill damage, slowed growth, weakened immune response, and even mortality. Elevated ammonia levels often occur in poorly managed systems with inadequate water exchange, overfeeding, or overstocking.

Remedies/correction: The addition of liming agents, such as hydrated lime or quicklime, can help reduce ammonia levels, although this technique is effective only in ponds with low alkalinity. In addition, Formaldehyde and zeolite treatments can also be used to bind ammonia chemically. For example, a dosage of 50 ml per 100 gallons can bind up to 1 ppm of ammonia, but it is important to follow the manufacturer's instructions carefully. Furthermore, Regular water changes are recommended to maintain water quality and reduce the accumulation of harmful substances.

Nitrite: Nitrite is an intermediate compound formed during the aerobic nitrification process by autotrophic bacteria called Nitrosomonas, which convert ammonia into nitrite by combining it with oxygen. This process is a crucial step in the nitrogen cycle within aquatic systems. Nitrite is often referred to as the "invisible killer" of fish because it interferes with oxygen transport in their blood. It oxidizes hemoglobin to methemoglobin, causing the blood and gills to turn brown, which impairs respiration. Additionally, nitrite exposure can cause damage to vital organs such as the nervous system, liver, spleen, and kidneys in fish. The ideal concentration of nitrite in any aquatic environment is essentially zero. Generally, nitrite levels between 0 and 1 mg/L are considered desirable, with concentrations below 4 mg/L regarded as acceptable.

Remedies/correction: Nitrite levels can be reduced by following proper management, chemical, and biological measures. First, maintain good husbandry: reduce stocking densities, improve feeding practices, ensure effective biological filtration, increase aeration, and temporarily stop feeding if necessary. Chemical measures include adding small amounts of chloride salts and performing regular water changes to dilute nitrite and protect fish. Biological methods, such as using bio fertilizers, help accelerate nitrification, converting nitrite into less harmful nitrate. Combining these approaches keeps the system safe and healthy for aquatic animals.

Nitrate: Nitrate is the most stable and oxidized form of nitrogen found in aquatic environments. It originates mainly from the oxidation of nitrite and the decomposition of organic matter, including uneaten feed and fish waste. While nitrate is less toxic to fish compared to ammonia and nitrite, excessive accumulation can still be harmful over time, leading to poor growth and stress in aquatic organisms. Nitrate levels also influence the productivity of ponds by promoting the growth of phytoplankton and aquatic plants. However, high concentrations can cause eutrophication, resulting in oxygen depletion and imbalance in the aquatic ecosystem. Regular monitoring and maintaining nitrate levels below 50 mg/L are generally recommended for most aquaculture systems.

Remedies/correction: Nitrate concentration can be reduced by periodic water exchange with low-nitrate water, application of ion-exchange resins, and increasing aquatic plant biomass to enhance uptake. Denitrifying biofilters can further convert nitrate into nitrogen gas, effectively lowering its accumulation in the system.

