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Water Quality Requirements for Biofloc Based Aquaculture Systems

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SUMMARY

Biofloc Technology has been shown to be cost-effective and sustainable in water quality improvement and intensification productivity of aquaculture production. This article accentuates the relevance of water quality management as being the key to success for biofloc-based aquaculture, with emphasis on heterotrophic microbial conversion of nitrogenous waste to biofloc biomass. The most important physicochemical parameters like temperature (28–30°C), dissolved oxygen (>7 ppm), pH (7.0–8.5), alkalinity (100–150 ppm as $CaCO_3$), total ammonia nitrogen (<1.5 ppm), nitrite (<2 ppm), and nitrate (<10 ppm) are thoroughly discussed, including ideal limits for suspended solids and turbidity. Microbial species which have an important role in floc formation and nitrogen cycling like Nitrosomonas, Bacillus spp., and Rhodobacter are mentioned. Interest lies in nitrogen removal processes including heterotrophic assimilation and nitrification. The best water quality parameters are supplied by BFT, hence achieving maximum microbial efficiency, lowering feed cost, reducing water exchange, and enhancing animal health. The results highlight the necessity of monitoring and parameter control continuously for establishing the aquaculture systems with bioflocs as successful ventures.

INTRODUCTION

Aquaculture, particularly intensive systems like shrimp and tilapia farming, has evolved significantly with the need to balance **high productivity and environmental sustainability**. One of the major challenges in aquaculture is the **accumulation of toxic nitrogenous waste**, mainly ammonia, resulting from uneaten feed, feces, and excretory products of aquatic organisms. In traditional systems, frequent water exchange is used to mitigate this problem, but this method raises concerns regarding biosecurity, water scarcity, and pollution of surrounding ecosystems.

