[ENV07] The performance of the biological filters in removing the ammonia-nitrogen from the recirculating system of an intensive freshwater fishpond

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Introduction

Aquaculture is a rapidly developing industry worldwide. It is the best alternative for the decreasing sources of protein supply from sea and river. Heggberget (1996) observed that new technologies have made a rapid increase possible during the last decades, especially in developing countries.

Currently, aquaculture is progressing towards intensive, controlled environment production units, i.e. intensive recirculating production potential (Ebeling, 1994). In addition, water and land availability constraints in some areas have raised an interest in this kind of system especially when it comes to water reuse and heat conservation.

It is a fact that the most important part in ensuring the success of a recirculating system, especially if it is an intensive culture, is the treatment units. Control of water quality in intensive fish culture systems is often the problem for their successful operation. The most common water quality problems in such systems are oxygen depletion and accumulation of organic matter, inorganic nitrogen, particularly ammonia, and CO_2 (Muir, 1982; van Rijn, 1996).

In-organic nutrients, especially ammonia nitrogen and nitrite nitrogen, are highly toxic to fish and other cultured aquatic species (Armstrong *et al*., 1976; Colt *et al*., 1981; Van Rijn, 1996). Thus the accumulation of these compounds should be avoided. High levels of total suspended solids (TSS) have a detrimental effect on both the fish (as it causes gill damage by fouling, resulting in stress and disease) and the recirculating system components (by clogging the filters) (Wheaton, 1977; van Rijn, 1996). In order to reduce these water quality parameters, biological treatment should be used. Biological treatment of intensive fish culture systems has so far been considered the most economically feasible (van Rijn, 1996) and it is the most promising and attractive method for the removal of nitrogen from wastewater (Chui *et al*, 1996).

Therefore, the objectives of this project are (1) to determine the effectiveness of the biological filter in reducing the ammonia in the recycling stream of an intensive pond, (2) to determine the optimum hydraulic retention time for the biological filter in reducing the ammonia and (3) to establish a design of the biological filter based on the capacity of the pond.

Materials and Methods

This research project, which was set up in KUSTEM, consisted of nine individual units and each unit has an individual configuration. The units were 1) fish tank, 2) sedimentation tank, 3) clarifier tank, 4) sand filter, 5) trickling filter, 6) Denitrification filter, 7) oxygenation and degassing unit, 8) additional oxygen unit, and 9) reservoir (aged tap water, pre-aeration). These units were constructed at different elevation to permit a gravity flow in order to reduce the energy utilization on pumps, except at two unavoidable places, where submersible pumps were used.

Water samples were collected and measured on a daily basis from the influent and effluent of the sand filter and trickling filter. Samples were also taken from the influent and in the fish tanks to determine the whole system's performance. The water quality parameters monitored were the concentrations of DO, BOD, COD, TSS, NH_3-N, NO_2-N, readings of pH and temperature. For DO, pH and temperature, the readings were measured with a portable meter. For BOD and TSS, the readings were analysed using the standard method (APHA, 1998). COD, NH_3-N and NO_2-N were analysed spectrophotometrically according to the standard method.

Tilapia niloticus were the species chosen because of their high immunization of disease (Popma and Masser, 1999). They were considered to be a fairly good food fish and popular among fish farmers (Mohsin and Ambak, 1991). More than 90% of all commercial farmed tilapia are *tilapia nilotica*

(Masser *et al*, 1999). The fish were reared in a concrete tank with the initial density of 5 kg/m^3 or 57 $fish/m^3$, and were reared until the final density became approximately 25 kg/m^3 or 225 $fish/m^3$.

Results and Discussion

In the experiment, the stocking density was considered as a highly intensive aquaculture system (Masser *et al*, 1999). Within this kind of culturing system, the high total suspended solids (TSS) and high in-organic nutrients would be serious problem.

Filtration methods are generally size and/or density limited. Thus one filtration alone is usually unable to remove the range of particle sizes found in recirculating systems and to do so with reasonable cost (McMillan *et al*, 2003).

The aim of the study was to determine whether the sand filter and trickling filter could reduce the TSS, especially through the sand filter and excess nutrients through the trickling filter.

Sand Filter

Figure 1 shows the readings of the unionized-ammonia (NH_3-N) concentrations from the influent and effluent flows of the sand filter. The first 16 days indicate the acclimation process of the system.

This process was established by rearing some fish in the fish tanks at low density in untreated water before starting the whole process. This was done to inoculate the system with nitrifying bacteria. The initial concentration of NH_3-N for acclimation was about 0.1 mg/l.

When the concentration of NH_3-N in the water reached a level which was lower than 0.08 mg/l, the desired density of fish were stoked into the fish tanks (system). Fish only could tolerate concentration of NH_3-N below 0.05 mg/l as according to recommended limit of aquaculture as listed in TABLE 1.

TABLE 1 Recommended Water Quality Requirements of recirculating systems (Masser *et al.*, 1999).

