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Application of submerged membrane bioreactor for aquaculture effluent reuse

T. Pulefou[a], V. Jegatheesan[a]*, C. Steicke[a], Seung-Hyun Kim[b]

[a]*School of Engineering, James Cook University, Townsville, QLD 4811, Australia*
Tel. +61 7 4781 4871; Fax +61 7 4781 6788; email: jega.jegatheesan@jcu.edu.au
[b]*Civil Engineering Department, Kyungnam University, 631-701, Masan, Korea*

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Abstract

Discharging the nutrient rich aquaculture effluents into inland water bodies and oceans is becoming a serious concern due to the adverse effect that brings in the form of eutrophication and subsequent damages to those waters. A laboratory scale biological reactor consisting of a denitrifying compartment followed by a submerged membrane bioreactor (SMBR) compartment was used to treat 40 L d^{-1} of aquaculture effluent with an average concentration of 74 mg L^{-1} nitrate (NO_3^-). Sugar was added to the aquaculture effluent in order that to enter into the denitrifying compartment at a carbon: nitrogen ratio (C:N) of 2:1 and 4:1. A hollow fibre membrane with a pore size of 0.4 μm and a filtration area of 0.20 m^2 was used in the SMBR and was operated at an average flux of 0.20 $m^3\,m^{-2}\,d^{-1}$. An intermittent suction period of 12 min followed by a relaxation period of 3 min was maintained in the SMBR throughout the experiment. Different aeration rates of 1, 3, 5 and 10 Lpm were applied to the SMBR to determine the rate of membrane fouling and 5 Lpm aeration rate was found to be optimum with respect to the rate of fouling of membrane at a C:N ratio of 4:1. The average rate of fouling at 1, 3, 5 and 10 Lpm were 1.17, 0.70, 0.48 and 0.52 kPa d^{-1}, respectively. The increase in the rate of fouling when the aeration was increased from 5 to 10 Lpm may be due to the breakage of suspended particles into finer particles which could have increased the fouling of membrane. It was also found that increasing the C:N ratio from 2:1 to 4:1 resulted in more cake being formed on the membrane surface as well as an increase in the reduction of NO_3^- from 64% to 78%. Preliminary calculations show that 2.4 to 3.2 g of suspended solids could be accumulated per square meter of membrane surface before physical cleaning of membrane is required (at a transmembrane pressure of 20 kPa).

Keywords: Aquaculture; Denitrification; Effluent reuse; Rate of fouling; Submerged membrane bioreactor

*Corresponding author.

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1. Introduction

Some of the major problems with the rapid expansion of the aquaculture industry due to high seafood demand include water quantity and quality, cost of land, restrictions on water discharge, environmental impacts (i.e. algal blooms and eutrophication) and diseases. These factors have driven the industry to undertake intensive practices as well as adopting environmentally friendly technologies due to increased regulatory pressure from environmental agencies to protect the environment [1]. In order for the industry to be sustainable, this continued expansion will depend entirely on the high level of production per unit area (or volume) and the type of technology used that is considered to be environmentally sustainable [2]. Currently, some of the main areas of research are focussed on genetics and stock improvement, improved feed formulations, disease control and farming of new species while intensive recirculated aquaculture systems (RAS) with linkages to hydroponics are considered as sound technologies that have minimal environmental impacts [3].

RAS is defined as "aquaculture systems that incorporates the treatment and reuse of water with less than 10% of total water volume replaced per day" [4]. RAS are also known as "closed systems" (i.e. denitrification included) due to minimal connection with ambient environment and water sources. They consists of mechanical and biological filtration components, pumps and holding tanks and may include a number of additional water treatment elements that improve water quality and provide disease control within the system [5].

RAS is considered to offer a number of potential advantages for aquacultural practices which includes the following:

- Full control of all parameters that influence growth so that the fish farmer can better manage economic and production performance,
- Production in locations where limited water is available,
- An ability to manage waste production to provide greater environmental sustainability than traditional aquaculture systems,
- Bio-security,
- Ability to locate the operation close to markets to reduce product transport time and costs,
- Reduction in land area required when compared to pond-based systems, and
- Ability to integrate with agricultural activities (e.g. use of water effluent for hydroponics, horticulture or pre-use of irrigation water).

However, despite these advantages, there are also impediments involved such as high capital and running costs (e.g. mechanical filtration, pumping and maintenance), rigorous monitoring of water quality thus requires high level of management and pathogen outbreak [3,4].

Ammonia stripping is classified as a chemical process while nitrifying and denitrifying biological filtrations (biofilters) are considered as biological processes used in RAS to remove nitrogenous wastes from the system [6]. Nitrifying biofilters are commonly used in recirculating systems for ammonia removal where nitrate is the end product which is relatively harmless to fish at low to moderate concentrations. The denitrifying biofilters are used particularly for nitrate removal and they are still under development [7]. Therefore accumulation of nitrate within RAS is usually controlled by water exchange (<10% per day) [8].

Physical processes such as mechanical filtrations are critical in high stocking densities in RAS to remove large amount of waste production (uneaten feed and faeces) due to high inputs of feed [4]. Efficient mechanical filtrations will greatly reduce oxygen demand since the breakdown of these organic solids consumes large amount of oxygen in the culture system. Coarse settleable solids (>100 μm) are generally removed from RAS using some form of settlement device such as swirl separators, settlement chambers, inclined plate separator while suspended solids