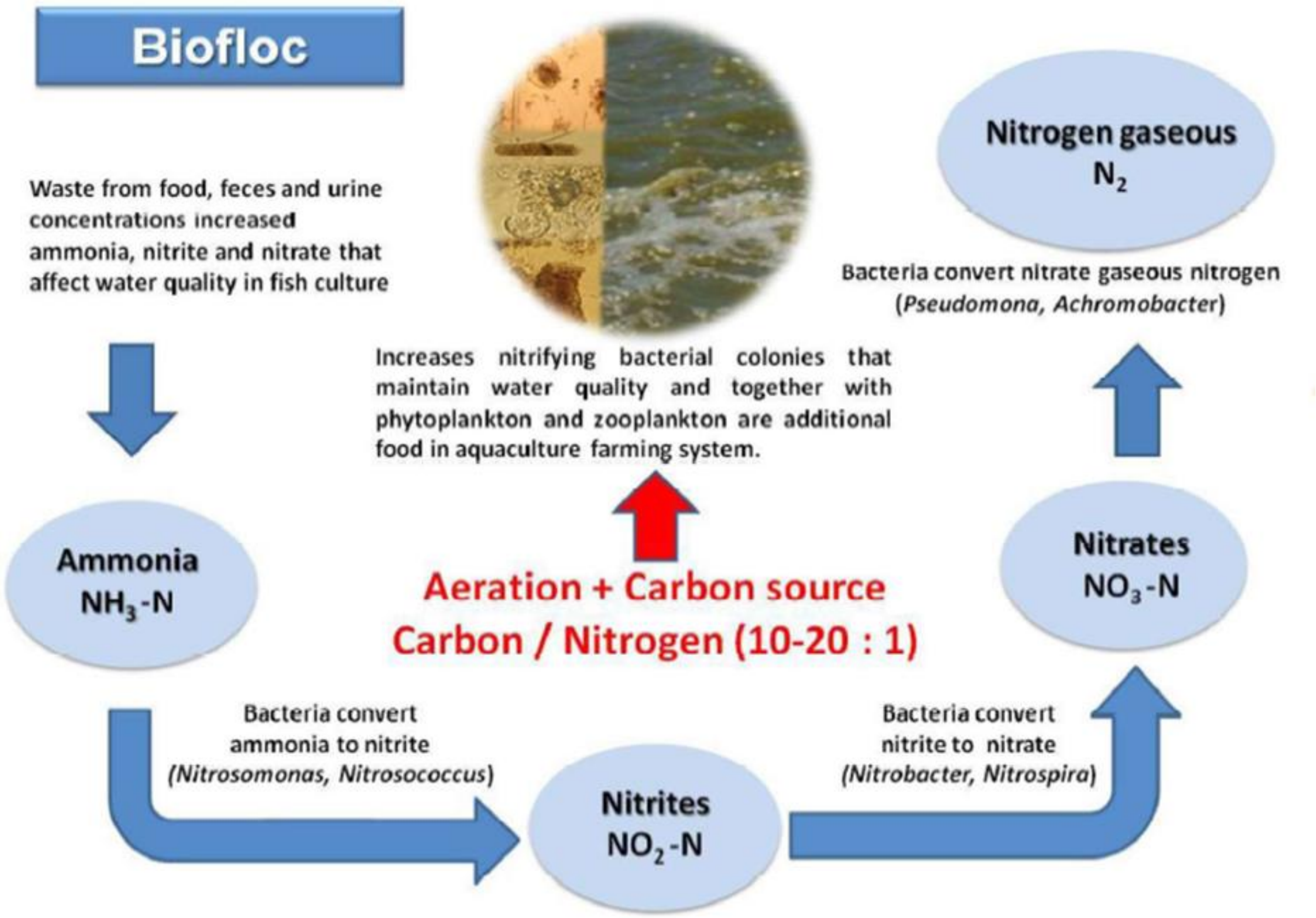

Figure 1: Biofloc development process

Biofloc Technology (BFT) offers a promising alternative by maintaining water quality through **biological waste recycling**. It supports high-density aquaculture while minimizing water exchange. Central to the success of BFT is the careful **monitoring and regulation of water quality parameters**, which directly affect microbial processes, animal health, and production efficiency.

Principle of Biofloc Technology

Biofloc technology works on the principle of **heterotrophic microbial conversion of nitrogenous waste** into microbial biomass (biofloc). The system promotes the growth of **heterotrophic bacteria** by adding a carbon source (e.g., molasses or starch) to adjust the **carbon-to-nitrogen (C:N) ratio**. This accelerates bacterial assimilation of ammonia and nitrite, reducing their toxic concentrations and creating microbial aggregates that serve as a **nutritious feed supplement** for cultured species.

The performance and efficiency of a biofloc system are highly dependent on **specific water quality parameters**, which must be closely monitored and managed. Maintaining optimal water quality is paramount for successful biofloc culture, as it directly impacts the health, growth, and survival of the cultured species, as well as the efficiency of the biofloc system itself.

Biofloc Technology (BFT) utilizes a controlled microbial community to maintain water quality in aquaculture systems. It works by converting excess nitrogen (primarily from uneaten feed and fish waste) into microbial biomass, which then serves as a supplemental feed source for the cultured species. This process reduces the need for water exchange, lowers feed costs, and improves overall water quality.

Bacteria Required for Bio-Floc Process

1. *Nitrosomonas*
2. *Nitrobacter*
3. *Bacillus subtilis*
4. *Bacillus licheniformis*
5. *Rhodococcus*
6. *Rhodobacter*
7. *Bacillus sps*
8. *Pseudococcus*

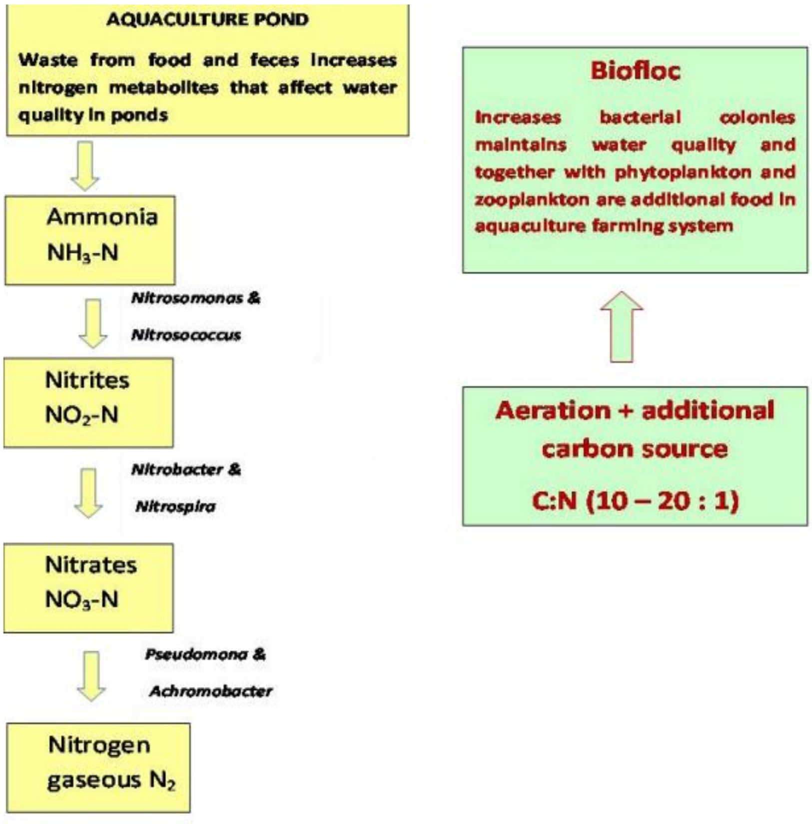

Figure 2 : Biological processes in biofloc system to improve water quality

2. Water Quality Parameters in Biofloc Systems

Temperature

Temperature significantly influences **metabolic activity**, microbial growth, and chemical equilibria in water. It affects the rate of nitrogen transformation processes such as **ammonification, nitrification**, and **photosynthesis**.

