Nwanna, L. C.; Ajani, E. K.; Omitoyin, B. O.; Magawata, I. Ayoola, S. O.; Orisasona, O.; Kareem, O. K and Abubakar, M. Y. (Eds.) (2024) ***Proceedings of the Fifth Conference of Association of Nigerian Fisheries Scientists.*** **"SUSTAINABLE FISHERIES AND AQUACULTURE PRODUCTION FOR ENHANCING LIVELIHOOD IN NIGERIAN ECONOMIC DEVELOPMENT"** 9TH – 11TH JULY, 2024 In the University of Lagos, Lagos, Nigeria

# Design and Construction of a Prototype of Dual Aquaculture System (Water Recirculatory and Flow-Through) Using Acrylic Glass

***T. E. Awolu, T. M. Aderotimi, and D. O. Ayinla**

Department of Fisheries Technology, Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria.

*Corresponding Author: taiawolu@fedpolel.edu.ng, +2348030539318

**ABSTRACT**

*This study focuses on the design and construction of a prototype dual aquaculture system, integrating both Water Recirculatory and Flow-Through mechanisms. The system, constructed using acrylic glass, comprises four culture tanks of dimensions (25cm x 30cm x 45cm) alongside essential components including sedimentation tank, filtration tank, pumping tank, and bio-filtration system. In the Water Recirculatory mode, waste from the culture tanks is efficiently channeled to the sedimentation tank through underground perforated pipes, while water is directed to the filtration tank via an intelligently designed partition. The filtered water undergoes further treatment in the pumping tank, propelled through a submersible aquarium pump to a bio-tower for oxygenation and nitrogenous waste breakdown. Subsequently, the water settles in a retaining tank before returning to the culture tanks under the influence of gravitational force. Simultaneously, the system incorporates a Flow-Through mechanism, utilizing a distinct inlet for water supply from the source and an independent outlet for draining the culture tank. This design feature enhances the versatility of the prototype, enabling comparative studies and real-time observation of different aquaculture methodologies. The use of acrylic glass enhances visibility, facilitating observation and comprehension of aquaculture processes. This prototype serves as a valuable educational tool, offering hands-on learning experiences and opportunities for research and innovation in sustainable aquaculture practices.*

**Keywords:**

*Recirculatory system, Flow-through, Acrylic glass, Sedimentation tank*

## INTRODUCTION

Aquaculture, which involves farming aquatic organisms like fish, shellfish, and aquatic plants, is an important sector in global food production due to declining wild fish stocks and increasing demand for seafood (FAO, 2020). Sustainable aquaculture practices are necessary to meet the nutritional needs of a growing population (Boyd & Tucker, 2012). Traditional open-water aquaculture systems have limitations such as susceptibility to disease outbreaks, water pollution, and inefficiencies in resource utilization. However, Recirculatory Aquaculture (RAS) have emerged as a promising solution to these challenges.

Recirculatory aquaculture and flow-through systems are a practical solution to meet the growing demand for fish and other aquatic products. These systems play a crucial role in ensuring food security and addressing the problem of overfishing (Boyd & Tucker, 2012).

The intensive aquaculture system culture uses intensive production system management to meet all of the biological needs of the cultured organism. This method is frequently used in a Recirculating Aquaculture System and Flow-Through, which is the most recent innovation in fish farming. The research and development of technology for designing reliable and cost-effective RAS is still ongoing. As a result, the slow adoption of RAS technology is partly due to the high initial capital expenditures needed to cover investment costs, which necessitates high stocking densities and productions (Schneider *et al.*, 2006). Water flowing rates have been shown to influence fish health (Davidson *et al*., 2009), and the impact of feed quality or feed content on water quality has been investigated (Jisa *et al* 1997). Unfortunately, little research has been done on the qualitative and economic effects of different management activities on the efficiency of re-circulating aquaculture systems. Where there is a scarcity of water, re-circulating aquaculture systems are commonly used (Morey, 2009). Re-circulating systems are a viable alternative to pond systems, requiring less than 10% of the water used in pond operations to produce the same amount of production. As a result, one of the key benefits of re-circulating systems is water conservation. Recent research underscores the importance of sustainable aquaculture practices in mitigating environmental impacts and ensuring food security (Troell *et al*., 2021, Naylor *et al*., 2020). Moreover, advancements in aquaculture technology highlight the need for efficient systems that optimize resource utilization and minimize waste production (Badiola *et al*., 2020, Hossain *et al*., 2021). This study aims to create a specialized aquaculture system that caters to the specific needs of teaching and research activities in the field of aquaculture and it intends to design and build a prototype system that incorporates water recirculation technologies and flow-through to minimize water usage, reduce environmental impact, and enhance disease control measures. The prototype will serve as a sustainable and customizable platform for educational institutions and research facilities to conduct experiments, study aquaculture practices, and train students and professionals in aquaculture techniques.