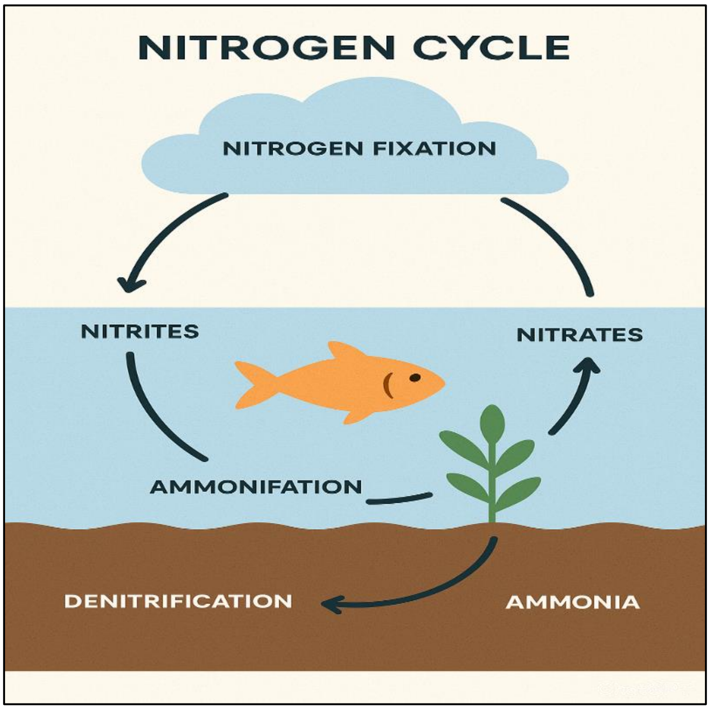

Fig1: Nitrogen Cycle in freshwater pond

Chloride: Chloride is an important water quality parameter that helps maintain the osmotic balance in fish and aquatic organisms. It is usually present in water as sodium chloride (NaCl) and other salts. Moderate chloride levels can reduce the toxicity of harmful substances like nitrite and nitrate.

Phosphorus: Phosphorus in water is primarily found in the form of phosphate (PO_4^{3-}), either dissolved or attached to organic and inorganic particles. As an essential nutrient, phosphorus supports the growth of aquatic plants and algae, thereby enhancing pond productivity. Low phosphorus levels result in poor biological activity, while adequate concentrations promote healthy plankton development and overall pond fertility. In aquaculture systems, a phosphate level of about 0.05 to 0.07 mg/L is considered ideal for maintaining balanced and productive ecosystems.

Remedies/correction: Chlorine in water should be minimized, as it is toxic to fish and other aquatic organisms. Residual chlorine can be removed by dechlorination using sodium thiosulfate or allowing water to stand in sunlight for a few hours before use. Continuous monitoring of chlorine levels is important, especially when using treated municipal water. Phosphorus levels should be managed to prevent excessive algal growth and water quality deterioration. This can be done by controlling feed input, avoiding overfeeding, and using feed with balanced nutrient content. Aquatic plants and sediment management can also help absorb excess phosphorus, maintaining a healthy aquatic environment.

Biological parameters:

Plankton: Plankton are aquatic organisms that drift with water currents rather than swim actively. They are classified into phytoplankton (plant plankton) and zooplankton (animal plankton), both serving as primary food sources for fish. Plankton abundance is closely linked to fish production, as they form the base of the aquatic food web. However, excessive plankton growth, particularly from blue-green algae, can lead to dense surface blooms. These blooms block sunlight, reduce oxygen levels, and create anoxic conditions in deeper water, often resulting in fish mortality.

Primary Productivity: Primary productivity in an aquaculture pond refers to the rate at which photosynthetic organisms mainly phytoplankton and aquatic plants produce organic matter (food) from inorganic substances using sunlight, carbon dioxide, and nutrients. It forms the foundation of the pond's food web, supporting zooplankton, benthic organisms, and ultimately fish. In simple terms, primary productivity measures how much natural food is generated in the pond ecosystem. High primary productivity indicates good nutrient availability and favourable environmental conditions, while very low or excessively high productivity can signal poor water quality or imbalance (such as algal bloom).

Remedies/correction: Maintaining balanced plankton populations is essential for healthy primary productivity in aquaculture systems. Imbalances, such as algal blooms or low plankton density, can be corrected using several remedies. Applying bio fertilizers or organic manures promotes the growth of beneficial phytoplankton, which serves as natural food for fish and shrimp larvae. In cases of excessive algal growth, controlled water exchange, shading, or using algicides in safe doses can help restore balance. Regular monitoring of water quality parameters, such as nutrient levels and light availability, also supports optimal primary productivity and a stable aquatic ecosystem.

