Global Scientific JOURNALS

GSJ: Volume 8, Issue 5, May 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

THE OVERVIEW OF UTILIZATION OF NUTRIENT REMOVAL IN RECIRCULATING AQUACULTURE SYSTEM

Fittrie Meyllianawaty Pratiwy*

**Lecturer, Department of Fisheries, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Jl. Raya Sumedang KM 21 Sumedang 45363, Indonesia*
fittrie.pratiwy@unpad.ac.id

KeyWords
Recirculating Aquaculture System, RAS, Nutrient removal, Microbial biofilter

ABSTRACT

The improvement of environtmentally sustainable aquaculture using Recirculating Aquaculture System (RAS) requires a total comprehension of the biological and technological component with wastewater treatment. This part discussed about the utilization of type nutrient removal and biofilter from microorganisms. This integration at least has one requirement from the following criteria; high technology, environmentally friendly, disease-free, etc. thorough the knowledge of wastewater treatment and has recently been focus on the maintaining the nutrient aspect.

Concentration of nitrogen compounds in aquaculture to low level or non-toxic level is a key requirement of Recirculating Aquaculture System (RAS). This review aims to summarize the potential ways and sources of nutrient removal in Recirculating Aquaculture System (RAS).

Introduction

Recently, the development of environmentally friendly of aquaculture has been increasing rapidly such as a closed-recirculating aquaculture system. It has been studying in the past decade to optimize the utility of water and control the water quality parameters. In addition, it prevent more cost effective alternatives for disease, water supply, land availability, or environmental changes [1]. Namely, Recirculating Aquaculture System (RAS), the design focused on minimization the water consumption and the water management. Even though the development of this system has been investigated since a long time ago in several fish species such as European sea bass Dicentrachus labrax [2], Gilthead seabream Sparus aurata [3], tilapia Nile tilapia, Atlantic salmon Salmo salar [4].

This system consume less water by reusing the water and require an effective systemic treatments [5] to maintain a good water quality [6] which nitrate and phosphate could be removed. In RAS, Ammonia (NH3) and nitrite (NO2-) are nitrified to nitrate (NO3-) [7]. However, the nitrate (NO3-) might be give a negative chronic effect to the aquaculture animals and for land-based recirculation aquaculture systems even though the aquaculture organisms could tolerate the levels of nitrate up to 100 mg/L NO3-N [4]. On the other hand, phosphorus as a wastewater would be removed by photosynthetic organisms [8] using organic carbon as an electron donor [9], but its biodegradable compounds are not available enough in RAS system.

Nitrogen removal could use denitrification processes to be one of the most feasible and cost-effective methods of NO3-N removal from water [10], but phosphorus removal required additional process such as enhanced biological phosphorus removal [8] because bio-filters like used for nitrogen removal are not enough to decrease the phosphate and phosphorus assimilation by photosynthetic microorganisms was not detected [8].

In general, the discharging nitrogen and phosphorus into the natural resources lead an eutrophication and might be harm for aquatic organisms. This review summarizes some selected studies related to nutrient nitrogen and phosphorus

removal in RAS. Emphasis is comparison of technology and the methods of biological processes within the RAS.

Potentiality of Nutrient Removal

Nitrogen removal
In RAS ammonia and nitrite became the most toxic for aquatic animals. One of the major treatment process in RAS to remove ammonia and nitrite is nitrification; ammonium converted to nitrite and at the end of phase transformed to the lower toxic nitrate [1], [7]. There were several studies about nitrogen removal and summarized based on the removal rate (Table 1).

