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Hydrogenotrophic denitrification of synthetic aquaculture wastewater using membrane bioreactor

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Abstract

A hydrogenotrophic denitrification system was evaluated in removing nitrate from synthetic aquaculture wastewater for recirculation purposes. Two membrane bioreactor (MBR) systems, namely, aeration–denitrification system (ADS) and denitrification–aeration system (DAS) were studied with 50 mg/L of influent concentrations for both organic matter and nitrate nitrogen. The DAS achieved better removal efficiency of 91.4% total nitrogen (T-N) and denitrification rate of 363.7 mg/L.day at a HRT of 3 h compared to ADS. Further, there was no nitrite accumulation in the DAS effluent. The nitrite accumulation in ADS effluent was lesser when CO_2 was used as buffer rather than K_2HPO_4 and KH_2PO_4. Estimation of kinetic parameters of hydrogenotrophic bacteria indicated lesser sludge production compared to heterotrophic denitrification. In the DAS, membrane fouling was nonexistent in the aeration reactor that was used to produce the recirculating effluent. On the contrary, membrane fouling was observed in the denitrification reactor that supplied hydrogen to the mixed liquor. Thus, this study demonstrated DAS capability in maintaining the acceptable water quality appropriate for aquaculture, in which a closed recirculating system is typically used.

Keywords: Aquaculture wastewater; Effluent re-circulation; Hollow fiber membrane; Hydrogenotrophic denitrification; Membrane bioreactor

1. Introduction

Aquaculture has been developed steadily over the last decade in response to the increasing world market demand for seafood. However, it also discharges an enormous amount of wastewater into the environment which contains high concentration of nitrites, nitrates and phosphorus, which eventually leads to eutrophication on receiving waters. Eutrophication affects benthic fauna, macroalgal growth and diversity, epiphyte communities, phytoplankton, zooplankton and bacterial communities. Concerned agencies have started issuing load-based licenses to aquaculture farmers to minimize discharge of nitrogen and phosphorous into the environment [1]. Consequently, aquaculture industries look for appropriate and better methods in treating wastewater prior to recirculation or discharge into the receiving waters.

Table 1 shows the production capacities and effluent qualities of several fresh and saline water aquaculture systems [2–5]. Ammonia produced by the animals undergoes nitrification in a recirculating system. Nitrate ion is the end product of the nitrification process and it tends to accumulate in a closed recirculating system. For high-density fish aquaculture, nitrate value can reach up to 500 mg/L as NO_3^--N in both brackish and seawater recirculating systems [6]. Similarly, a recirculating seawater system used in rearing tiger shrimp brood stock showed an accumulation of NO_3^--N up to 50 mg/L in a 40-day trial period [7]. Substituting a fraction of the water with low nitrate value water (i.e. fresh water) can reduce nitrate concentration in the system. However, this is not a suitable approach because of high cost involved in large water exchange especially in areas where water supply is limited, the environmental assimilative capacity is low and have strict legislative restrictions on effluent discharge [8,9]. Hence, biological denitrification is an alternative means to remove the nitrate. In this process, nitrate is reduced to gaseous nitrogen prior to release in the atmosphere [10–12]. In biological denitrification, organic carbon serves as electron donor for heterotrophic bacteria whereas inorganic compounds are consumed by autotrophic bacteria. Most of the water in aquaculture has low biochemical oxygen demand (BOD); hence, an external electron donor is required [13]. Traditionally, organic

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