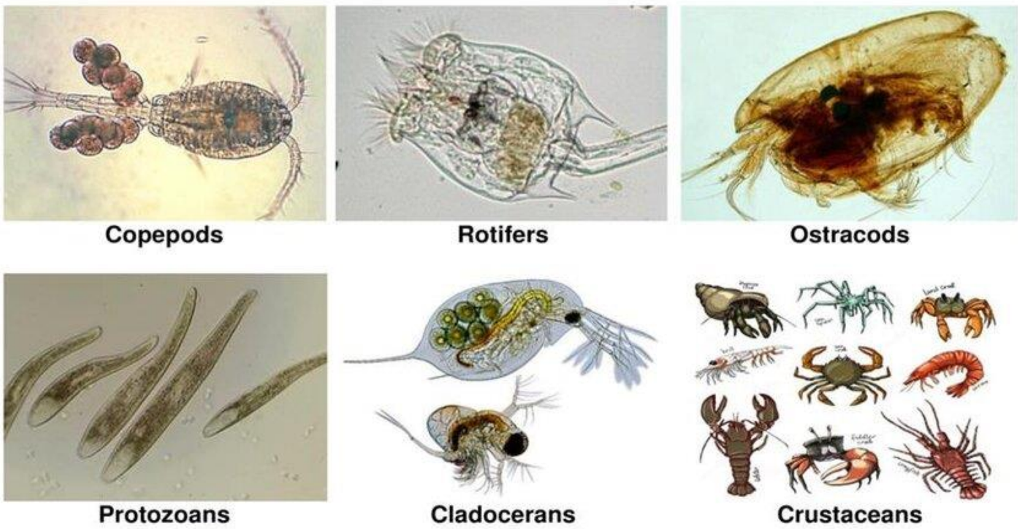

Fig 2: Plankton abundance in water bodies

Assessment Techniques for Water Quality

Effective assessment of water quality is essential for maintaining a healthy aquatic environment. It involves a combination of sampling, testing, analysis, and documentation to ensure timely detection of potential problems and support informed management decisions.

Regular Sampling: Regular sampling of water is the foundation of water quality assessment. Water should be collected from multiple points within the pond, tank, or water body, including different depths and locations. This ensures that the data accurately represents the overall condition of the environment rather than just a single spot. Sampling frequency can vary depending on the species being cultured and the stage of growth, but weekly checks are generally recommended for intensive aquaculture systems.

Field Testing Kits: Field testing kits provide a quick and convenient way to measure key water quality parameters on-site. Parameters such as pH, dissolved oxygen (DO), ammonia, and nitrite can be tested easily using portable kits. These kits allow for immediate detection of potential issues, enabling quick interventions such as water exchange, aeration, or the addition of corrective treatments. Regular use of field kits helps in monitoring trends and maintaining conditions within optimal ranges.

Laboratory Analysis: For a more detailed and accurate assessment, samples can be sent to specialized laboratories. Laboratory analysis provides precise measurements of chemical and microbiological parameters, including hardness, alkalinity, total nitrogen, phosphates, and harmful bacteria. These results offer a deeper understanding of water quality, helping to identify subtle changes or potential risks that may not be evident through field testing alone. Laboratory testing is particularly useful for diagnosing disease outbreaks or investigating unexplained mortality in aquaculture systems.

Data Recording and Trend Analysis: Maintaining systematic records of water quality data is crucial for effective management. All measurements, whether from field kits or laboratory analysis, should be logged with the date, time, location, and depth of sampling. Over time, this record allows for trend analysis, helping to identify seasonal changes, recurring problems, or the effects of management practices. Data recording also supports decision-making, ensuring that interventions such as water treatment, aeration, or stocking adjustments are based on objective information rather than guesswork.