Component	**Recommended value**
Temperature	28 - 30°C[a]
Dissolved Oxygen	> 5 mg/l for warmwater fish > 2 mg/l in biofilter effluent
pH	7.0 – 8.0
NH_3-N	< 0.05 mg/l
Nitrite-N	< 0.5 mg/l
(TSS)	< 80 mg/l[a]
Total hardness	50 – 100 mg/l or more
Total alkalinity	50 – 100 mg/l or more
Carbon dioxide	< 20 mg/l

[a] adapted from Claude (1990).

The overall performance of the sand filter was measured from the removal capacity of the listed water quality parameters as shown in TABLE 2.

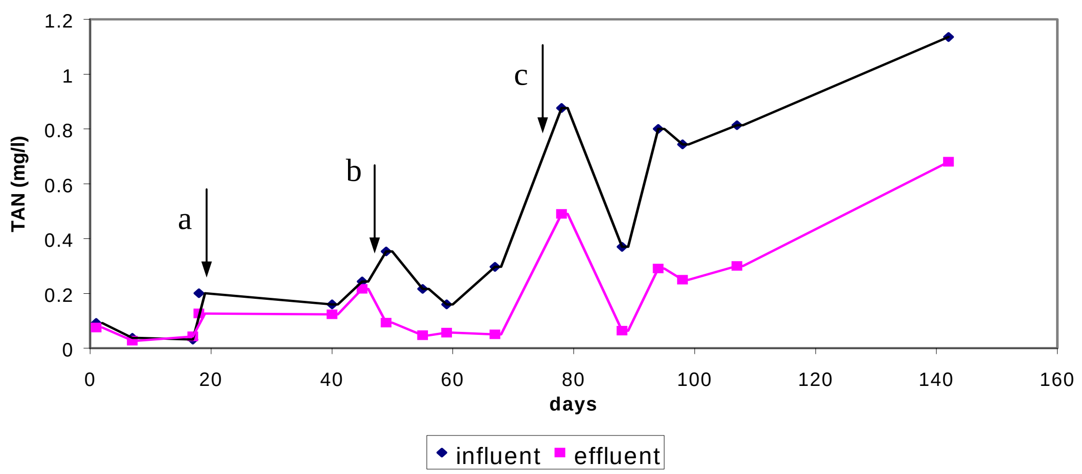

FIGURE 1 The ammonia removal of Sand Filter.

TABLE 2 The performance of sand filter based on the removal capacity of NH_3-N, NO_2-N, NO_3-N, TSS and COD.

Sampling Protocol	NH_3-N	NO_2-N	NO_3-N	TSS	COD
Influent of the Sand Filter (mg/l)	0.52±0.02	0.51±0.02	1.67±0.02	1.35±0.21	24.58±0.24
Effluent of the Sand Filter (mg/l)	0.41±0.02	0.39±0.01	1.44±0.05	0.35±0.07	19.79±0.29
Removal capacity (mg/l)	0.12	0.12	0.23	1.00	4.79
Removal percentage (%)	21.15%	23.53%	13.77%	74.07%	19.49%

The sand filter was constructed to reduce fine solids, especially TSS. In this study, the sand filter could reduce 74.07% of the TSS. This was considered very good. Furthermore, from the data, it is also obvious that the nutrients (NH_3-N, NO_2-N and NO_2-N) had also been reduced. This is acceptable as according to Wheaton (1977), sand filters used with aquatic cultural systems may also be biological filters.

Sand filters also remove some bacteria from water and may also be used to lower the BOD of culture system effluent (Wheaton, 1977). Besides, the gravel arrangement of the sand filter in the experiment was also similar to the submerged biological filter, which influences the process of reducing the nutrients concentrations.

Trickling Filter

As with the sand filter, the concentration of NH_3-N in the acclimation period was very good and remained low. After the first batch of fish stocking in (point a) the trickling filter showed good tolerance (FIGURE 2).

The effluent concentration of NH_3-N steadily decreased. This represents the colony of nitrifying bacteria (nitroso- and nitro-species) grow successfully. The concentration getting lower and reach under the recommendable limit.

On the second batch of additional stocking, the influent showed an increment, but still, the trickling filter could restrain it and the water quality was kept stable even after the input of fish with high a concentration in NH3-N, maintaining the concentration of unionised-ammonia in effluent stream under the considerable limit.

After the third batch of additional stocking, the influent flow had a very high concentration of NH_3-N due to the increment in fish density. However, the trickling filter was in a very good condition and could oxidize high concentration of NH_3-N into less harmful substance, NO_3-N, keeping the concentration of NH_3-N in the effluent flow, stable. The trickling filter did manage to removed unpredictable loading of NH_3-N and oxidize it to NO_3-N and it could cope with high-density fish culturing, giving us a good water quality aquaculture system with a reasonable cost.

