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Nutrient removal from membrane bioreactor permeate using microalgae and in a microalgae membrane photoreactor

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ABSTRACT

This paper explores the use of a novel microalgae membrane photoreactor (mMR) to polish the effluent from an aerobic membrane bioreactor (MBR) fed with domestic wastewater. Four microalgae species *Chlorella* (*Chlorella* sp.), *Chlorella vulgaris* (*C. vulgaris*), *Scenedesmus quadricauda* (*S. quadricauda*) and *Scenedesmus dimorphus* (*S. dimorphus*) were isolated from the environment and tested in batch reactors fed with permeate from the aerobic MBR to evaluate the nutrient removal rates for each species. All four microalgae species were able to completely remove NH_4 in the reactor within 3 days. The removal rates of NO_3, NO_2 and PO_4 were between 43–54%, 83–95% and 70–92%, respectively after 3 days in the batch reactor. Subsequently, an MBR–mMR system was operated for 23 days. The mMR was able to remove on average 50% of NH_4, 75% of NO_2, 35% of NO_3 and 60% of PO_4 consistently from the MBR effluent under the conditions tested.

1. Introduction

Nutrient removal is becoming an important priority for wastewater treatment plants due to the deleterious impact these chemicals have on the receiving bodies of wastewater treatment plant effluent. Aerobic membrane bioreactors are increasingly being used in wastewater treatment due to their better effluent quality, compact nature and low footprint compared with conventional activated sludge processes. With sufficient oxygenation, high carbon removal from the wastewater as well as significant nitrification commonly takes place in most MBRs. However, the nitrate (NO_3), nitrite (NO_2) and phosphate (PO_4) concentrations of the effluent increase after aerobic MBR treatment. Aerobic treatment processes alone are insufficient for removal of nutrients, e.g. nitrogen and phosphorous from wastewater. With more stringent regulations on nutrient concentration discharge limits impending, further treatment/polishing of wastewater effluent after MBR treatment will be required.

Biological nutrient removal (BNR) methods are currently one of the best methods for the removal of nutrients such as total nitrogen and total phosphorous from waters. These techniques typically make use of anaerobic/anoxic and aerobic processes to be used one after another. In practice several anaerobic/anoxic and aerobic treatments are required before the effluent nutrient levels are reduced to acceptable levels. Many of these processes require several tanks, internal recycles of activated sludge, long HRTs that increase costs, process complexities and high energy input. In some cases, an external carbon source such as acetate, methanol, ethanol or volatile fatty acids have to be added to wastewater in order to achieve denitrification for ammonia removal. This increases chemical use at the plant, and leads to increased operating costs for the plant in terms of energy, chemical consumption and sludge disposal. In such BNR processes, very precise operation and control of the system is required to ensure good total nitrogen (TN) and total phosphorous (TP) removal rates. Parameters not limited to temperature, dissolved oxygen levels, pH, filamentous growth and recycle loads can all affect the TN and TP amounts in the effluent as well as the health of the BNR system. Although the limits of BNR technology for TN and TP are 3 mg/L and 1 mg/L, respectively, these are seldom achieved at most plants (Foess et al., 1998; Jeyanayagam, 2005). Despite this, unless better technologies can be developed, BNR processes remain the best methods for the removal of nutrients from wastewaters.

Besides BNR, chemical nutrient removal methods such as chemical precipitation through the addition of alum and iron salts could also be used (Barnard, 1975; Malhotra et al., 1964; Wang et al., 2006). However in general nutrient removal through chemical methods have higher operating costs, produce more sludge and result in sludge high in chemical concentrations compared to BNR (Metcalf and Eddy, 2003).

Alternative methods for nutrient removal that could reduce energy cost, do not require the addition of chemicals or is simplified without numerous modes of operations and internal recycles will be preferred. Microalgae have been previously suggested as one alternative method for the removal of nutrients from waters

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