Next Generation Water Treatment System: Ultrafiltration and Ozone-Enhanced Protein Skimmer

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ABSTRACT: Conventional aquatic water treatment systems use nitrifying bacteria in biological filters to detoxify ammonium nitrogen, a by-product of fish and invertebrate metabolism. These biological filters require a large space and need several weeks to stabilize after introduction. In addition, the use of biological filters necessitates replacement of 3 - 10% of system water each day to reduce accumulated nitrate nitrogen to acceptable concentrations. ORGANO Corp. and Kitasato University have developed a compact and easy to operate filtration system that reduces ammonia nitrogen using a combination of ultrafiltration and ozone-enhanced foam fractionation. This new system requires a small installation space, removes ammonium nitrogen immediately upon startup, and results in a reduced accumulation of nitrate nitrogen. We conducted a comparative test of conventional and new system. It was performed on a 100 L (approx.) aquarium supporting moon jelly of the species: Aurelia coerulea. The test was conducted with 2 cases. In the first case, acclimated nitrifying bacteria were not introduced. For the conventional system, all moon jellies died at early stage. On the other hand, all moon-jellies grew ideally in the new system. The second case was conducted with the presence of acclimated nitrifying bacteria in the conventional system. From the commencement of operation, both ammonium nitrogen and nitrate nitrogen were maintained at less than 0.1 and 3.0 mg N/L, respectively, with a seawater replacement of <0.1% per day in the new system. The ratio of wet weight to bell diameter of jellyfish showed an ideal growth compared to the conventional system throughout the trial (180days). Space required for the new filtration system is estimated to be half (50%) of that required for a more conventional water treatment system incorporating a biological filter.

INTRODUCTION

In Japan, large-scale aquariums are built in urban and inland areas. These aquariums reuse seawater through water treatment systems[1].

An important role of the aquatic water treatment system is to detoxify ammonium nitrogen. While conventional aquatic water treatment systems use nitrifying bacteria in biological filters to detoxify ammonium nitrogen, nitrate nitrogen as a by-product is produced. High concentration of nitrate nitrogen is toxic to aquatic organisms. To avoid the accumulation of nitrate nitrogen, it is necessary to replace the aquatic water or add a de-nitrification system[2]. Seawater replacement increases the operation cost, effluent cost and environmental load by discharge of waste water. Adding a de-nitrification system increases the capital cost and requires a large space because of low reaction rate. In addition, the conventional system will need several weeks to remove toxic ammonium nitrogen with stability[3]. It is then possible that toxic ammonium nitrogen can be accumulated at start up.

Ammonia is decomposed to nitrogen by hypobromine[4]. We considered using the bromine in seawater to produce hypobromine by ozone oxidation. Furthermore, we use ultrafiltration for removal of turbidity and bacteria instead of sand filtration. In this paper, we described a compact and easy to operate filtration system that reduces ammonia nitrogen using a combination of ultrafiltration and ozone-enhanced foam fractionation.

EXPERIMENTAL METHODS

Water treatment system

We tried a comparison test between the conventional biological filter system (hereinafter, conventional system) and the ultrafiltration and ozone-enhanced foam fractionation system (hereinafter, new system).

In the conventional system, the flow passed through the nonwoven fabric filter, the activated carbon column, the ceramic filter and then returned to the tank (Fig.1).

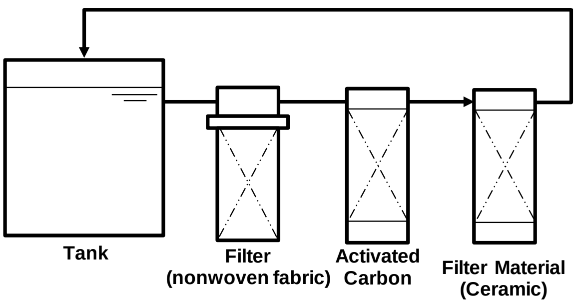

Fig.1. Flow diagram of conventional system

On the other hand, in the new system, the flow passed through the safety filter, the ultrafiltration (UF), and the activated carbon column and returned to the tank (Fig.2). The UF concentrate passed through the ozone-enhanced foam fractionation, and then returned to the tank. The operating conditions are summarized in Table 1.