## MATERIALS AND METHODS

### Design and Construction Location

This prototype was design and constructed in the Department of Fisheries Technology Laboratory, Federal Polytechnic, Ile-Oluji, Ondo State.

### Materials and Equipment used:

Tank materials include acrylic glass, Pumps (28watts 800litres/hour submersible aquarium pump-model JYC-1550), Silicon Gum, Saw Blade, ½" pipe, ½" Ball guage, ½" Union Connector, Aquarium Pump, Bio-Tower, Scouring Knife, Netting Material, Ruler, ½" Elbow, ½" Tee Junction, ½" Socket.

### Construction Process:

This prototype Recirculatory Aquaculture and Flow-through System was constructed using acrylic (Perspex) glass sheets (Plate 1). The rectangular acrylic (Perspex) glass has a thickness of 3mm. The glass was cut to shape and Sellotape was used to hold them together before the silicon sealant gum was now applied.

The system consists of four culture tanks [25 x 30 x 45cm] each and treatment units which include the sedimentation tank, filtration tank and the pumping tank. Attached to the tanks and treatment unit is the bio-tower tank that carries the bio-filter. The four culture tanks were arranged in series and connected to each other with two drainage pipes on one side of the tank and linked to the treatment unit which is the sedimentation tank. The water flows from the tank sector into the sedimentation tank and settles down, which later passes through the filtration tank to the clean water tank where the water is sent to bio-filter. The water from the clean water tank is later picked up with a suction submersible aquarium pump into the bio-tower system where the water is oxygenated and settles down on the overhead tank and later flows through a returning pipe through a Ultra-violet light to the four culture tanks. The system was created to regulate the flow of water and recirculate it for 24 hours every day.

**Plate 1:** Showing the four tanks held together with sellotape.

**Construction of Treatment tank:**
The treatment tank has a dimension of 15 x 25 x 45cm which is divided into 3 to accommodate the 3 filtration system namely sedimentation chamber, filtration chamber and clean water chamber. These unit tanks are constructed using acrylic (Perspex) glass sheets of 10 x 20 x 15cm [length, breadth and depth] and the glass was cut to shape and a Sellotape was used to hold them together before the silicon sealant gum was now applied.

**Sedimentation chamber:**
Water from the sedimentation passes through materials such as white stones, activated carbon, white sand (bags) and then passes through an opening at the wall that divides the sedimentation tank from the filtration tank and enters into the filtration tank.

**Filtration chamber:**
Consists of the following materials, white stones, activated carbon, white sand (bags) and filter/ net.
**Pumping tank:**

The pumping tank serves as a reservoir for clean and purified water that serves as a major supply to the system. The pumping tank section consists of a 22 watts aquarium pumps that picks water from the tank and drop at the bio tower system.