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Chapter 8. Correct Dose, Frequency and Method of Lime, Potassium permanganate and probiotics use in Fish Ponds

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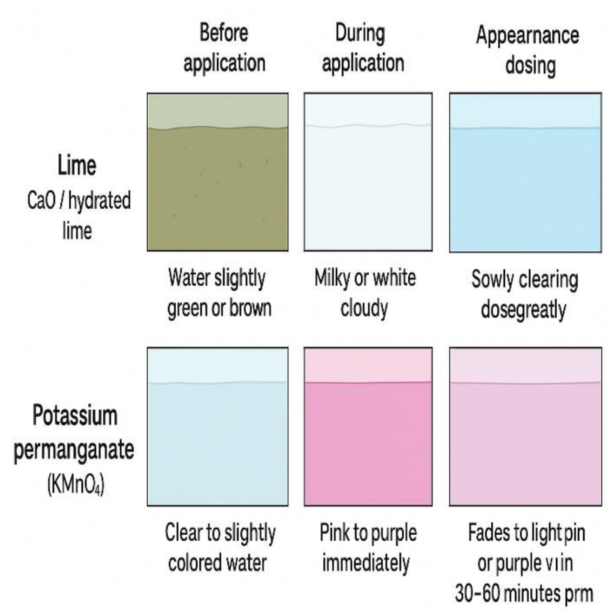
CHEMICAL & PROBIOTIC DOSE REFERENCE FOR FISH PONDS

POND AREA	DEPTH	QUICK LIME (CaO)	SLAKED LIME $(Ca(OH)_2$	POTASSIUM PERMANGANATE $(KMnO_4)$
500 m²	10–25 kg	10–15 kg	7.5–12.5 kg	0.1–0.25
1000 m²	20–50 kg	20–30 kg	15–25 kg	0.2–0.5
2000 m²	40–100 kg	40–60 kg	30–50 kg	0.4–1 kg
5000 m²	100–250 kg	100–150 kg	75–125 kg	10–25 kg
1 ha	200–500 kg	200–300 kg	150–250 kg	2–5 kg

Key Guidelines for Farmers

- **Depth Adjustment:** If pond depth more or less than 1 m, adjust $KMnO_4$ dose proportionally
- **Application Method:** Lime: Spread evenly on dry pond bottom or dissolve in water before application
- **$KMnO_4$:** Dissolve in water and broadcast evenly: use gloves
- **Probjotics:** Mix with water for broadcasting or with feed
- **Safety First:** Always wear protective gloves and masks whenaniling chemicals
- **Monitoring:** Observe water quality and fish behavior after each treatment
- **Record Keeping:** Maintain records of doses, dates, and observations



Chemical / Product	Purpose	Dose for 1000 m² Pond	Frequency / Timing
Lime (CaO / $Ca(OH)_2$	Correct pH, improve soil, reduce toxicity	100–200 kg	Before stocking; repeat every 3-4 weeks or after partial harvest
Potassium Permanganate $(KMnO_4)$	Disinfect water, control pathogens	1–3 g per 1000 L of pond water	Before stocking; also as needed during culture if disease appears
Probiotics	Improve water quality, reduce organic waste, enhance fish heal	10–20 g per 1000 L of pond water	Once or twice a week; increase if water quality deteriorates

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Chapter 9. Post-Harvest Management in Aquaculture — Safe Chemical Handling & Fish Quality

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Introduction: Post-harvest management is a critical stage in aquaculture that directly affects the safety, freshness, and market value of the final product. Because fish have high moisture content and nutrient-rich flesh, they are highly perishable and encourage rapid microbial growth. Improper handling after the harvest leads to spoilage, reduced nutritional value, and significant economic losses. Implementing effective practices ensures that fish reaching consumers is safe, fresh, and of high quality, ultimately reducing losses and increasing profitability.

Harvesting and On-Farm Handling: The journey to maintaining fish quality begins immediately at the harvest site. Gentle handling is crucial, as rough handling can damage flesh and accelerate deterioration. Avoid excessive dropping, dragging, or stacking of fish.

Key Harvesting Practices: Harvesting fish should be carried out during the cooler parts of the day, such as early morning or late evening, to minimize stress on the fish and slow down spoilage. Maintaining proper hygiene at the source is crucial; all nets, boats, and containers used during harvesting must be clean to prevent contamination. Immediately after harvest, fish should be thoroughly washed with clean, potable water to remove slime, blood, and dirt, ensuring better quality and freshness for storage or sale.

