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Original Research Article

Effluent Quality of a Locally Designed Recirculation Aquaculture System

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Abstract: The study presents the assessment of water quality of a recirculation aquaculture system (RAS). In this study, a laboratory- scale recirculation aquaculture plant was designed and fabricated to reduce, recycle and reuse fish farm wastewater. The system incorporates trickling filter as a biological treatment processes. Development of bacteria on the trickling filter was done by continuous recirculation of highly concentrated fish farm waste water for 16 days when a considerable mass of bacteria enough for nitrification was observed to have developed. In the experiment, two different systems were compared: a RAS with trickling filter and a conventional open pond system. A sample of effluent from the trickling filter was analyzed for ammonia, nitrite, nitrate, dissolved oxygen, pH and total suspended solid. The result of the analysis showed that the water parameters in RAS were within acceptable level for African catfish culture; 32.89L of water was used up in the RAS for the 21 days culture and percentage increase in weight ranging from 17.69% - 37.05% was observed in the RAS. This shows that the system was effective in producing required effluent quality for catfish fish rearing.
Keywords: recirculation, aquaculture system, trickling filter, water quality, reuse, effluent.

INTRODUCTION

Aquaculture (farming of fish under controlled conditions) is an expanding high value primary industry in many countries. It is a food source that is fast growing to meet current and future global consumption requirement. Today, aquaculture is growing rapidly: according to the FAO [1], aquaculture provides 47% (51 million tons) of the global human fish consumption. Increasing public demand for healthy and affordable food, with a decline in wild fish population, as a result of overharvest and water pollution have all contributed towards the fish farming in the indoor tank system.

In recent years long-forgotten historical approaches have been recovered and adapted to new technologies, such as the parallel production of fish with filter feeders and plants or algae, even in multi-trophic systems [2,3]. This concept is applicable to many standard aquaculture installations, such as ponds or net cages.

Recirculation aquaculture system (RAS) is a new and unique cultivation system in which effluents from fish rearing units is partially or completely reused in the same unit or other rearing units after treatment and conditioning [4]. The interest in RAS by many researchers such as [5-8] is due to its perceived advantage of reduced water requirement.

RAS generally require at least one or more treatment processes and one of such treatment processes can be trickling filter because biological filtration is the method used for the destruction of organic and inorganic waste compounds in RAS [9]. However, maintaining good water quality conditions is of primary importance in any type of aquaculture system especially in RAS. This water quality depends on several factors most importantly the source, the level of recirculation, the cultured specie and the waste water treatment process within the system

Trickling filter is an aerobic treatment system that utilizes micro-organisms attached to a medium to remove organic matter from waste water. In municipal wastewater treatment systems, trickling filters were traditionally constructed of rock, but today, most filters use plastic media because of its low weight, high specific area(100-300m^2 /m) and void ratio(>90%). Though trickling filter plants has been justified by their low initial cost, low operation and maintenance costs, and relatively simplicity of operation, yet they are mostly conventional in nature. This made them hardly affordable by fish farmers from developing countries. This paper aims at designing trickling filters using low cost material for producing effluent of required quality for safe reuse in the recirculation system.

MATERIALS AND METHODS

Description of lab – scale recirculation aquaculture plant

The laboratory scale aquaculture recycling plant was designed and fabricated to incorporate a settling tank and trickling filter. Feed water from the fish tank was pumped into the settling tank by means of 0.5Hp centrifugal pump at a flow rate of 18L/min through a 20mm diameter Polyvinyl Chloride (PVC) conduit. The settling tank was placed at a height of 1.05m from the ground. The water flows from the settling tank to the trickling filter and finally to the fish culture tank by gravity. The settling tank was fabricated with galvanized metal sheet of 24mm gauge and was enclosed with a plastic container. Fig-2 shows the laboratory – scale recirculation aquaculture plant and figure 1 shows its experimental set up.