Moreover, we tested two cases. In the first case, the conventional system didn't use acclimated nitrifying bacteria, while it was used in the second case. Rearing animals in those systems were moon-jelly, *Aurelia coerulea*. 20 individuals were used in first case, and 10 individuals were used in second case in each system.

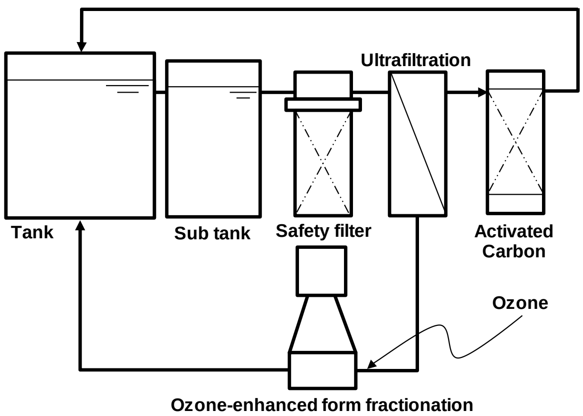

Fig. 2. Flow diagram of new system

RESULTS AND DISCUSSION

a) First Case

Growth of Moon Jelly

The ratio of wet weight to bell diameter of jellyfish in the new system showed an ideal growth for 30 days (Fig.3). The exponent of the power relation was 2.78. On the other hand, all moon-jellies died at early stage, about seven days, in the conventional system. The result was not in correlation with the water quality and reasons are yet to be concluded but the fact still remains that the new system showed ideal growth.

b) Second Case

Seawater Quality

Figs. 4 and 5 show the change of ammonium nitrogen and nitrate nitrogen concentration, respectively. At the start-up, the ammonium nitrogen concentration of the new system was lower than the conventional system because the biological filter was not yet effective in detoxifying ammonium nitrogen due to less acclimatization days. After a few weeks, both new and conventional systems detoxified ammonium nitrogen. But for nitrate nitrogen, there was a difference on the behavior of between two systems. While nitrate nitrogen of conventional system increased up to 11 mg/L, that of new system is less than 3 mg/L for 180 days. These results show the frequency of seawater replacement of the new system to control nitrate nitrogen is less than the conventional system.

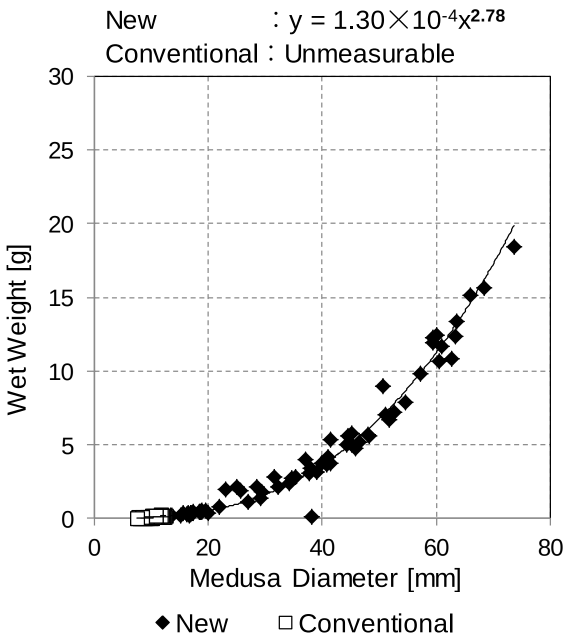

Fig.3. Growth rate (First Case)

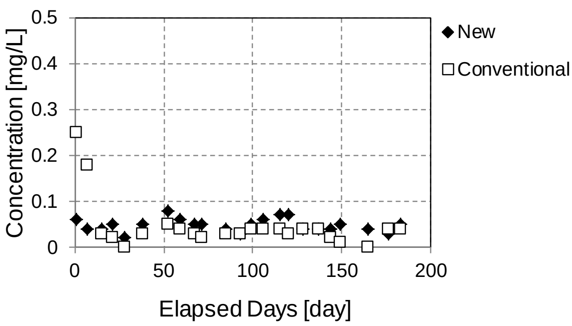

Fig. 4. Ammonium Nitrogen.