Preservation method: Rapid chilling is a critical step in preserving fish quality after harvest. Immediately after washing, fish should be iced using crushed ice to slow down microbial growth and enzymatic spoilage. The recommended ratio is one part ice to one part fish, ensuring effective cooling throughout. Iced fish should then be stored in insulated containers or refrigerated trucks, maintaining a temperature between 0–4°C, to preserve freshness and extend shelf life until processing or sale.

Chemical Use in Post-Harvest Operations: Certain chemicals can be used for sanitation and quality preservation, but they must be applied safely and legally.

Chemicals	**Purpose**	**Recommended Dose**	**Notes / Precaution**
Chlorine	Sanitizing water & surfaces	5 to 10 ppm	Rinse with potable water
Sodium metabisulfite	Prevent black spot in shrimp	1 to 1.25% dip	Monitor residue limit
Food-grade detergent	Cleaning utensils & surfaces	As per label	Avoid residue
Ice with salt	Rapid chilling	1:1 Ice: fish	Use potable water ice

Note: Certain chemicals should never be used in fish handling or preservation due to their harmful effects on human health and fish quality. These include formalin or formaldehyde, borax, ammonia, and bleaching powder. Antibiotics should never be applied without proper veterinary prescription, and non-food-grade preservatives or colorants must be strictly avoided. Using such substances can contaminate the fish, pose serious health risks, and violate food safety regulations.

Safe handling tips/Recommendation: For safe handling of chemicals in aquaculture, it is important to store all chemicals in a secure, clearly labeled area, separate from food items to prevent accidental contamination. Protective equipment such as gloves, masks, and goggles should be worn during handling to reduce exposure risks. Maintaining a detailed chemical log, including the date, batch, quantity, and purpose of use, helps ensure proper record-keeping and accountability. Additionally, always follow the correct dilution procedures and the manufacturer's instructions to ensure safe and effective application.

Hygienic Handling, Processing, and Storage: Hygiene is key to maintaining fish quality after harvest. Processing areas should be clean, dry, and pest-free. Workers must maintain personal hygiene and wear clean uniforms, gloves, and hair covers. Stainless steel surfaces and knives are preferred, while wooden surfaces should be avoided. Only potable water should be used for washing, icing, and cleaning equipment.

Packaging and transport: During packaging and transport, fish should be packed using food-grade materials such as HDPE or LDPE bags, or insulated boxes to ensure safety and maintain quality. Each package should be clearly labeled with the harvest date, species, weight, and source to facilitate traceability. It is essential to maintain the cold chain throughout transportation and storage: fresh chilled fish should be kept at 0–4°C, while frozen fish must be -18°C.

Fish Quality Assessment: Fresh fish should show clear, bulging eyes and shiny skin with tightly-attached scales. The flesh ought to feel firm and bounce back when pressed — not stay indented. Good-quality fish also has red or pink gills and gives a mild sea-like smell rather than a strong "fishy" or ammonia odour. If you notice sunken or cloudy eyes, dull or discoloured skin, soft flesh or sticky slime, and a foul or sour odour that usually signals spoilage. To extend shelf life and increase market value, fish can be processed into fillets or steaks, quick-frozen (IQF), or converted into value-added products like smoked, dried, pickled or marinated fish. These methods help slowly down spoilage from bacterial, enzymatic or oxidative activity, making the fish more transportable and giving it longer storage life.

Record Keeping and Traceability:

Maintaining proper records ensures transparency and market confidence. Documentation should include:

- Harvest dates and pond sources
- Chemical usage and residue monitoring
- Ice usage and storage temperatures
- Processing, packaging, and transport details

Traceability is increasingly required for domestic and export markets and supports consumer safety.

Conclusion

Post-harvest management is essential to ensure fish reaching consumers is safe, fresh, and high-quality. Effective practices include timely harvest, rapid chilling, hygienic handling, responsible chemical use, cold chain maintenance, and proper record keeping. Implementing these practices reduces losses, increases profitability, and ensures sustainable aquaculture.

