Novel Mechanical Filter for reducing Ammonia Concentration of Silver Barb culture in a Recirculating Aquaculture System (RAS)

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Abstract
This study aims to reduce the concentration of ammonia in the silver barb culture in recirculation system by adding a mechanical filter. This research was conducted on January to February 2014 at hatchery of Freshwater Aquaculture Production Development Centre (BPPBAT) Singaparna, Tasikmalaya Regency, West Java, Indonesia. The study was designed experimentally with two treatments i.e. treatment without filter and filtering treatment. The experiment was carried out for 24 days and observed every two days. The results showed that the addition of filter can reduce total ammonia up to 92.82%, unionized ammonia up to 89.12% and it is able to increase dissolved oxygen up to 54.23% and silver barb survival rate equal to 99.87%.

Keywords: Ammonia, recirculation, silver barb, mechanical filter.

Introduction

Aquaculture is an economic activity that increases in order to fulfill animal protein requirement. This activity is having a positive impact in the fulfillment of animal protein requirement, making aware on waste generated. Waste generated from aquaculture can cause negative impact on the waters if it is not managed properly. Aquaculture waste entering the aquatic environment composed of organic and inorganic materials including ammonia, phosphorus and dissolved organic carbon[1,2]. Waste generated from the intensive aquaculture can lead to decrease in water quality both in the aquaculture environment and in the surrounding waters, this can have an impact on the decrease in aquaculture productivity due to decreasing fish growth and cause death in severe condition[1,2].

Ammonia is one of the wastes to be noticed. Ammonia in the aquaculture is mainly derived from uneaten feed, fish faces and fish urine. Ammonia concentration will increase as the protein content in the feed increases. Ammonia is a growth inhibiting factor[3]. Furthermore, it is stated that at concentrations of 0.18 mg/ L ammonia can inhibit fish growth. An un-ionized ammoniacal nitrogen (NH_3-N) level of 0.019 mg/L would be considered acceptable for channel catfish production.

However, the un-ionized NH_3-N concentration of 1.2 mg/L recorded at 1600 hr could be lethal to channel catfish within several hours[4]. Even, according to Sawyer et al[5], unionized ammonia concentrations above 0.2 mg/ L can cause death in some species of fish. Therefore, the concentration of ammonia in the water needs to be observed. Treatments that can be done to overcome these problems include by applying aquaculture recirculation system. According to Suantika[6], the aquaculture recirculation system has been used since the 1990s. This system has advantage of repeated water utilization[7].

The use of filters in aquaculture with recirculation system plays an important role to improve water quality in fish ponds. The filter used is a mechanical filter using materials such as zeolites, confirmed by Purtie[8] which states that zeolites and activated charcoal as absorbent in filtration can reduce ammonia concentration of 85.40%. The effectiveness of filtration using a mechanical filter is related to the filter design used, as Collins[9] states that water filters with down-flow and up-flow water flow systems can maximize the filtering process.

The recirculating aquaculture system (RAS) can be defined as an aquaculture system related to treatment and reuse of water with less than 10% daily replacement of water. The treated water is required to accommodate feed inputs of high amounts to support high growth rate and stocking density [10].

Several researches on the RAS have been done to improve the quality of water in the form of physical quality such as temperature[11] and chemicals such as oxygen, ammonia, nitrate, pH, alkalinity[12], water equilibrium model of aquaculture recirculation system[13,14]. Water flow models for mechanical filtration and changes in hydraulic properties[13] and fish growth in the aquaculture recirculation system[12] have been studied.

Nurhasani et al[15] in their study stated that the activated carbon can be used as an absorbent with an adsorption efficiency value up to 88.43% and 41.6% for Al ion and Fe ion respectively and the value of adsorption capacity for each ion is of 1.0262 mg/ g and 0.2473 mg/ g. Sumarlin et al[16] stated that zeolites can absorbs ammonium (NH_4^+) of varying urine concentrations from 5% up to 25%. The smallest ammonium concentration was found in the treatment with a urine concentration of 20% i.e. 51.243 mg/L with an initial concentration of 72.513 mg/L. Meanwhile, Putrie[8] states that the mixture of zeolite and activated charcoal is the most effective absorbent in filtration because it can reduce the concentration of ammonia in the vermicelli liquid waste up to 85.40%. While Irmanto and Suyata[17] stated that acid-activated, alkali-activated and acid-impregnated zeolites can be used to decrease the concentration of ammonia in liquid waste in tofu industry with an efficiency of 84.26%.

