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A review of the management of inflow water, wastewater and water reuse by membrane technology for a sustainable production in shrimp farming

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ABSTRACT

The growth of the human population, shrinking seafood supply and polluted seawater are amongst the reasons that have encouraged a more stringent practice of water management in the aquaculture industry. The productivity of cultured shrimps is greatly restricted by limited access to “clean” seawater for aquaculture areas, however, which lack leads to severe disease outbreaks and reduced shrimp survival rates. Water management has thus become the core issue for increasing shrimp production by reducing the contamination from fresh water intake, fresh water usage and aquaculture wastewater discharge. The objective of this study is to evaluate the feasibility of setting up an integrated recirculating aquaculture system using the membrane technology, which possibly utilizes microfiltration, ultrafiltration, nanofiltration or reverse osmosis modules, to improve the quality of aquaculture water while minimize the wastewater discharge and increase the water reuse. Feasibility of the integrated recirculating aquaculture system will be evaluated based on the effectiveness of improvement on the aquaculture water quality and limitations of the current membrane technologies. This study is highly useful for the researchers to modify the membrane characteristics before they are adopted in aquaculture water management system.

1. Introduction

Water management in aquaculture is an urgent need to minimize the impacts to the environment by reducing its effluent discharge and freshwater usage. This review article will discuss the importance of water management in shrimp farming industry and their current stage of research and development. In addition, this review article will discuss the water quality requirements (based on the key parameters) in shrimp farming in order to increase the shrimp survival rates and prevent massive disease outbreaks in the culture ponds. Lastly, this review article will evaluate the possibility of integrating membrane technology into shrimp farming industry based on their separation performance and their previous usages in aquaculture industry. By analysing designs of recirculating aquaculture systems that have been studied by other researchers, an integrated recirculating aquaculture system will be proposed at the end of this review article to allow researchers to conduct data collection and investigation in the near future.

2. Importance of water management in shrimp farming industry

Continuous development of desalination and water treatment technology has encouraged its employment in aquaculture water pretreatment and reclamation stages. Over 50% of the global shrimp supply for human consumption has been obtained in shrimp farming activity since 2006 [1]. Fig. 1 shows the world aquaculture production for crustaceans from 2006 to 2015. The world aquaculture production for crustaceans has increased to around 68% from year 2006–2015. Fig. 2 shows the fishery product exportation amount from top five exporting countries from 2013 to 2015. China appears to be the leading country in both aquaculture production and exportation of fishery commodities. Based on a research work that was previously conducted, every single tonne of shrimp aquaculture production can be translated into 5345–7157 m^3 of effluent discharge [2]. Based on the world aquaculture production for crustaceans, effluent discharge from the aquaculture industry around the world can be close to 3.74×10^{10} m^3

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Nomenclature

H_F	Convection steric parameter
H_D	Diffusion steric parameter
J	Flux $\left(\frac{m^3}{m^2.s}\right)$
η	Ratio of solute radius to membrane pore radius
P_T	Trans-membrane pressure (bar)
Δπ	Osmotic pressure (bar)
μ	Viscosity of water at specific temperature (Pa.s)
R	Solute rejection
R_M	Membrane resistance value (m^{-1})
R_F	Fouling resistance (m^{-1})
R_{CP}	Concentration-polarization resistance (m^{-1})
S_F	Distribution coefficient of solute by steric hindrance effect under convection condition
S_D	Distribution coefficient of solute by steric hindrance effect under diffusion condition
σ	Reflection coefficient

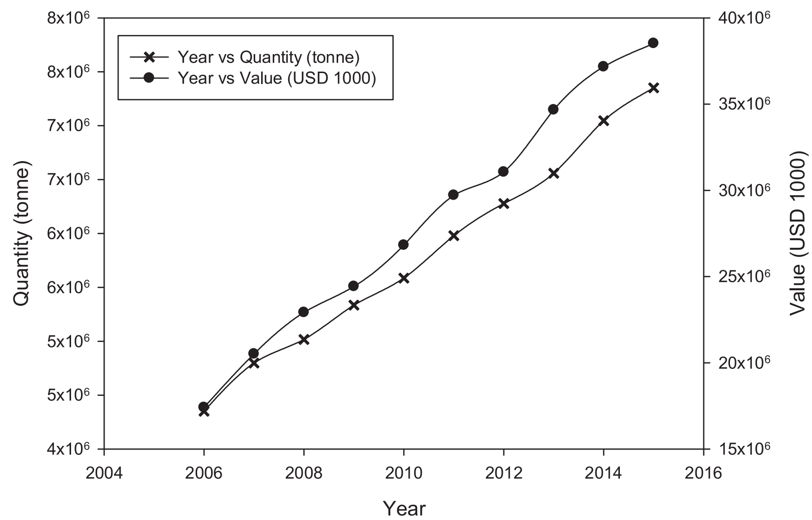

Fig. 1. World aquaculture production for crustaceans from 2006 to 2015.
Source [3]

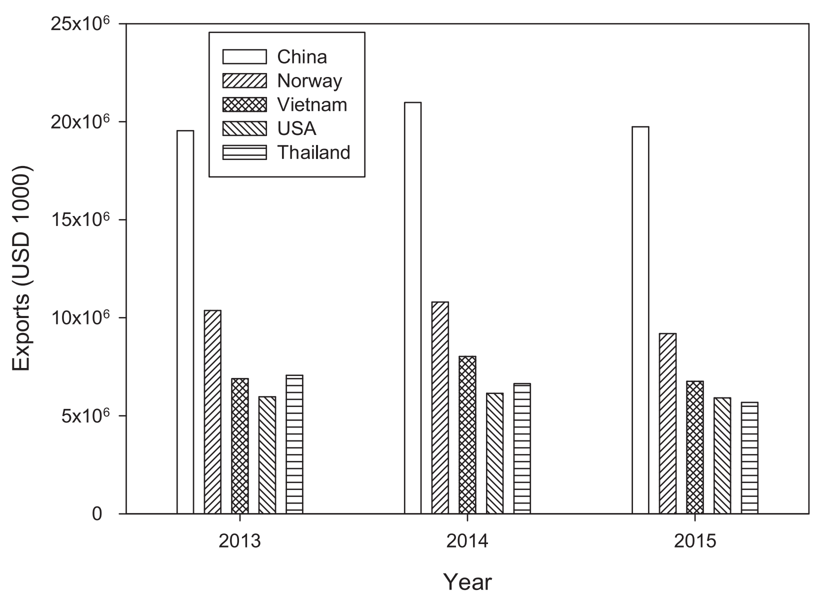

Fig. 2. Fishery product exportation amount from top five exporting countries from 2013 to 2015.
Source [3]

with the assumption that no recirculating aquaculture system is used for water treatment.

The importance of the shrimp industry to global economic growth can be clearly seen through shrimp exportation [4] and related research activities. According to data obtained from indexed databases, there was significant growth in shrimp aquaculture related publications from 1969 to 2016 (Fig. 3). In addition to being a driving force from the economic perspective, continual advances in science and technology have also contributed to the involvement of various countries in shrimp-related studies. United States, Thailand and India are the top countries that actively playing a role in shrimp research and development (Fig. 4). The global supply of shrimp products and its development is still restricted by poor water management, however, which could possibly contribute to a massive disease outbreak [5]. As in finfish aquaculture, the food supplied to shrimp aquaculture systems will generate a large amount of organic matter and nutrients (mostly