Post-Harvest Management in Aquaculture

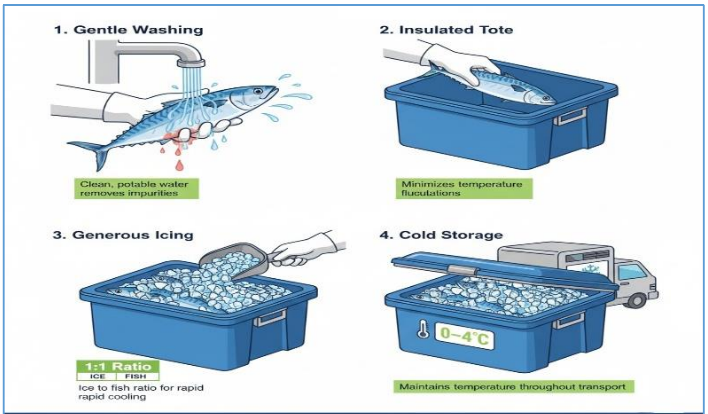


Figure 1: The Rapid Chilling Process – Essential for Fish Quality

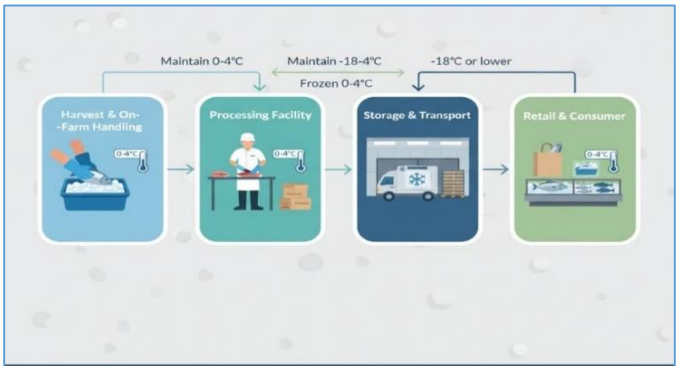
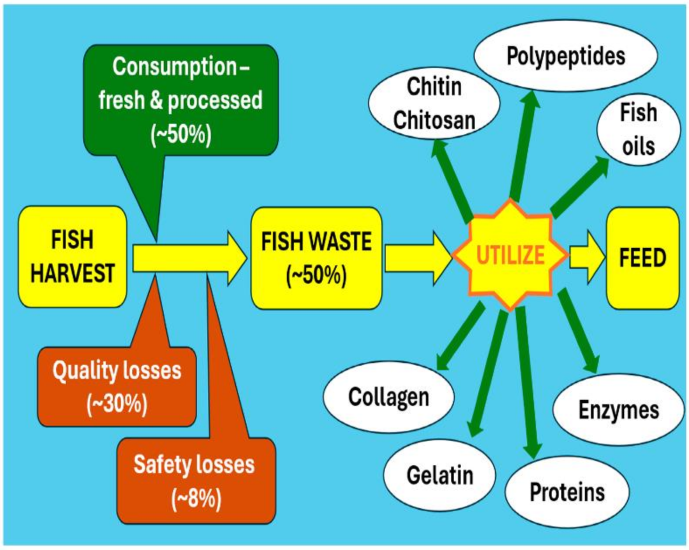


Figure 2: Cold Chain Maintenance

Maintain the cold chain throughout transportation and storage to prevent spologe.