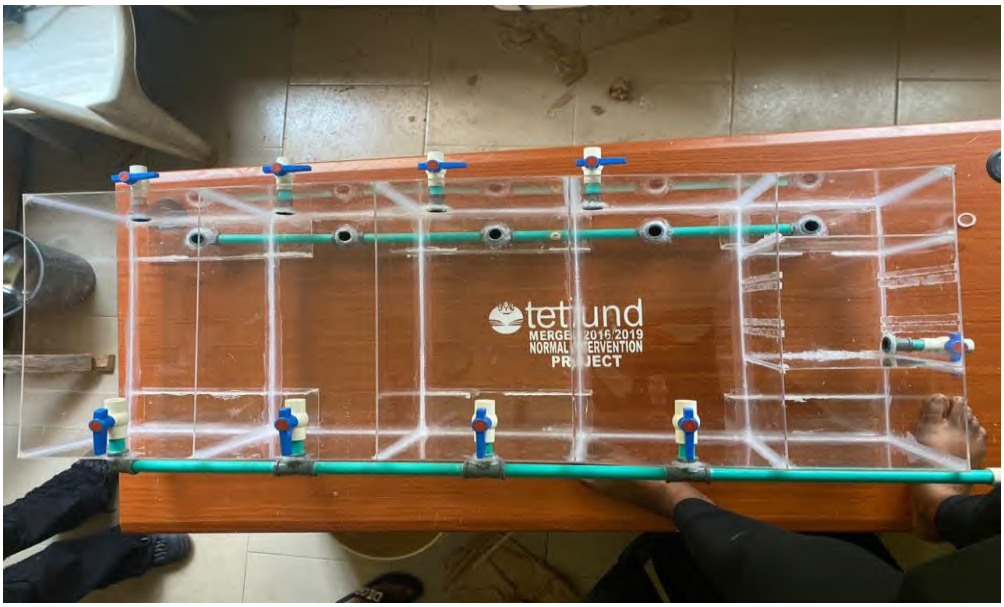

**Plate 2:** Construction process showing inlet and outlet flow pipes

**Plate 3:** Submersible Aquarium Pump

**Plate 4:**Construction process

**Bio tower system:**

The bio-tower system tank is constructed above the pumping tank; this section has a retaining tank that contains the bio-filter and the pumped water. It has an opening that is connected to a pipe that conveys water back to the cultured tanks.

**Construction of Pipes**

Half inch (½") pipe was used to connect the four tanks together to the sedimentation tank. These pipes were connected using ½" pipe, ½" Elbow, ½" Ball gauge, ½" Tee Junction, ½" Union Connector and ½" Socket.

Half inch (½") pipes were also used to run the flow system from the bio-tower to each of the culture tanks. This serves as a returning pipe that carries water from the bio-tower to serve the four culture tanks. The pipe was connected to the 22 watts aquarium pump underneath the bio-tower system to supply the bio-tower by collecting water from the pumping tank. ½" pipe was connected to the main source of water using a Tee joint and directed to the culture tanks which serve as a main source of water supply to the tanks which is also used for flow-through system.

**Plate 5:** Dual Aquaculture System.

**RESULT**

The layout of the unit and holding tank constructed is presented in Plate 5. Four sets of culture tanks were constructed having a capacity of about 34liters water holding capacity. The flow line pipes were of diameter, ranging from ½ inches pipes. Each cultured tank has two types of flow lines (the outlets and inlet flow lines) as illustrated in plate 2. Each tank has an inlet and outlet lines for recirculation and flow-through. The inlet line to the cultured tank has a diameter of ½ each with a spray of tap designed at an interval length of 5cm away from the main source of water to promote the water distribution from the main source and as well as introduction of oxygen. The outlet was equipped with a ½ mesh drain pipe at the bottom, which empties water/effluent into the sedimentation tank. Each of the four lined cultured tanks had a recirculation line that runs parallel and another outlet by the side to run the flow-through.

A Suction submersible aquarium pump was installed in the re-circulatory system to pump water from the clean water tank to the bio- tower that flows gradually through a series of ½" pipe and release in form of spray in order to breakdown nitrogenous waste from the water and add oxygen from the air to

continue the recirculation supply system. There were varying methods of filtration unit adopted in the construction process, the sedimentation tank which aid in the removal of solid waste and serves in the purification process. The filtration tank contains netting material for filtration. The installed ultra violet light ray was located at the entrance that return water into the culture tank which aids in the destruction of escaped microorganisms from other chambers as oxygenation in the unit was achieved by the distance of water fall and splash from tap into the bio tower (from a height of about 60cm).

