

# **Development of Integrated Recirculating Aquaculture Systems (RAS) for Sustainable Inland Fish Farming**

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**Abstract:** Recirculating Aquaculture Systems (RAS) are a creative method of ecologically friendly fish farming that provides a valuable substitute to satisfy the growing worldwide demand for seafood and reduces environmental effects. Unlike conventional aquaculture systems, these closed-loop systems recycle and reuse water, lowering water use by up to 99%. RAS lowers the risk of disease transmission, escapement, and pollution by separating farmed fish from natural populations and their surroundings. Advanced RAS provides perfect water purity for fish growth by using mechanical, biological, and disinfecting filters and other methods. Many species, particularly predatory finfish, benefit from this increased degree of control to be grown far from coastal regions. Including aquaponics inside RAS allows one to design an ecologically friendly closed-loop system by growing premium vegetables and herbs using nutrient-dense wastewater. RAS has shown consistent profitability and the potential for significant gains, even with a larger initial investment required. RAS enhances neighborhood economic development by supporting "in-sourced" projects and local job creation, reducing the carbon footprint related to the global fish trade. As aquaculture technology advances, RAS are positioned to play a significant role in guaranteeing the long-term survival of the aquaculture process. Combining technological developments with conservation efforts allows RAS to provide a sensible approach to fulfill the increasing global demand for fisheries while maintaining the integrity of the aquatic habitats.

**Keywords:** Recirculating Aquaculture Systems; Fish Farming; Sustainable; Aquaculture.

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## **I. Introduction**

Self-sustaining, intensive aquaculture systems known as recirculating aquaculture systems (RAS) make extensive use of water Voicea et al. (2024). By purifying and filtering aquarium water before reuse, such systems minimize the water needed for aquaculture. Constantly recycled, the water is added to offset garbage collecting, splashing, evaporated water, and other sources. By reusing and recycling aquaculture water post-filtration, RAS is a focused form of aquaculture requiring little land and water resources.

RAS produces fish in indoor tanks in a controlled environment instead of in natural ponds and racing rivers Das, Mandal & Khairnar (2022). RAS's water is constantly filtered and recycled; more water is added only to cover waste disposal, evaporation, and splashing. The system components convert the produced waste products into non—toxic compounds, including solid waste, ammonia, and CO<sub>2</sub>. After that, the cleaned water is oxygenated and returned to the fish tanks. By allowing high-density farming of many fish species, RAS achieves production levels of up to 500 kg yearly within the area where traditional methods produce 2-12 tons per hectare. Applicable to any species grown in aquaculture, the technique uses physical and biological filtration.

Strict criteria guide RAS systems' operation, lowering the use of antibiotics and chemicals damaging human well-being and the aquatic environment Li et al. (2023). Using residual nitrogen from fish as a vegetable farming supply, RAS incorporates aquaponics, improving the system's long-term sustainability and profitability. While supporting local manufacturing and employment, RAS offers a more ecologically friendly and efficient way for aquaculture, addressing essential concerns such as water preservation, ecological protection, and disease management. This work aims to clarify RAS as a safe and efficient aquaculture technique that can meet the rising demand for aquatic agricultural products and minimize environmental problems Gupta et al. (2024).

## **II. Background**

Among the fast-growing food industry sectors is aquaculture. The rapidity of technological advancement surpasses suitable regulation and managed sector growth, possibly exacerbating ecological and societal harm.

- **Food Security**

The worldwide demand for animal protein is anticipated to rise substantially due to the expanding world population and improving living standards, contributing to increased meat intake in various regions Smith et al. (2024). This indicates that an increased number of individuals will consume greater quantities of meat. It is reasonable to conclude that neither meat manufacturing nor fishing can bridge this gap. Given the significant environmental repercussions and the adverse circumstances prevalent in extensive industrial farming of animals, the moral desirability of continued expansion in current meat production seems questionable.

- **Ichthyological Welfare**

Due to comprehensive management choices and prevailing veterinary perspectives, RAS could offer the most fish-friendly atmosphere Oldfield & Bonano (2023). Considering these alternatives, the administration of RAS has a specific obligation. Regarding fish welfare and biological safety, RAS claims to possess significant benefits over traditional aquaculture methods. In RAS, appropriate stocking densities are maintained to avoid stress caused by territorial behavior (insufficient stock) or overcrowding (overpopulation). The regulated environment promotes other critical aspects of fish health, including water quality and eliminating outside factors like predation.

- **Ecological Advantages**

RAS are considered significant advancements for sustainable fish farming since they effectively reduce negative ecological impacts compared to traditional organic farming Taufik et al. (2023). Due to the local operation of RAS and the short-distance distribution of its goods, travel has diminished consequences, including the release of Greenhouse Gases (GHG) and pollution. The emissions generated by plant operations might be mitigated by sourcing electricity from renewable resources.

- **Social Developments**

RAS are gaining prominence within the urban farming movement, which aims to integrate food planting and manufacturing into urban environments Srinivasan & Yadav (2023). Urban farming highlights alternate methods of using and occupying urban public areas. A significant focus is on educating people about food growing and processing, and the adverse environmental impacts of traditional agriculture. Urban farming provides environments where individuals with many social backgrounds converge and foster communities, such as intercultural gardening. In this regard, it assumes societal roles that social agriculture is dedicated to, namely, integrating agriculture with community-oriented social and health services. Social farming seeks to enhance the standard of living for specific demographic groups.

- **Regional Output**

RAS addresses customer desires in the North for regional goods. Disturbed by several crises in the food sector and the intricacies of global supply networks, consumers have increasingly sought enhanced transparency of agricultural goods. This tendency is seen in the rising demand for natural and local food, which both conjure comparable ideas of enhanced flavor, long-term viability, and nutritional safety. Comparative analyses indicate that customers who choose organic goods prioritize regional factors above ecological considerations.

