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Fakunmoju FA
Dept of Fisheries Technology,
Lagos State Polytechnic,
Ikorodu, Lagos State, Nigeria

Babalola AO
Dept of Fisheries Technology,
Lagos State Polytechnic,
Ikorodu, Lagos State, Nigeria

Adesina BS
Dept of Agric and Bio –
Environmental Engineering,
Lagos State Polytechnic,
Ikorodu, Lagos State, Nigeria

Corresponding Author:
Fakunmoju FA
Dept of Fisheries Technology,
Lagos State Polytechnic,
Ikorodu, Lagos State, Nigeria

Design and construction of a Prototype Aquaculture Pond Re-Circulatory system using locally sourced materials (Wood and PVC Blind)

Fakunmoju FA, Babalola AO and Adesina BS

Abstract
The study focused on the design of construction of a prototype re-circulatory pond system (RAS) using the locally sourced raw material (wood, planks and pvc blind). The system consists of three culture ponds of 6ft by 4ft by 4ft (L x b x h) dimension each, sedimentation tank, filtration tank and pumping tank 4x4x4ft each and a bio-tower system. The culture ponds are linked to each other with a pipe connector and to the sedimentation tank. The waste from the culture pond moved to the sedimentation tank and the water moves to the filtration tank through an opening from the base of the wall partition. The water is filtered through the sharp sand, white stones, oyster shells and the activated charcoal and likely through the filtration Net. The water rises to a point where the clean filtered water enters into the pumping tank and get sucked up through a suction pipe from the surface engine to the bio-tower where the water gets mixed up with the oxygen from the air and the nitrogenous waste get broken down with the splashing effect of the water on the bio-filter. Water get settled on the retaining tank and with a gravitational force moves through the returning pipe to service the culture ponds.

Keywords: Re-circulatory system, sedimentation tank, filtration tank, pumping tank, Bio-tower system

1. Introduction

Increased production efficiencies and intensities, as well as the use of less water and financial capital, are key to the future of aquaculture in Africa [7] The need for environmentally conscious operating practices and facility designs becomes more relevant as the aquaculture industry grows in response to increased demand for fish products [1]. The intensive aquaculture system culture employs intensive production system management, in which the culturist must meet all of the cultured organism's biological needs [14]. In a recirculating Aquaculture System, this method is frequently used. The recirculating aquaculture method (RAS) is the most recent innovation in fish farming. Usually, RAS is an indoor device that helps farmers to monitor environmental conditions all year round. The costs of building a RAS are usually higher than those of pond or cage culture, but when the system is properly maintained, fish can be raised all year, making the higher investment worthwhile. The RAS has advantages over other aquaculture systems in terms of reducing incoming water volume [18], reusing more water inside the culture system, reducing the amount of water released and effluent quality [3], and biological pollution control [14, 16]. Solids removal, system removal exchange, piping size and configuration, filtration process, biofiltration unit, gas balancing and carbon (iv) oxide removal, oxygenation device, and disinfection process should all be considered when designing a good RAS [12]. 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 [15]. Water flushing rates have been shown to influence fish health [3], and the impact of feed quality or feed content on water quality has been investigated [8]. 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 [12]. 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.

The majority of re-circulating systems are only planned to replace 5-10% of the device volume per day [15]. To maintain the high water quality levels needed for proper fish health, these systems require continuous filtration. Higher water exchange rates minimize the need for filtration, but at the cost of less efficient water use. Studies in Denmark and the Netherlands [6] as well as Nigeria [2] have shown that African catfish (Clarias gariepinus) can be successfully cultured in RAS at full commercial scale.

The choice of fish species to be cultured in RAS is vital to the venture's success, which is largely dependent on the conditions of the culture fish, their feeding habits, the availability of seeds for stocking, the acceptability of artificial feed, and market demand. Catfish are one of the most common fish species in the Nigerian market, with a high level of demand. Catfish aquaculture, such as *Clarias gariepinus*, *Heterobranchus bidorsalis*, and their hybrids, has been practiced in Nigeria for a long time [1]. The hybrids are said to have higher growth rates in captivity, better environmental tolerance, hardiness to adverse environmental conditions, potential for aquatic and aerial respiration, and resistance to parasites and diseases, as well as a strong consumer preference in the market [4], all of which are necessary for ensuring fish food protection in Africa [4].