The advantage of mechanical filter is to allow for aeration through diffusion (figure 1). The aeration caused dissolved oxygen needed by fish for respiration and for nitrification process became more available.

Material and Methods

This research was conducted in January to February 2014 at hatchery of Central of Freshwater Aquaculture Production Development (BPPBAT) Singaparna, Tasikmalaya Regency, West Java, Indonesia. The research was conducted experimentally with two treatments i.e. treatment without filtering and filtering treatment. The study was conducted for 24 days and the observation was done every two days, so there were 12 pairs of research data. Fish pond used were two fiber pond size 200x100x60 cm^3, the observed fishes are 2 - 3 cm silver barb fry as much as 10 kg (± 7200 seeds). The first pond is without filter while the second one was provided with filter as shown in figure 1.

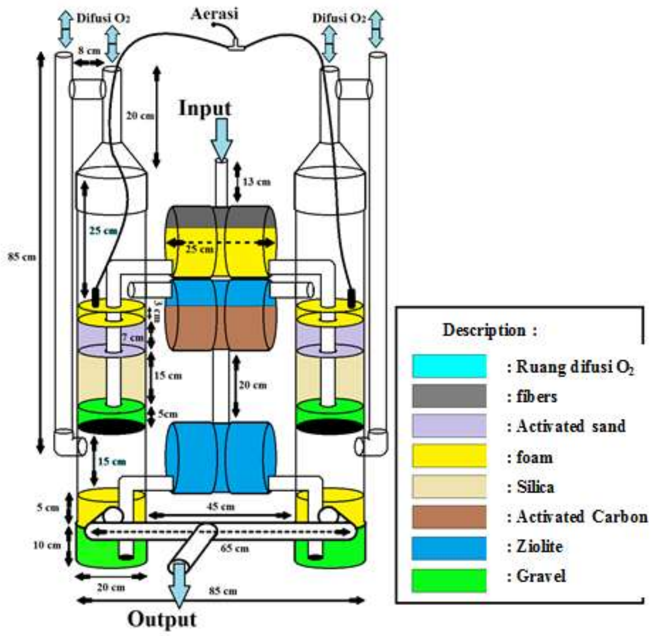

Figure 1: Filter designed

The data obtained were analyzed using paired t test with 95% confidence level. In addition, water quality data obtained was compared to water quality standards for freshwater fish culture in Indonesian Government Regulation No. 82 of 2001.

The parameters tested in this study consist of the main parameters and supporting parameters. The main parameter of this research is water quality which consisted of ammonia and DO while supporting parameter that is survival rate (SR) of silver barb fish as test fish. The parameters measured and its methods are shown in table 1.

Ammonia and dissolved oxygen were measured every two days meanwhile fish survival rate calculating was done at the end of the study. To obtain the effectiveness of the filter, percentage of ammonia decreasing is calculated with the following equation[17]:

$$K = \frac{Co - Ct}{Co} \times 100\ \%$$

where K = Percentage decrease of ammonia concentration; Co = Concentration of ammonia in water without filter and Ct = Concentration of ammonia in water using filter.

The fish survival rate was calculated using the formula[18]:

$$SR = \frac{Nt}{No} \times 100\%$$

where SR = Survival rate (%); Nt = Number of fish that live at the end of the observation and No = Number of fish at the beginning of observation.

Results and Discussion

Ammonia: The results showed that the use of filters on fish ponds using the recirculation system can reduce the ammonia concentration in water as shown in figure 2.

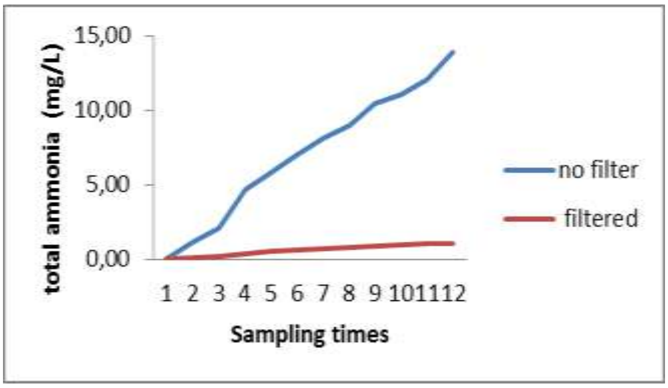

Figure 2: Total ammonia concentrations during study

Ammonia concentrations in water in fish pond equipped with a filter were lower than that of ammonia in water in fish pond without filter. The use of filter on fish ponds using recirculation systems can reduce the total ammonia concentration in water averaging 91.53%. The effectiveness of filter in decreasing ammonia concentrations depends on the filter mechanism and filter media used, the most important filter media in minimizing ammonia concentration is zeolite because it is capable of adsorbing ammonia and ammonium ions and releasing ions Na^+ or K^+ ions.