- **Optimum temperature for BFT**: 28°C to 30°C
- Nitrifying bacteria function between 8°C and 30°C.
- Efficiency drops by **50% at 16°C** and **80% at 10°C**.

Maintaining optimal temperature enhances microbial activity, promotes feed conversion, and supports better immune responses in cultured organisms.

Dissolved Oxygen (DO)

Dissolved oxygen is vital for the respiration of both the cultured species and the microbial community in biofloc systems. Oxygen is consumed rapidly due to microbial activity and biological oxidation of nitrogen compounds.

- **Minimum DO requirement**: > 5 ppm
- **Ideal range**: 7–8 ppm to support high microbial and animal metabolism

Low DO levels can lead to stress, poor growth, and increased mortality. Therefore, **continuous aeration** is essential in BFT to maintain adequate oxygenation.

pH

The pH of water affects **ammonia toxicity**, microbial metabolism, and nutrient solubility. In BFT, pH tends to decline due to the consumption of alkalinity during microbial conversion of ammonia to nitrate (nitrification).

- **Ideal pH range**: 7.0 to 8.5
- pH should be stabilized using **buffering agents** like **hydrated lime [$Ca(OH)_2$]** or **sodium bicarbonate**.

Prolonged exposure to pH levels below 7 can impair shrimp growth and microbial efficiency.

Alkalinity

Alkalinity refers to the water's ability to **buffer pH changes**. It is essential for maintaining stable pH in biofloc systems due to continuous acid production during microbial activities.

- **Recommended alkalinity**: 100–150 ppm as $CaCO_3$
- Supplementation: **0.25 kg of sodium bicarbonate per kg of feed**

A drop in alkalinity can hinder nitrifying bacteria, leading to ammonia buildup and reduced feed intake.

Total Ammonia Nitrogen (TAN)

Ammonia exists in water as **NH_3 (toxic unionized form)** and **NH_4^+ (less toxic ionized form)**. The proportion of toxic NH_3 increases with **rising temperature and pH**. Controlling TAN is one of the primary goals of BFT.

- **Ideal TAN concentration**: < 1.5 ppm
- For *Litopenaeus vannamei* (whiteleg shrimp):
  - Post-larvae: < 1.2 ppm
  - Juveniles: < 6.5 ppm

Excessive TAN affects gill function, blood chemistry, and growth performance.

Nitrite-Nitrogen (NO_2^--N)

Nitrite, an intermediate in nitrification, is toxic as it interferes with **oxygen transport** in aquatic animals (similar to methemoglobinemia in fish).

- **Safe concentration**: < 2 ppm
- Nitrite toxicity increases at low chloride levels and low oxygen availability.

Proper carbon management and biofloc activity can keep nitrite levels under control.

Nitrate-Nitrogen (NO_3^--N)

Nitrate is the **end product of aerobic nitrification** and is generally less toxic than ammonia and nitrite. However, in closed systems like BFT, nitrate can accumulate and cause **osmotic stress** if not regulated.

- **Recommended limit**: < 10 ppm

Partial water exchange or denitrifying bacteria can help in controlling nitrate buildup.

Suspended Solids (TSS) and Settleable Solids

Suspended solids provide surface area for microbial colonization but can cause oxygen demand and clogging of gills if in excess.

- **Total Suspended Solids (TSS)**: 250–450 ppm
- For *L. vannamei*: ~453 ± 50 ppm TSS and 256 ± 106 ppm volatile solids
- **Settleable solids**: 10–15 mL/L for shrimp, 25–50 mL/L for tilapia

Solids should be managed through **foam fractionation or settling chambers** to maintain balance.

Turbidity

Turbidity is caused by suspended solids, microorganisms, and plankton. Excess turbidity can interfere with light penetration and photosynthesis.

- **Acceptable turbidity**:
  - Secchi disk reading: 35–40 cm
  - NTU (Nephelometric Turbidity Units): 75–150, provided there is no severe colour interference

Mechanism of Nitrogen Removal in BFT

Biofloc systems remove nitrogenous wastes through:

- **Heterotrophic assimilation**: Rapid uptake of ammonia and nitrite by bacteria using carbon supplementation.
- **Nitrification**: Ammonia → Nitrite → Nitrate (slower, oxygen-demanding).
- **Algal uptake**: In systems with phytoplankton dominance.

Among these, **heterotrophic assimilation** is favored in BFT due to its speed and efficiency.

Table 1 : Summary of Water Quality Guidelines for Biofloc Systems

Parameter	Recommended Range
Temperature	28–30°C
Dissolved Oxygen (DO)	7–8 ppm
pH	7.0–8.5
Alkalinity	100–150 ppm (as $CaCO_3$)
Total Ammonia Nitrogen	< 1.5 ppm
Nitrite-Nitrogen	< 2.0 ppm
Nitrate-Nitrogen	< 10.0 ppm
TSS	250–450 ppm
Settleable Solids	10–15 mL/L (shrimp)
Turbidity	35–40 cm (Secchi disk)

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