Chapter 10. Use of Feed Additives and Growth Promoters in Aquaculture

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Introduction: In aquaculture, feed accounts for the highest share of production cost, often contributing 50 to 70 percent of the total operational expense. Because of this, improving feed efficiency and growth performance is critical for profitability. Feed additives and growth promoters are added to aqua feeds in small quantities to enhance digestibility, stimulate appetite, improve gut health, strengthen immunity and support overall physiological development. Their use has become increasingly important as farming systems intensify and stocking densities rise, creating a higher risk of stress and disease. Healthy fish convert feed efficiently and grow faster, while stressed or unhealthy fish require more feed and are more vulnerable to infection. Additives help maintain biological balance within the digestive system and create conditions that allow fish to utilize nutrients optimally. Many additives also reduce waste discharge into ponds, improving water quality and reducing the likelihood of disease outbreaks. This supports sustainable and eco-friendly farming. The modern approach to fish farming encourages reducing dependency on antibiotics and chemical treatments. Natural additives such as probiotics, prebiotics, enzymes, herbal extracts and organic acids offer safer long-term solutions by boosting immunity and enhancing resistance to disease without leaving harmful residues. Their responsible use aligns with market regulations, export requirements and consumer demand for safe and high-quality aquaculture products. Feed additives and growth promoters are valuable tools, but they must be selected carefully, based on species, culture environment and production goals. Using them blindly or without understanding their function can increase costs and reduce benefits. When used correctly and combined with good management practices, they contribute significantly to improved survival, faster growth, reduced disease risks and better farm profitability.

Feed additives:

Binders: They are feed additives used to improve water stability of pellets. They help the feed hold its shape after entering the water, reducing disintegration and minimizing nutrient loss through leaching. Good water stability ensures that fish have enough time to consume the feed and improves feed utilization efficiency. Gelatinized starch from sources like tapioca, wheat flour and rice flour works well as natural binders in most aquaculture feeds. They create a firm structure in the pellet, enhance texture and help maintain pellet integrity in water. This supports better water quality and reduces waste in the pond environment. Typically inclusion levels range from 3 to 8 percent in most of the commercial formulations.

Antioxidants: Generally they are added to fish feed to protect fatty acids and other oxidizable nutrients from rancidity, maintaining feed quality and shelf life. Common synthetic antioxidants include ethoxyquin (0.015%) and BHA or BHT (0.2% each). They prevent lipid oxidation, preserve essential nutrients, and improve palatability. Vitamin E, a natural antioxidant, also protects feed while providing nutritional benefits and supporting fish health.

Chemo-attractants and feeding stimulants: They are added to fish feed to attract and encourage fish to consume the feed. Free amino acids and nucleotides are commonly used as stimulants to enhance feed intake. Ingredients like squid, shrimp, clam, mussel, and polychaetes are also effective in stimulating feeding behavior. These additives improve feed acceptance and help ensure better growth and feed utilization.

Growth Promoters: Other potential growth-promoting additives in aquaculture feeds include hormones such as thyroxine, insulin, triiodothyronine, growth hormone, and recombinant bovine somatotropin. Certain antibiotics, like terramycin, have been used to enhance growth in carp. Glucosamine has been reported to improve growth in crustaceans, while enzymes such as papain and other amylolytic and proteolytic enzymes aid digestion and nutrient utilization. Commercial products like Nitrovine (trade name Payzone), which contain growth-promoting compounds, have also been shown to accelerate growth in cultured species.

Vitamins and minerals: They are essential feed additives in aquaculture that ensure balanced nutrition, support metabolic functions, enhance immunity, and promote proper bone and tissue development. Including the right levels of vitamins (such as A, D, E, and C) and minerals (like calcium, phosphorus, zinc, and selenium) helps maintain overall health, improves growth performance, and reduces susceptibility to diseases in cultured fish.

Probiotics and immunostimulants: They are added to fish feed to enhance gut health, improve digestion, and strengthen the immune system. By promoting a balanced intestinal micro flora, they increase nutrient absorption, support growth, and help fish resist infections, contributing to overall health and better survival in aquaculture systems.

Colour enhancers: They are feed additives used to improve the natural coloration of ornamental and edible fish. Pigments like carotenoids are commonly included to intensify skin, flesh, and fin colours, making the fish more attractive and marketable while supporting overall health.

General guidelines:

- Always follow recommended doses specified by feed manufacturers or regulatory authorities.
- Combine additives carefully; some may interact or reduce effectiveness.
- Store additives in a cool, dry place to preserve activity.
- Monitor fish response regularly and adjust as needed.
- Use additives as part of an integrated aquaculture management strategy including water quality management and disease prevention.

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