Hence, the need to develop a prototype aquaculture pond re-circulatory system using locally sourced materials (Wood and PVC blind) that would reduce the cost of design, operation and maintenance without compromising standards.

2. Materials and Methods

2.1 Construction site: The construction site is located in fisheries departmental fish farm, Lagos state polytechnic Ikorodu.

2.1.2 Construction materials

2.1.3 Pebbles (Stones)

A pebble is a class of rock with a particle size of 4 to 64 millimetres based on the Krumbein phi scale of sediments. Pebbles are generally considered larger than granules (2 to 4 millimetres diameter) and smaller than cobbles (64 to 256 millimetres diameter). A rock made predominantly of pebbles is termed a conglomerate. Pebbles come in various colours and textures and can have streaks, known as veins, of quartz or other minerals. Pebbles are mostly smooth but, dependent on how frequently they come in contact with the sea, they can have marks of contact with other rocks or other pebbles.

2.1.4 Charcoal

Charcoal is a lightweight black carbon residue produced by strongly heating wood (or other animal and plant materials) in minimal oxygen to remove all water and volatile constituents. In the traditional version of this pyrolysis process, called charcoal burning, the heat is supplied by burning part of the starting material itself, with a limited supply of oxygen.

2.1.5 White Stone: It is a clear colourless imitation gem (as a rhinestone) that simulates the diamond

2.1.6 Oyster shell: The shell of an oyster. A product made from the shell of the oyster, such as calcium supplements for humans or laying hens.

2.1.7 PVC: Polyvinyl chloride (colloquial: polyvinyl, vinyl] is the world's third-most widely produced synthetic plastic polymer (after polyethylene and polypropylene) PVC comes in two basic forms: rigid (RPVC) and flexible.

2.1.8 Surface pumping machine: Surface pumps are designed to pump water from surface sources like springs, ponds, tanks, or shallow wells. Most of our surface pumps are either diaphragm pumps or rotary vane pumps and can run solar-direct for simple, inexpensive operation.

2.1.9 Aluminium frame: Aluminium is a chemical element with the symbol Al and atomic number 13. Aluminium has a density lower than those of other common metals, at approximately one third that of steel. Aluminium has a great affinity towards oxygen that is why it is adopted in usage.

2.2.0 Pipes and fitting: A fitting or adapter is used in pipe systems to connect straight sections of pipe or tube adapt to different sizes or shapes, and for other purposes such as regulating (or measuring) fluid flow. These fittings are used in plumbing to manipulate the conveyance of water, gas, or liquid waste in domestic or commercial environments, within a system of pipes or tubes.

2.2.1 Tangit-gum: Tangit is an adhesive containing solvent on the basis of tetrahydrofurane (THF stabilized). It is suitable for joints resistance to shear strain of pressure pipes (such as drinking water and gas pipes) and for gluing of cables conduits, drain pipes made of PVC.

2.2.2 Duration

The research was conducted for four months.

2.2.3 Design equations

According to the relevant standard and result from related studies, recirculatory ponds system was designed following the equation below.

$$\text{Volume} = V = \frac{Q_{av}\, t}{3}$$

Where Qav is the average flow [m^2/day], t is the retention time [day], v is the volume [m3] and S is the surface area of the tank

2.2.4 System construction

The system consists of three culture ponds [6x4x4ft] each and purification units which include, the sedimentation tank, filter tank and the pumping tank. Above the pumping tank is located the bio-tower tank that carries the bio-filter. The three culture ponds were arranged in series and connected to each other with two drainage pipes on one side of the pond and linked to the purification unit which is the sedimentation tank. The water flows from the pond sector into the sedimentation tank and settles down, which later passes through the filtration tank where the water is bio-filtered and sent to the pumping tank. The water from the pumping tank is later picked up with a suction engine into the bio-tower system where the water is oxygenated and settles down on the overhead tank and later flows through a returning pipe to the three [3] culture ponds. This system was designed such that the flow system was regulated to re-circulate water for 24hours daily.