$$(Zeolite – Na^+ / K^+) + NH_3 \rightarrow (Zeolite – NH_3) + Na^+ / K^+$$
$$(Zeolite – Na^+ / K^+) + NH_4^+ \rightarrow (Zeolite – NH_4^+) + Na^+ / K^+$$

The higher availability of dissolved oxygen in filtered ponds resulted in a higher nitrification process performed by aerobic nitrosomonas and nitrobacter bacterias. The higher nitrification means the lower ammonia concentration.

The fraction of total ammonia nitrogen is largely in the form of non-toxic ammonium ions because cell walls cannot be penetrated by ammonium ions, whereas unionized ammonia (NH_3) will easily diffuse across the tissue in high concentration and potentially toxic to fish[19]. Ionization of ammonia depends on pH and water temperature. The higher pH and temperature make the ammonia toxicity higher. The concentration of ammonia unionized (NH_3) based on temperature and pH at the time of the study can be seen in figure 2. Concentrations of total ammonia, ammonia unionized and ammonium during the study are shown in table 2.

Table 2 shows that the highest unionized ammonia concentration found in the filtered fish pond is in the 9th sampling of 0.0988 mg/L. This value does not exceed the water quality standard for freshwater fish culture as stated by Boyd[20] that the standard of NH_3 for freshwater fish culture is less than 0.1 mg / l at pH value 7.0-9.0. This value is also suitable with quality standard required for aquaculture based on Indonesian government regulation no 82 years 2001.

Dissolved Oxygen (DO): Based on the measured data of the oxygen concentration in water (figure 4), the fish pond without filtration has lower dissolved oxygen compared to fish pond with filtration. The average dissolved oxygen concentration in the unfiltered pond was about 3.19 mg/L whereas in the filtered pond the value was 4.92 mg/L (table 3).

According to Boyd[20], dissolved oxygen concentration optimal for freshwater fish culture is 5.0-15 mg/L while based on Indonesian Government Regulation no. 82 Year 2001 on water quality criteria class 2, this value is suitable for aquaculture activities with minimal dissolved oxygen concentration of at least 4.0 mg/L.

Survival rate: The survival rate of silver barb as a observed fish in an unfiltered pond continues to decline as it is suspected because of the growing burden of ammonia contaminants during fish maintenance and exceeds the tolerance limit for fish so that the silver barb fishes are classified as sensitive to many dead ammonia concentrations. The survival data of silver barb fish as a test fish was associated with inionized ammonia concentrations as can be seen in table 4.

Based on table 4, it can be seen that fish mortality in unfiltered pond occurred since the beginning, but high mortality started in the 3rd sampling. The survival rate of the silver barb is still high up to 6th sampling with the percentage above 90%, but in the 7th survival rate dropped dramatically until there were no fish living on the 11th sampling. The survival rate of silver barb on filtered pond is very high that is 99.8%. Death of fish is only found in the first sampling of 8 seeds and in this case the death is not due to the presence of pollutants, but due to technical faults in the installation of water pump sieves that causes the fish to be sucked and caught in the filter valve recirculation pump that pushes water from the fiber to the filter.