Table 1. Studies of Nitrogen Removal in RAS

Nutrient removal (removal rate/day)	*Treatments*	*References*
Nitrate 0.71 ± 0.07 and 0.80 ± 0.15 g N removed/L	fluidized sulfur-based autotrophic denitrification biofilter	Christianson, et al. 2015
Ammonia(52.1 g-N m−3)/nitrate(169.1 ± 8.8 g-N m−3)/nitrite/COD	pumice bottom substrate nitrification-denitrification	Pungrasmi, et al. 2016
Nitrate (15.85 ± 2.24 mg/L), Ammonia, and COD	microbial fuel cell (MFC)	Zhou, et al. 2018
Nitrate removal rate of 22.0 ± 6.9 g NO3-Nm−3	Woodchip bioreactor	Ahnen, et al. 2019
TN Removal (60.1%)	Simulation Nitrification and Denitrification (SND)	Zhang, et al. 2020
ammonia (92%)/nitrate(63%)/nitrite (99%)	simultaneous partial nitrification, anammox and denitrification (SNAD)	Lu, et al. 2020

Several previous study have successfully utilized to remove nitrogen with low carbon nitrogen ratio, such as SND (Simulation Nitrification and Denitrification) [11]. In the meantime, anaerobic ammonium oxidation (anammox) have been widely applied to nitrogen removal [12], which was an energy-saving friendly. The development of Anammox as the important nitrogen removal process in RAS could be the potential agent during the reducing oxygen demands and the autotrophic process. Anammox could be the one of the potential bacteria to replace conventional denitrification reactors.

Utilization of Microbial Biofilter

The stability of the aquaculture environment in RAS is depends on the microorganism [13]. The biofilter is a microbial refinement connect to RAS and acts to eliminate the nitrogenous waste by-products created by fish protein catabolism and oxidation process [14]. However, the biofilter is a complicated system and mechanism. Several studies have established the microbial community composition in the bioreactor for the efficiency of the biofilter.

Mostly, microbial community composition in biofilter dominantly composed by Proteobacteria (Nitrobacter sp., Nitrosomonas sp., and Nitrosospira sp.) [15]and there are three genera; Nitrosomonas, Nitrosospira and Nitrosococcus as the ammonia-oxidizing bacterium (AOB) and four genera; Nitrobacter, Nitrospina, Nitrococcus and Nitrospira as the nitrite-oxidizing bacterium (NOB) in the process of nitration [13]. Nitrospira reported could maintain the concentration of ammonium and nitrite below the toxic level for fish [13]. The utilization of microorganisms in biofilter of RAS summarized in

Table 2. Some microorganisms such as Streptomyces, Myxobacteria and Cyanobacteria are accociated with the accumulation of off-flavour compounds; the presence of geosmin [16].

Table 2. The utilization of microorganisms in biofilter of RAS*

Proccess	*Microorganism*	*Author*
Nitrification		
Ammonium oxidation	*Nitrosomonas* sp.	[Chen & Kreuter 1996][Tal, et al. 2003]
Nitrite oxidation	*Nitrospira* sp.	[Chen & Kreuter 1996][Foesel, et al. 2008]

*Adopted from Schreier et al. (2010)

References

[1] R. Malone, "Recirculating Aquaculture Tank Production Systems A Review of Current Design Practice," *South. Reg. Aquac.*, no. 453, pp. 1–12, 2013.

[2] E. Metaxa, G. Deviller, P. Pagand, C. Alliaume, C. Casellas, and J. P. Blancheton, "High rate algal pond treatment for water reuse in a marine fish recirculation system: Water purification and fish health," *Aquaculture*, vol. 252, no. 1, pp. 92–101, 2006.

[3] A. Schuenhoff, M. Shpigel, I. Lupatsch, A. Ashkenazi, F. E. Msuya, and A. Neori, "A semi-recirculating, integrated system for the culture of fish and seaweed," *Aquaculture*, vol. 221, no. 1–4, pp. 167–181, 2003.

[4] J. Davidson, C. Good, C. Williams, and S. T. Summerfelt, "Evaluating the chronic effects of nitrate on the health and performance of post-smolt Atlantic salmon Salmo salar in freshwater recirculation aquaculture systems," *Aquac. Eng.*, vol. 79, no. May, pp. 1–8, 2017.

[5] J. H. Wang, J. Lu, Y. X. Zhang, J. Wu, Y. Luo, and H. Liu, "Metagenomic analysis of antibiotic resistance genes in coastal industrial mariculture systems," *Bioresour. Technol.*, vol. 253, pp. 235–243, 2018.