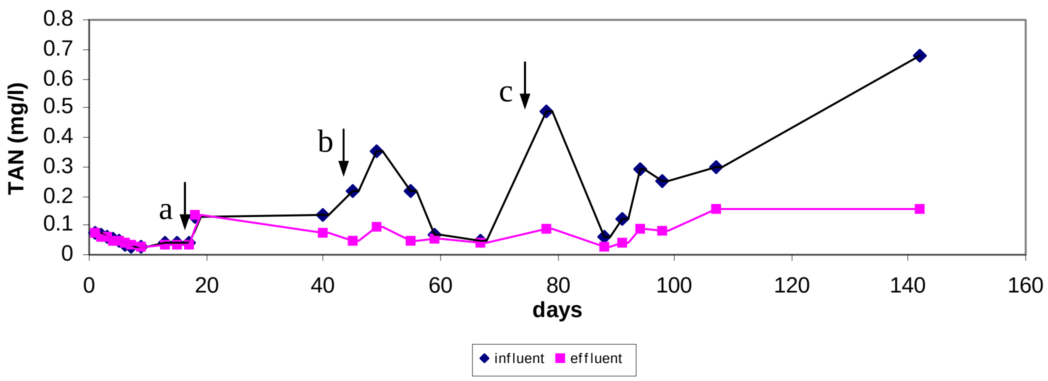

FIGURE 2 The ammonia removal of Trickling Filter.

TABLE 3 The performance of trickling filter based on the removal capacity of NH_3-N, NO_2-N, NO_3-N and COD.

Sampling Protocol	NH_3-N	NO_2-N	NO_3-N	COD
Influent of the Trickling Filter (mg/l)	0.41±0.02	0.39±0.01	1.44±0.05	19.79±0.29
Effluent of the Tricking Filter (mg/l)	0.10±0.01	0.30±0.01	1.33±0.05	16.54±0.29
Removal capacity (mg/l)	0.31	0.09	0.11	3.25
Removal percentage (%)	75.60 %	23.08%	7.64 %	16.42 %

TABLE 4 The performance of denitrification filter based on the removal capacity of NH_3-N, NO_3-N and COD.

Sampling Protocol	NH_3-N	NO_3-N	COD
Influent (mg/l)	0.10±0.01	1.33±0.05	16.54±0.29
Effluent (mg/l)	0.05±0.01	1.13±0.04	14.42±0.35
Removal capacity (mg/l)	0.03	0.19	2.13
Removal percentage (%)	30.00%	15.04%	12.82%

The system also can restrain the nutrients well, resulting in the under- recommendable-limit water quality environment.

The overall performances of the trickling filter established from the removal efficiency of listed water quality parameters as listed in TABLE 3.

The results showed that the trickling filter's removal efficiency of NH_3-N was 75.6%. This was a very good performance as according to Losordo (1994), recirculating production system has indicated that 30 – 50 % of the ongoing nitrification within the system is "passive".

TABLE 4 shows the summary of the removing capacity of a denitrification filter that was set-up after the trickling filter. There was slight NH_3-N and COD removals occurred in addition to the NO_3-N removal. This was desirable as the concentrations of NH_3-N flow out from the trickling filter were still slightly high than the recommended concentration. So, the decomposition happened here would improved the whole efficiency of the recirculating system.

The whole performance of the recirculating system was satisfying as all the critical water quality parameters for aquaculture were in control as shown in TABLE 5 in the next page. The ammonia removals through our whole recirculating system were very good. The high percentage of the removal were contributed not only from a single trickling filter (the main nitrification unit) but had been removed all the way through the whole system.

Conclusion

The recirculating system with the particular studied design was able to show the improvement of fish farming technology as well as good culture environment. From the results, it might be concluded that the freshwater fish species, either its fingerlings or market-sized crops, can be cultured in this recirculating system, producing better yield. In conclusion, it could be stated that, the studied recirculating system technology is technically feasible and economically viable.

TABLE 5 The performance of the whole recycling system

Parameter	Concentration during culture period (mg/l)		Whole system's removal capacity	Whole's system removal percentage
	Fish Tank	Influent of the fish tank		
Biological oxygen demand (BOD)	5.24±1.13	0.97±0.27	4.28	81.49%
Chemical oxygen demand (COD)	34.39±2.62	11.52±1.60	22.87	66.50%
Un-ionized ammonia-Nitrogen (NH_3-N)	0.70±0.06	0.05±0.01	0.63	92.86%
Nitrite- Nitrogen (NO_2-N)	0.72±0.03	0.20±0.00	0.52	72.22%
Nitrate-Nitrogen (NO_3-N)	2.20±0.09	1.10±0.01	1.10	50.00%
Total suspended solid (TSS)	3.40±0.31	0.32±0.12	3.08	90.56%
Dissolve Oxygen (DO)	4.55±0.34	5.55±0.89	1.00	18.02%
pH	6.77±0.05	7.09±0.12	-	-
Temperature	27.54±0.37	27.61±0.31	-	-

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