2.2.5 Construction of culture ponds

The three cultured ponds were constructed using planks in the dimension of 6x4x4ft [length, breadth and depth] and then lined up using the pvc liner. These three cultured ponds were linked together to each other with an opening that was connected to a pipe that runs through the three cultured ponds at one end of the pond.

One of the linked channel pipes was perforated in order to allow the free flow of water from one cultured pond to the other, while the second linked opening was meant for discharge of waste from the tank. The linked pipe was connected through the three ponds to the sedimentation tank where the bulk of the waste were discharged.

2.2.6 Construction of purification tank

Purification unit consists three tanks which are sedimentation tank, filtration tank and the pumping tank.

These unit tanks are constructed using planks of 12x4x4ft [length, breadth and depth]. These complete unit structure is later divided into 3 equal size using planks of 4ftx4ft and each of the unit box is lined with a Pvc liner.

2.2.7 Sedimentation tank: Water from the sedimentation passes through an opening at the wall that divides the sedimentation tank from the filtration tank and enters into the filtration tank.

2.2.8 Filtration tank: consists of the following facilities, white stones, activated carbon, white sand (bags) and filter/ net.

2.2.9 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 surface engine that picks water from the tank and drop at the bio-tower system.

2.2.0 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 ponds.

3.0 Structure of A Recirculatory Fish Pond

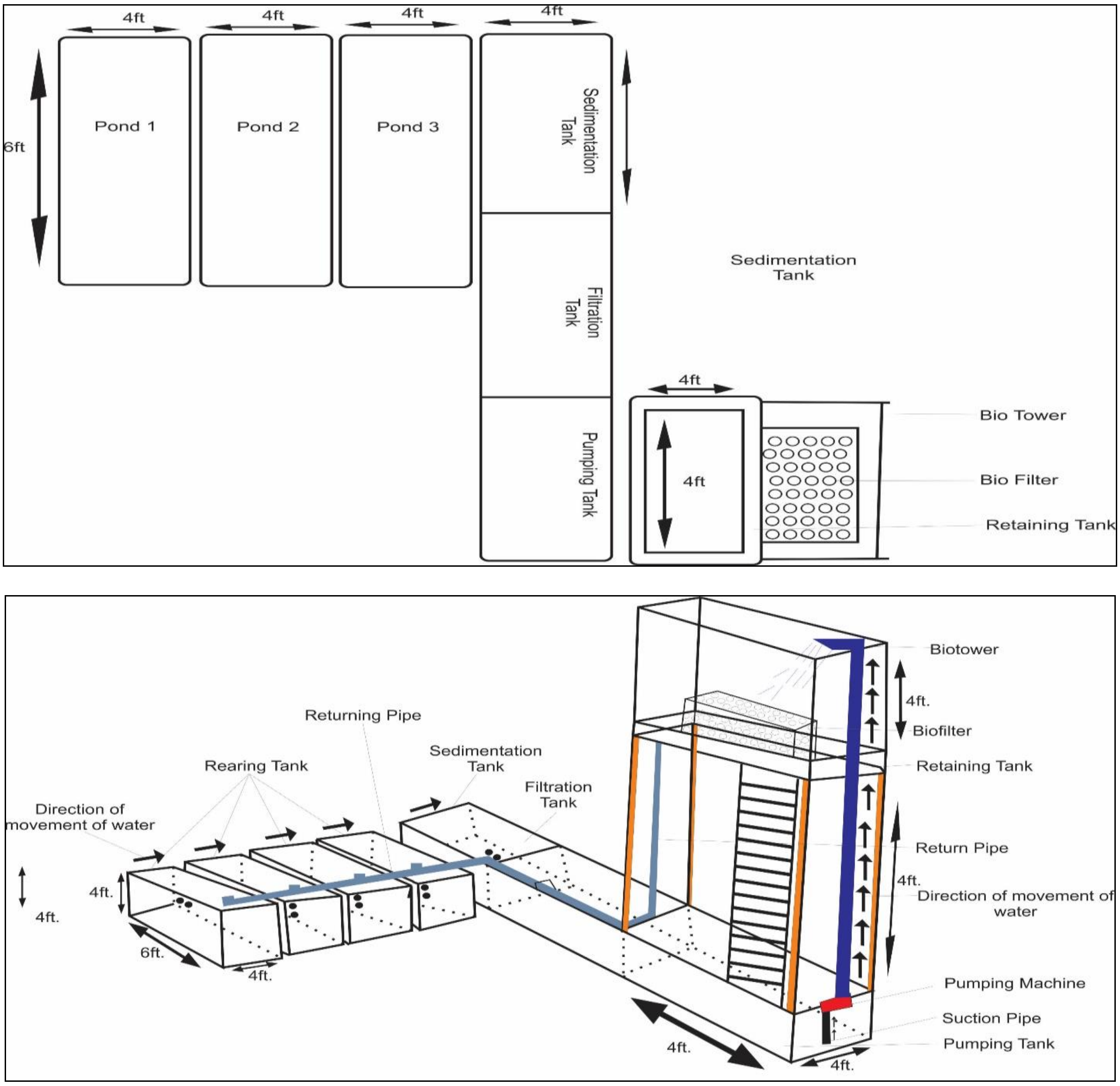

Fig 1: Structure of A Recirculatory Fish Pond

3.1 Construction of Pipes

3 inches pipe was used to connect the three ponds together to

the sedimentation tank. These pipes were connected using 3"bend, 3"Tee, 3''lock and 3''back nut.

Two inches pipe were also used to run the flow system from the bio-tower to each of the culture ponds. This serves as a returning pipe that carries water from the bio-tower to serve the three culture ponds.

The pipe was connected to the surface engine underneath the bio-tower system to supply the bio-tower by picking water from the pumping tank. 2" pipe was connected to the main source of water and directed to the culture tanks which serve as a main source of water supply to the tanks.

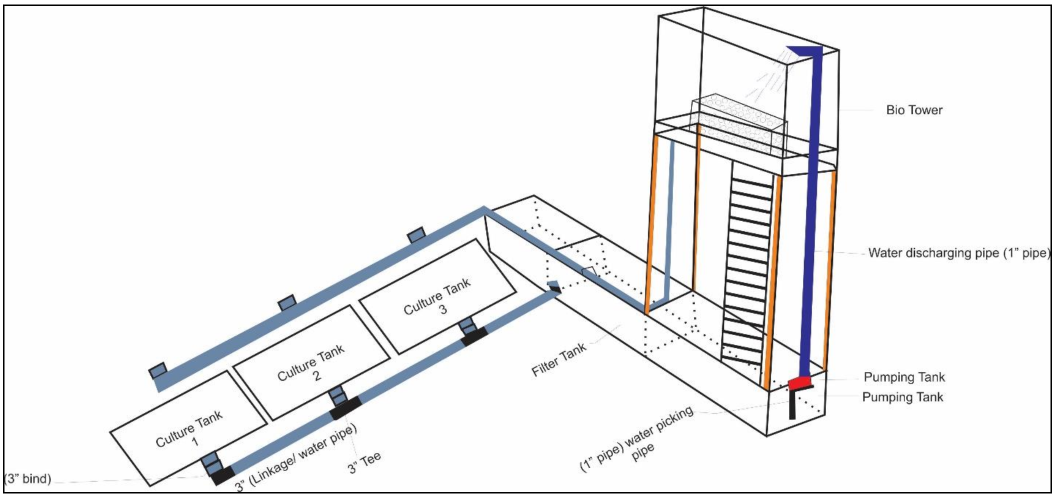

Fig 2: Construction of Pipes

Plate 1: Design for flow of water in the recirculatory pond system

Plate 2: Design for flow of water in the recirculatory pond system

3.2 Determination Calculation

Design for flow of water in the recirculatory pond system.

To calculate the rate of water flow in the pond with an equation-based pressure formula.

V = A x h.

Where

Volume of water in the bio-tower system tank (M^3)

A = Area of Bio-tower Tank (m^2)

H = height or depth of the pond/ culture tank (m^2)

Therefore; πD^2 x h.