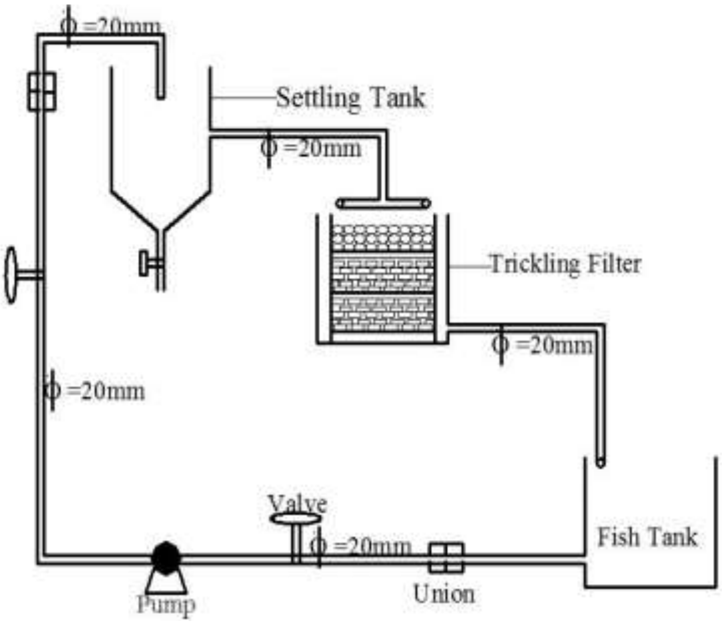

Fig-1: Experimental set up

Fig-2: Aerial view of a Fabricated Lab-scale Recirculation Aquaculture Plant

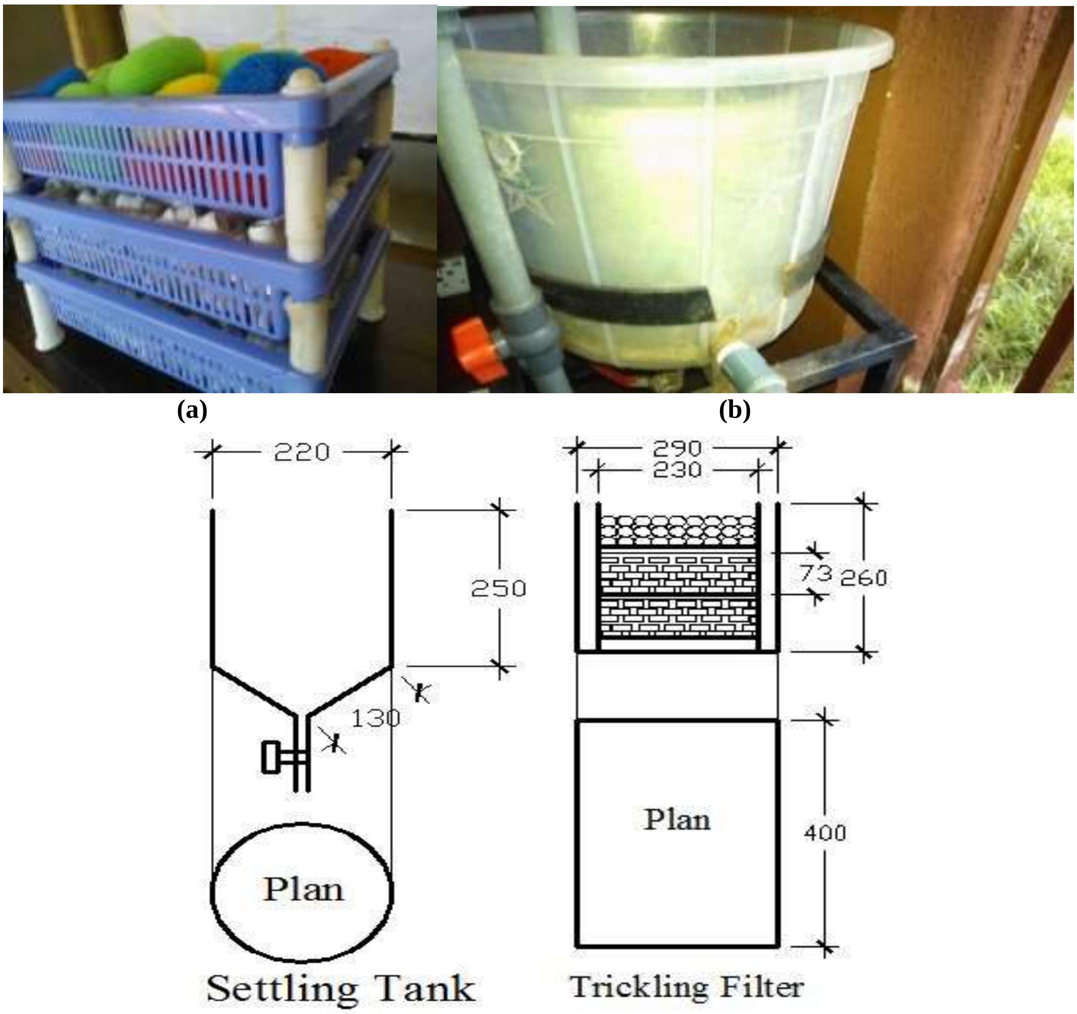

Fig-3: Pictural and Dimensional Diagram of thr Treatment Units (a. Settling tank, b) Trickling filter)

METHOD

Sedimentation Process

The first stage of the treatment of the fishery wastewater was sedimentation which is carried out in settling tank. The tank was cylindrical in shape with a conical bottom (hopper) where sludge is deposited and removed. It was later released to the trickling filter tank.

Filtration Process

This is the biological treatment process for the wastewater. The trickling filter has three compartments. The first compartment contains the nylon kitchen sponge as a mechanical filter while the second and third compartments are filled with plastic rings having an inside diameter of 1.3cm, outside diameter of 2cm and length of 4cm.

Treatment Process in a closed system