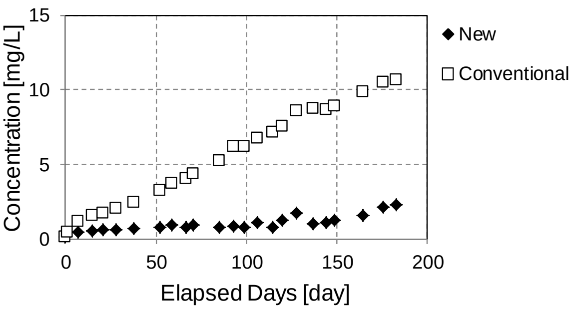

Fig. 5. Nitrate Nitrogen

Growth rate of moon jellies

The ratio of wet weight to bell diameter of jellyfish in the new system showed an ideal growth for 180 days (Fig.6). The exponent of the power relation was 2.81. In the conventional system, the power relation was 2.52 which is less than that of the new system. These results show that the new system provides better aquatic water conditions for moon-jellies.

c) Installation space

As an example, we have estimated the installation area for 300 m^3 aquarium unit based on these results. The installation area of the new system would be about half the space of the conventional system. (New system: 315 m^2, Conventional system: 600 m^2)

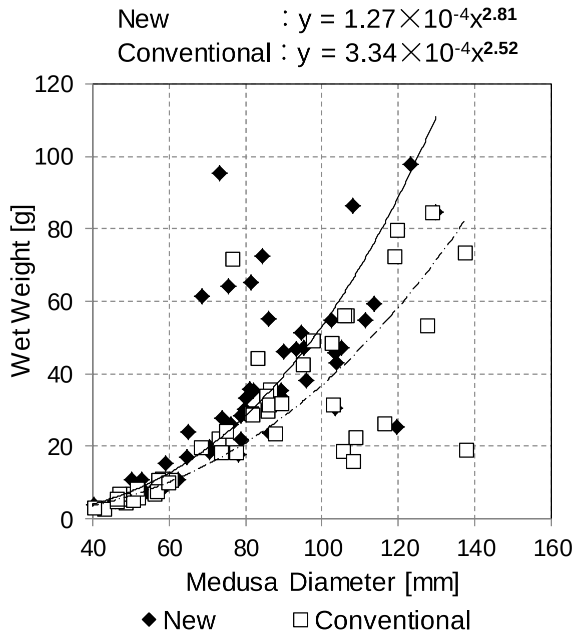

Fig.6. Growth rate (Second Case)

Table 1. Operating conditions

Parameters	unit	Conventional	New
Moon-jellies	-	Aurelia coerulea	
Seawater	-	Artificial Seawater (Live SeaSalt) about 3.5%	
Tank Volume	L	125	110
Flow rate	turn/d	45	7
Density	kg/m^3	0.1-3.5	0.1-5.5
Recovery	%/d	> 99.9	
Temperature	℃	23-26	

CONCLUSION

The new system which uses a combination of ultrafiltration and ozone-enhanced foam fractionation controls the ammonium and nitrate nitrogen with the seawater replacement of <0.1 % per day. The ratio of wet weight to bell diameter of jellyfish showed an ideal growth for 180 days. Installation space required for the new filtration system is estimated to be half (50%) of that for the conventional system. This new system is expected to be a candidate for the new generation of water treatment system for aquariums.

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