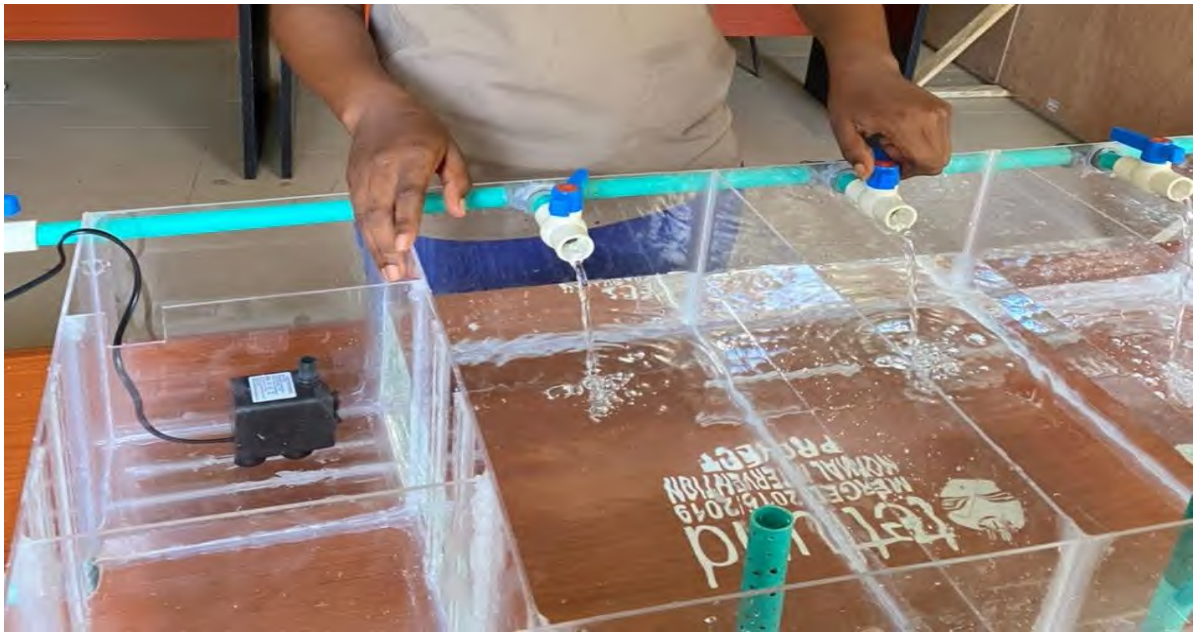

**Plate 6:** The system running of Flow-Through

**Table 1: Materials list and approximate costs for the dual Aquaculture system.**

| S/N | Item | Quantity/Unit Cost | Total Cost |
|---|---|---|---|
| 1 | Acrylic glass | 2Sheets @ #32,000 | #64,000 |
| 2 | Silicon gum | 3 @ #2,500 | #7,500 |
| 3 | Submersible Aquarium Pump (28watts) | 1 @ #25,000 | #25,000 |
| 4 | ½" PVC pipe | 2 @ #800 | #1,600 |
| 5 | ½" PVC Elbow | 7 @ #150 | #1,050 |
| 6 | ½" PVC Tee Joint | 6 @ #200 | #1,200 |
| 7 | ½" PVC Socket | 2 @ #150 | #300 |
| 8 | ½" PVC Ball Guage | 10 @ #600 | #6,000 |
| 9 | ½" PVC Union Connector | 1 @ #600 | #600 |

| | | | |
|---|---|---|---|
| 10 | Cellotape | 1 @ #700 | #700 |
| 11 | Scouring Knife | 1 @ #2,000 | #2,000 |
| 12 | Logistics/ | | #10,000 |
| | **TOTAL** | | **#119,950** |

## DISCUSSION

The designed dual aquaculture system was an indoor system that used gravitational flow to move water between components, as the components were placed at the appropriate elevation relative to one another to enhance water flowing. A submersible aquarium pump was used to move water from the clean water tank as reported by (Akinwole and Faturoti, 2007). The sedimentation tank was used to remove settle-able solids and create a more natural environment for the fish. The use of rectangular tank had been supported for aquaculture (Timwas *et al.*, 2008, Losordo *et al*., 2008). The system required only a small amount of new water each day due to its recirculating design.The filtration mechanism used in the system was similar to that reported by Akinwole and Faduroti (2007), where the filtration chambers were groove with - acrylic (Perspex) glass sheets. Water aeration was achieved through a simple mechanism of water flowing into the culturing tank from a height. This method of oxygenation of water have been used and recommended by Losordo *et al.*, 2008. Therefore, considering the design of water flow from the water inlet into the culturing tank down to the effluent pipeline as well as the water filtration unit suggested that the design system was effective and flexible (Morey, 2009). The significance of sedimentation and filtration mechanisms is the management of the amount of feed going into the system and waste coming out to maintain optimal water quality. The designed prototype dual aquaculture system reveals that it can support a high stocking density of fish with a relatively less mortality rate of cultured breed of fish.

## CONCLUSION

The functionality of the RAS involves a continuous circulation of water through various stages, ensuring efficient waste management and water quality maintenance. Waste from the culture tanks is directed to the sedimentation tank through perforated pipes, while water undergoes filtration before being pumped to a bio-tower for further treatment. This process facilitates the breakdown of nitrogenous waste, promoting a healthier aquatic environment.