Where
D = Diameter of the bio-tower (m)
The volume of water should of discharge Q in M^3/ Sec was calculated

$$Q = \frac{\text{Volume discharged}}{\text{Time taken}}$$

Volume of discharge = Area of velocity of discharge pipe

$$\text{Area of Discharge pipe} = \frac{\pi D^2}{4}$$

The energy pressed by the moving fluid (water) at an altitude above datum (ground surface) also given by Bernoulli's Equation.
Pressure head of velocity head + potential head = Total head

$$\text{Pressure head from the bio-tower tank} = \frac{P}{pgh}$$

Where
P = Density of water flowing in the culturing pond (kg/m^3)
P = Potential (head above datum (reference point) N/m^2
g= Acceleration due to gravity

Therefore

$$\text{Velocity head} = \frac{v^2}{2g}$$

Where
P = Water density
H = Height of the bio-tower tank
Fluid pressure was given as 21582 N/ m^2
Atmospheric pressure was given as 1.01325 N/m^2
Total pressure was reserved before discharge inform as
Ps + Atmospheric pressure [5]

4. Results
The layout of the unit and holding tank designed or constructed is presented in fig1.
Three sets of culture tanks were constructed having a capacity of 500 liters water holding capacity. Three other tanks were also constructed known as sedimentation tank, filtration tank and pumping tank with a capacity of 300liters each.
The flow line pipes were of diameter, ranging from 5.0 to 3.0inches pipes depending on the location and the function/ carrying capacity. Each cultured tank has two types of flow lines (the outlets and inlet flow lines) as illustrated in fig 2. The supply line operates at a maximum system flow width of 0.8 m/s with a minimum slope of 0.20 percent. The slope is to allow the free flow of water from one culture pound to the other and also allow the drainage of all water inside cultured tank when required. Each tank has an inlet and outlet lines. The inlet line to the cultured tank has a diameter of 2.0 each with a spray of Tap designed at an interval length 0.3 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 3.0 mesh drain pipe at the bottom, which empties water/effluent that empties into the sedimentation tank. Each of the three lined cultured tanks had a recirculation line that runs parallel.
All the efficient lines were designed with an average water velocity of 0.8mls for a proper transport.
A 0.5 HP pumping machine was installed in the re-circulatory system (fig 2) to pump water from the pumping 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 contain graded levels of gravel, coarse and sharp sand that helps in the breakdown of toxic ammonia and nitrates component of the used water into non-toxic nitrates before the gasses are removed by activated carbon which was located in the filtration tank. The 1.0 and 5.0 µm filters aids in the removal of particles that were not removed in the earlier stages. This was located after the carbon filter in sequential order. The installed ultra violet light ray was located at the last chambers that return water into the overhead bio-tower tank which aids in the distribution 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 0.8m).

5. Discussion
The designed re-circulatory pond system was typically outdoor system. The water flow in the components was by gravitational flow, as the components were placed at the appropriate elevation relative to one another to enhance water flowing. The pumping machine moves water from the pumping tank as earlier reported by [2]. The designed re-circulatory pond system gives an appropriate tank diameter to depth ratio of 4 ft/4ft which enhanced an effective flow injection mechanism. The sedimentation tank used to enhance the removal of settleable solids and give fishes impression of living in the wild. The use of rectangular tank had been supported, [17, 10]. Since the water was "re-circulated" the system requires relatively small addition of new water of the total volume daily. The use of different filtration mechanism in this construction as encased in a framed enclosure was similar to that reported by [2], where the filtration chambers were wrapped with tarpaulin. Water aeration could be activated through a simple mechanism of water flowing into the culturing tank from a Height. This method of disinfection and oxygenation of water have been used and recommended by [10]. 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 [12]. 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 recirculatory pond system reveals that it can support a high stocking density of fish with a relatively less mortality rate of cultured breed of fish.

6. Conclusion

It could best be concluded that RAS is the best method of fish culture in any aquaculture system, since it reduces the use of excessive water and the cost of pumping water from the borehole at regular intervals. It could be concluded also that RAS is the most suitable and appropriate method of fish culture in that it reduces the time of getting the fish to the market in terms of maturity and also produces the best quality weight fish at the shortest possible time.

7. Recommendation

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

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