### III. System Design and Layout

RAS aims to filter and recycle water inside an enclosed structure to reduce water consumption and adverse ecological effects (Fig. 1). The fundamental elements of RAS and the frequency of administration are delineated.

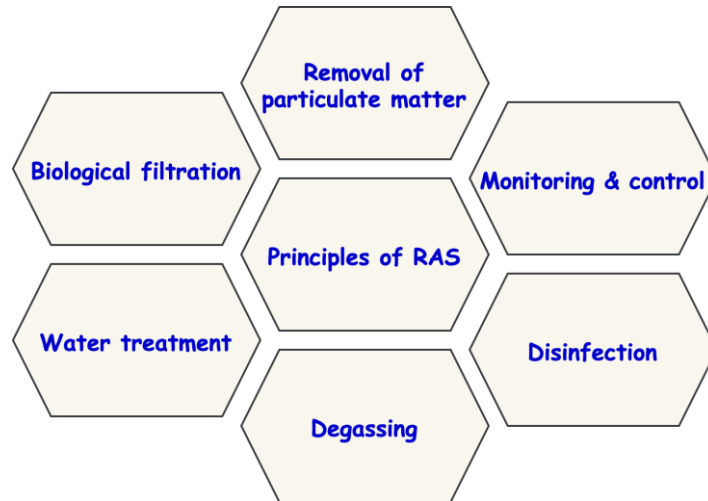


Figure 1: Principles of RAS Design

1. **Water Recycling:** The cultural water undergoes continual purification and reuse, with only a minimal proportion (often less than 10%) replenished daily to compensate for evaporation and garbage removal.
2. **Mechanical Filtering:** Mechanical screens, such as drum screens or deposition tanks, eliminate solid garbage, including fish excrement and uneaten feed.
3. **Biological Filtering:** Ammonia from fish is transformed into less hazardous nitrate by nitrifying microbes in biofilters such as biotowers or floating bed filters.
4. **Oxygenation:** The cleansed water is infused with air before being returned to the fish cages.
5. **Controlled Conditions:** RAS enables meticulous regulation of water quality factors such as temperatures, pH, and oxygen concentration to enhance fish development and health. Through the recirculation and treatment of water, RAS can accomplish water conservation of up to 90% compared to conventional flow-through aquaculture farms. RAS is especially appropriate for regions with few water supplies or where ecological constraints mandate minimum wastewater outflow.

### IV. Operational Aspects

- **Nutritional Approaches**

Effective RAS cannot exist without feeding techniques. Appropriate diet choice determines fish welfare as well as economic viability in RAS. RAS tanks have little to no natural production; thus, feeding must meet the fundamental dietary needs of grown-up organisms. Feeds low in pollution and "green" nature help reduce the system's nutrients. Feed control will help improve feed efficiency and lower nutrient loss in RAS.

Variables in feeding rate, rate, and protein concentration influence the Total Ammonia Nitrogen (TAN) entering the system, defining the dimensions and cost of filtering components. Meals with ideal amino acid balance reduce TAN levels and encourage development. RAS feed efficiency is increased by including lues, incitants, and stimulants. Investigating artificial intelligence and neural network-based autonomous

food control systems will help to improve feeding efficiency in quite packed RAS aquariums. Optimal feeding strategies, surroundings, and disinfection techniques are among the basic elements that must be controlled to guarantee effective and consistent RAS operation. Fish growth is a basic need of indoor RAS since the choice of appropriate food and feeding techniques determines their growth.

- Health and Disease Prevention

Maintaining fish populations in RAS depends on controlling diseases and infections. These abound in public aquariums, aquaculture facilities, and companies marketing tropical fish. They go under the moniker "water reuse structures." Good management helps to maintain the fish's health and prevent disease outbreaks. Understanding how species live, what they eat, how they obtain water, how they remain isolated, how they clean, and how they kill germs will help strengthen their immune system and reduce their risk of becoming sick. Understanding farmed species' structure, physiology, behavior, genetics, and biological requirements allows one to manage them effectively. Before reintroducing fresh fish into the environment, quarantine, cleaning, and sanitary practices should be established to prevent the spread of diseases.

People must follow the guidelines, monitor water quality data, and maintain thorough records if health management functions correctly. Along with ways to separate and treat affected fish groups, unexpected disease outbreaks must be anticipated in systems. Examining many records and test systems and working with experts helps control disease cases properly.

## V. Conclusion

The findings on a RAS underscore its importance for developing aquaculture owing to its many benefits. RAS facilitates diminished water use, reduced land demands, adaptability in site selection, lower wastewater effluent quantity, improved biosecurity, and effective environmental management. It allows increased fish stocking densities, meticulous surveillance of ecological variables, and autonomy from meteorological variations. Implementing RAS necessitates a significant initial investment, elevated running expenses mainly attributed to energy, and the need for proficient personnel. RAS exhibit elevated greenhouse gas emissions relative to non-RAS. Specialized forms of RAS include Aquaponics, which integrates fish and plants inside a closed-loop system, and Fish tanks designed for aesthetic display with regulated water quality. Aquaponics has the benefit of reduced waste production and various crop yields. RAS offers a viable method for sustainable and intense aquaculture, necessitating a thorough evaluation of its advantages and obstacles. To examine the problems and chances for the advancement of RAS, such as managerial concerns, knowledge deficiencies, substantial investment expenditures, and a requirement for technologies such as denitrification furnaces and managing sludge.

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