[6] J. P. Schroeder, P. L. Croot, B. Von Dewitz, U. Waller, and R. Hanel, "Potential and limitations of ozone for the removal of ammonia, nitrite, and yellow substances in marine recirculating aquaculture systems," *Aquac. Eng.*, vol. 45, no. 1, pp. 35–41, 2011.

[7] J. Van Rijn, "Waste treatment in recirculating aquaculture systems," *Aquac. Eng.*, vol. 53, pp. 49–56, 2013.

[8] S. Burut-Archanai, J. J. Eaton-Rye, A. Incharoensakdi, and S. Powtongsook, "Phosphorus removal in a closed recirculating aquaculture system using the cyanobacterium Synechocystis sp. PCC 6803 strain lacking the SphU regulator of the Pho regulon," *Biochem. Eng. J.*, vol. 74, pp. 69–75, 2013.

[9] G. Luo, Z. Hou, L. Tian, and H. Tan, "Comparison of nitrate-removal efficiency and bacterial properties using PCL and PHBV polymers as a carbon source to treat aquaculture water," *Aquac. Fish.*, no. August 2018, pp. 0–1, 2019.

[10] L. Chu and J. Wang, "Denitrification performance and biofilm characteristics using biodegradable polymers PCL as carriers and carbon source," *Chemosphere*, vol. 91, no. 9, pp. 1310–1316, 2013.

[11] Y. Zhang, L. Zhao, T. Song, Y. Cheng, M. Bao, and Y. Li, "Simultaneous nitrification and denitrification in an aerobic biofilm biosystem with loofah sponges as carriers for biodegrading hydrolyzed polyacrylamide-containing wastewater," *Bioprocess Biosyst. Eng.*, vol. 43, no. 3, pp. 529–540, 2020.

[12] J. Lu, Y. Zhang, J. Wu, and J. Wang, “Nitrogen removal in recirculating aquaculture water with high dissolved oxygen conditions using the simultaneous partial nitrification, anammox and denitrification system,” *Bioresour. Technol.*, vol. 305, p. 123037, 2020.

[13] Z. Chen *et al.*, “Effects of water recirculation rate on the microbial community and water quality in relation to the growth and survival of white shrimp (Litopenaeus vannamei),” *BMC Microbiol.*, vol. 19, no. 1, pp. 1–15, 2019.

[14] R. P. Bartelme, S. L. McLellan, and R. J. Newton, “Freshwater recirculating aquaculture system operations drive biofilter bacterial community shifts around a stable nitrifying consortium of ammonia-oxidizing archaea and comammox Nitrospira,” *Front. Microbiol.*, vol. 8, no. JAN, 2017.

[15] M. Auffret *et al.*, “Impact of water quality on the bacterial populations and off-flavours in recirculating aquaculture systems,” *FEMS Microbiol. Ecol.*, vol. 84, no. 2, pp. 235–247, 2013.

[16] K. K. Schrader and S. T. Summerfelt, “Distribution of Off-Flavor Compounds and Isolation of Geosmin-Producing Bacteria in a Series of Water Recirculating Systems for Rainbow Trout Culture,” *N. Am. J. Aquac.*, vol. 72, no. 1, pp. 1–9, 2010.

[17] J. Y.-T. K. Ming-Ju Chen, Kreuter, “Nanoparticles and microparticles for drug and vaccine delivery.,” *J. Anat.*, vol. 189 (Pt 3, no. Ii, pp. 503–505, 1996.

[18] Y. Tal, J. E. M. Watts, S. B. Schreier, K. R. Sowers, and H. J. Schreier, “Characterization of the microbial community and nitrogen transformation processes associated with moving bed bioreactors in a closed recirculated mariculture system,” *Aquaculture*, vol. 215, no. 1–4, pp. 187–202, 2003.

[19] B. U. Foesel *et al.*, “Nitrosomonas Nm143-like ammonia oxidizers and Nitrospira marina-like nitrite oxidizers dominate the nitrifier community in a marine aquaculture biofilm,” *FEMS Microbiol. Ecol.*, vol. 63, no. 2, pp. 192–204, 2008.