Furthermore, the integration of gravitational force allows for the return of treated water to the culture tanks, reducing water consumption and waste production. This approach not only enhances the sustainability of aquaculture practices but also aligns with the global demand for eco-friendly systems. Overall, the development of this prototype RAS represents a significant step towards achieving sustainable aquaculture by addressing key challenges related to water usage and waste management. Further research and implementation of such systems hold promise for the advancement of environmentally responsible aquaculture practices.

The most effective method of fish culture in aquaculture systems is RAS and flow through systems, as they reduce water usage and pumping costs. RAS is particularly suitable as it shortens the time it takes for fish to mature and produces high-quality, weighty fish quickly.

**RECOMMENDATION**

It is hereby recommended that these dual Aquaculture systems should be adopted by large scale farmers in other to meet the market requirement of the fish buyers in the shortest possible time.

The Government should assist farmers in adopting the use of Dual Aquaculture System by providing funds. There should be intensified education and training of student on the running of Recirculatory Aquaculture System and Flow-Through system.

**REFERENCE**

Akinwole A. O., and Faturoti E. O., (2007) Biological Performance of African Catfish (*Clarias Garipinus*) Cultured in recirculatory system in Ibadan Agriculture Engineering; 36:18-23.

Badiola, M., Bostock, J., McAdam, B., Varga, D., Bunting, S., Besson, M., and Dalsgaard, J. (2020). Environmental impacts of high-intensity recirculating aquaculture systems: A life cycle assessment. Aquaculture, 522, 735124.

Boyd, C. E., and Tucker, C. S. (2012). Pond Aquaculture Water QualityManagement. Springer Science & Business Media.

Davidson J., Good C., Brazil B., and Summerfelt S., (2009). Heavy metal and waste metabolite accumulation and their potential effect on rainbow trout performance in a replicated water reuse system operated at low or high system flushing rates. Aquacultural Engineering 2009;41:136-145.

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Food and Agriculture Organization of the United Nations.

Hossain, M.S., Ayar, P.V., Kumar, V., Chowdhury, P., Singh, R., and Das, P. (2021). Recent advances in recirculating aquaculture systems: A review. Aquaculture, 531, 735907

Jisa D. O., Davis D. A., and Arnold C. R., (1997) Effects of Dietary Nutrient Density on Water Quality and Growth of Red drum, Sciaenops Ocel latus, in closed systems. Journal of the world Aquaculture Society 1997; 28(1):68-78.

Losordo, T. M., Piedrahita, R. H., and Masser, M. P. (1998). Design and operating criteria for minimizing environmental impacts of tank culture systems. Aquacultural Engineering, 18(5), 381-395.

Morey R. I. (2009) Design Keys of a recent recirculatory built in chile operation with fluidized bed biofilter. Aquaculture Engineering ;41:85- 90.

Schneider O., Blancheton I. P., Varadi L., Eding E. H., and Verreth J. A. J. (2006). Cost price and production strategies in European recirculation systems. Linking Tradition and Technology Highest Quality for the consumer. Was, Firenze, Italy 2006.

Naylor, R. L., Hardy, R. W., Buschmann, Bush, A. H., Ling Cao, S. R., Klinger, D. H., Little, D. C., Lubchenco, J., Shumway, S. E. and Troell, M. (2020). A 20-year retrospective review of global aquaculture. Nature, 591(7851), 551-563. DOI: 10.1038/s41586-021-03308-6.

Timwas M. B., Dummerfelt S. T., and Vinci B. J., (2008) Review of circulatory Tank Technology and Management. Aquaculture Engineering; 18:51- 69.

Troell, M., Naylor, R. L., Metian, M., Beveridge, M. C. M., Tyedmers, P. H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A. S., Ehrlich, P. R., Gren, Å., Kautsky, N., Levin, S. A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B. H., Xepapadeas, A., and de Zeeuw, A. (2021). Aquaculture systems and global food security. Global Food Security, 30, 100541

**ANIFS** 2024
© 2024
***Proceedings of the Fifth Conference of Association of Nigerian Fisheries Scientists.*** **"SUSTAINABLE FISHERIES AND AQUACULTURE PRODUCTION FOR ENHANCING LIVELIHOOD IN NIGERIAN ECONOMIC DEVELOPMENT"**
9TH – 11TH JULY, 2024 in the University of Lagos, Lagos, Nigeria