In this study, the treatment was carried out in a continuous system. Water sample was collected at the outlet of the filtration tank. The schematic diagram is shown in figure 4 below.

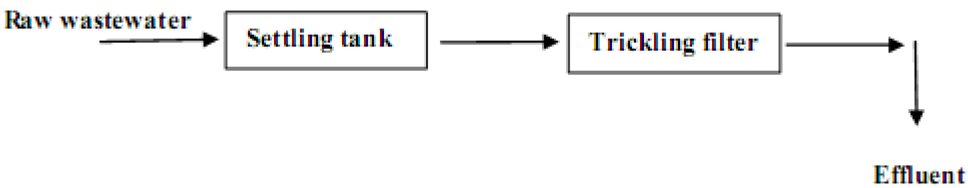

Fig-4: Flow diagram of the treatment process

Experiment

In this experiment, four fingerlings tagged A, B, C, D were cultured in a rectangular tank ($0.29 \times 0.40m \times 0.21m$) with 24.36L to determine the performance of the recirculation system. A fixed volume of water was continuously used for the culture period with 5% addition in every two day to make up for losses due to evaporation and dislodging. Water from the filter was discharged into the fish tank at a rate of 0.64L/s. The fishes were cultured for a total period of 21 days and fed with commercial food around 3% of body weight with 30% of protein content. No mortality was observed throughout the culture period. At the end of the experiment, water quality parameters such as pH, temperature ammonia, dissolve oxygen, nitrate, and total suspended solid were recorded during the experimental period with an interval of 7 days using the standard methods outlined in [10].