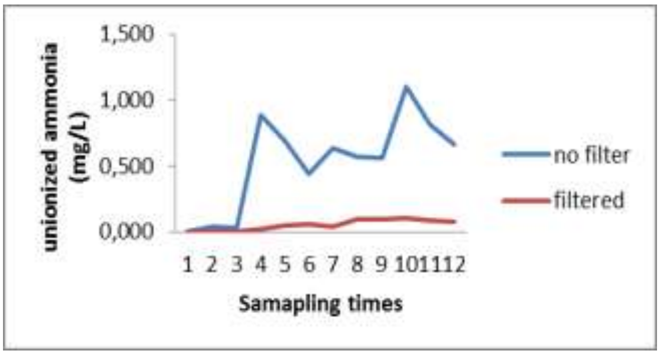

Figure 3: Unionized ammonia concentration during study

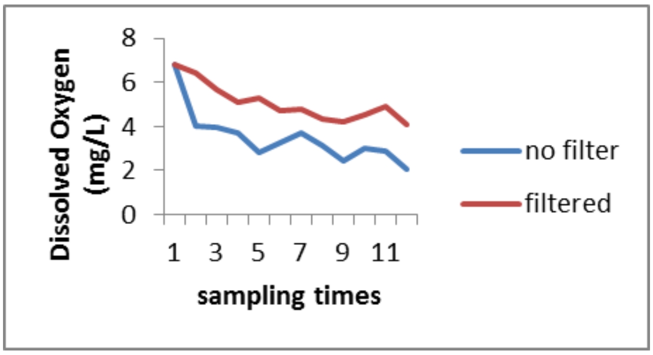

Figure 4: Dissolved oxygen during study

Table 1
Parameters Measured and Methods

S.N.	Parameter	unit	Methods
1	Ammonia	mg/L	Spectrophotometry
2	DO	mg/L	Winkler
3	Survival rate	%	numeric

Table 2
Concentration of total ammonia, unionized ammonia and ammonium during study

Sampling times	Filtered			without Filter		
	NH_4+NH_3 (mg/l)	NH_4 (mg/l)	NH_3 (mg/l)	NH_4+NH_3 (mg/l)	NH_4 (mg/l)	NH_3 (mg/l)
0	0.01	0.0093	0.00007	0.01	0.0093	0.00007
1	1.17	1.1306	0.0394	0.10	0.0966	0.0034
2	2.04	2.0114	0.0286	0.22	0.2167	0.0033
3	4.65	3.7646	0.8854	0.32	0.3036	0.0164
4	5.80	5.1070	0.6930	0.49	0.4423	0.0477
5	7.03	6.5919	0.4381	0.58	0.5223	0.0577
6	8.10	7.4611	0.6389	0.71	0.6736	0.0364
7	9.00	8.4269	0.5731	0.76	0.6691	0.0909
8	10.42	9.8621	0.5579	0.83	0.7366	0.0934
9	11.06	9.9612	1.0988	0.95	0.8112	0.0988
10	12.10	11.2849	0.8151	1.08	0.9929	0.0871
11	13.93	13.2637	0.6663	1.00	0.9275	0.0725

Table 3
Dissolved oxygen during study

Sampling times	DO (mg/l)	
	Filtered	without Filter
0	6.81	6.81
1	4.01	6.43
2	3.97	5.68
3	3.72	5.12
4	2.80	5.30
5	3.28	4.70
6	3.72	4.75
7	3.14	4.36
8	2.43	4.21
9	3.01	4.50
10	2.88	4.93
11	2.09	4.10
Average	3.19	4.92

Table 4
Survival rate of silver barb and unionized ammonia concentration

Sampling times	Filtered		without Filter	
	Ammonia conc. (mg/L)	No. of fish death	Ammonia conc. (mg/L)	No. of fish death
0	0.0394	1	0.0034	8
1	0.0286	7	0.0033	-
2	0.8854	70	0.0164	-
3	0.693	138	0.0477	-
4	0.4381	189	0.0577	-
5	0.6389	321	0.0364	-
6	0.5731	441	0.0909	-
7	0.5579	720	0.0934	-
8	1.0988	1207	0.1388	-
9	0.8151	1683	0.0871	-
10	0.6663	3.602	0.0725	-
11	0.0394		0.0034	-

As indicated in table 4, the high unionized ammonia in water is a major factor in fish mortality. In unfiltered pond, ammonia concentrations has exceeded the tolerance limit since 3rd sampling that is 0.8854 mg/ L. This value has exceeded the quality standard required by Indonesian government regulation of 0.2 mg/ L and Boyd's recommendation which states that ammonia concentration for freshwater aquaculture cannot exceed 0.1 mg/ L[20].

Conclusion

The conclusion of this research is that the filter used can reduce total ammonia concentration of 92.82%, unionized ammonia by 89.12 % and increase the concentration of dissolved oxygen by 54.23% and resulted in the survival rate of 99.87%

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