DISCUSSION OF RESULT

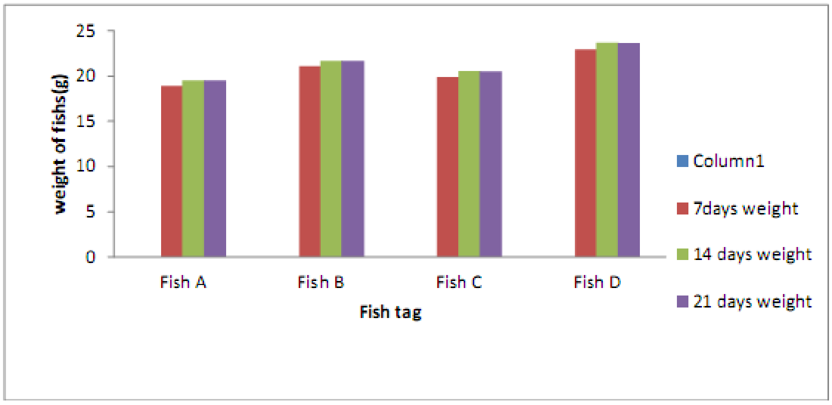

Fig-5: A graph of weight of fish against fish tag

Figure 5 shows that fish A weighed 2.48%, 3.32%, and 0.05%, fish B weighed 2.98%, 2.68%, and 0.05%, fish C weighed 2.11%,3.21%, and 0.14% ,while fish D weighed 2.87%,2.96%,and 0.12% for days of 7,14 and 21 respectively. The result shows that there is a steady and relative weight increased in the weights of the fishes in the experiment up to 14 weeks, but at 21days, there is a decline in the fish's weight. Logically this expresses that the quality of the water can be used to rear fish up to 14 weeks before it can be changed. This result is in confirmation to those of [4] who states that deterioration of the water in RAS caused negative effects on fish growth, increased fish stress and caused health problems in the fish.

Table 1: Effluent quality result for different days (days) and water quality standard

Parameter	effluent concentration for days			Water quality standard	Reference
	7days	14days	21days		
pH	7.0	7.4	6.86	6-9	[12]
Temperature ^{0}C	25	25	27	20 – 30^{o}c	[12]
Ammonia	0.46	0.15	0.53	< 1.0	[4]
Nitrate (mg/L)	5.93	7.19	11.96	< 10	[14]
Nitrite (mg/l)	0.19	0.33	0.50	< 1.0	[4]
Total Suspended Solid (mg/L)	4.93	4.90	5.56	<80	[13]

pH

The reduction of pH in the effluent after 21 days might be related to the micro-organism that has accumulated in the filter which would cause changes of the surrounding pH through the process of respiration and decomposition [11] The pH result shows that the water is slightly acidic at the end of the culture period. The pH within the range 0f 6-9 reported by [12,4]. Thus, the water is suitable for use in Recirculation Aquaculture System in terms of pH.

The Total suspended solids (TSS)

These values are generally below the limit of 15mg/L reported by [14]. Also, [13, 4] had considered a TSS concentration less than 80mg/L and the result of the analysis is far below this value.

Ammonia

The ammonia concentration in recycled water was found to be 0.46mg/L - 0.53mg/L which was below the limit of 1.0mg/L for long- term exposure recommended by [4]. This is confirmed by the pH (6.86) which is almost neutral and almost room temperature of 27^0c as they relate to the concentration of ammonia [13].

Nitrite

From the test result, nitrite was below, but at 21days nitrite concentration increases, which may be due to an imbalance in the nitrification process caused by insufficient dissolve oxygen. So nitrite was slightly above the limit of 1.0mg/L recommended by [14, 4].

Nitrate (NO_3^-)

Nitrate concentration was slightly above the limit recommended. It can be observed that the concentration of nitrite was more than that of ammonia while that of nitrate was more than that of nitrite confirming the actions of microorganism in the trickling filter. This reason for that was lack of a denitrification process. Contrary to ammonia and nitrite, nitrate is relatively non toxic to aquatic animals.

Dissolved Oxygen

The dissolved oxygen requirement of fish varies from specie to specie. It has been observed that optimum range of dissolved oxygen for profitable fish culture is 5.0 to 9.5mg/L [12]. The dissolved oxygen recorded in this experiment decreased during the study but still fall within the recommended range. This indicates that there is sufficient quality of DO in the effluent to sustain the fish. This may be as a result of aeration introduced as water trickles down.

CONCLUSION

The present study assesses the water quality of a recirculation aquaculture system. Based on the findings of this study, the system adopted three 'R^s' of water i.e. reduce, recycle and reuse. The result reveals that the water can be reuse to rear fish for at least two weeks before completely new water can be introduced into the system. The increase in removal rate of the parameter concentration is due to increased thickness observed in the biofilm. The system can be reproduced into a pilot scale for rearing catfish at least a minimum of 14days as it has proved efficient.

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