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Short Communication

Comparison between MBR and SBR on Anammox start-up process from the conventional activated sludge

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ABSTRACT

Anammox start-up performances from the conventional activated sludge were compared between a MBR and SBR. Both the reactors successfully started up Anammox process. The start-up period in the MBR (59 days) was notably shorter than that in the SBR (101 days), and the max nitrogen ($NH_4^+ + NO_2^-$) removal capacity of 345.2 mg N L^{-1} d^{-1} in the MBR was also higher than that of 292.0 mg N L^{-1} d^{-1} in the SBR. FISH analysis showed that Anammox bacteria predominated in both reactors. Phylogenetic analysis further disclosed that the MBR had the better biodiversity of Anammox bacteria and gained a higher ecological stability. Generally, the results showed that MBR exhibited a more excellent performance for Anammox start-up.

1. Introduction

The Anammox process has got much attention and has been put forward as a new and economical alternative to treat nitrogenous compounds from wastewater due to its excellent capacity to remove nitrogen without addition of organic carbon source. However, the application of Anammox process is limited by a long start-up period due to the very low growth rate (0.003 h^{-1}) of Anammox bacteria (Jetten et al., 1999). Various reactor configurations tried to start up Anammox process. Recently, Membrane bioreactor (MBR) was also used as a novel reactor to start up the Anammox process (van der Star et al., 2008; Wang et al., 2009). SBR and MBR are both considered to be the ideal reactors for Anammox start-up. The good sludge settle property in SBR is helpful in retaining slowly growing biomass, while MBR can realize full biomass retention by membrane permeating. However, there were limited researches on the comparisons between MBR and SBR on Anammox start-up from the respects of reactor configuration and operation strategy.

The study aimed at comparison of Anammox performance between two promising reactor configurations, namely, MBR and SBR. The MBR and SBR were inoculated with the same type of the seed sludge for Anammox start-up. Start-up time and nitrogen removal performances were compared between the two reactors. When Anammox reaction was stable, the cultivated sludges were collected from MBR and SBR respectively and used for Fluorescence in situ hybridization (FISH) analysis and phylogenetic analysis. The research was expected to provide useful information on quick start-up of the Anammox process from the conventional activated sludge.

2. Methods

The MBR and SBR were depicted in Fig. 1. They were both cylindrical reactors with a total capacity of 4.8 L (16 cm inner diameter and 24 cm height), which were fitted with a water jacket to maintain a fixed temperature of 35 °C. The reactors were covered to protect Anammox bacteria from light. The reactors and feed vessels were sealed to maintain the anaerobic conditions. The MBR had a submerged hollow fiber membrane module of curtain shape. The hollow fiber membrane with a pore size of 0.1 μm was arranged in the center of the reactor to ensure the complete biomass retention, which was made of polypropylene with total area of 0.2 m^2.

Aerobic activated sludge (MLSS 2.31 g/L, MLVSS 1.38 g/L) from Lingshuihe Wastewater Treatment Plant (Dalian, China) were mixed with the same amount of nitrifying activated sludge (MLSS 2.15 g/L, MLVSS 1.66 g/L) from a lab-scale A/O reactor where simultaneous nitrification and denitrification (SND) occurred. The mixed activated sludge was used as the seed sludge for Anammox start-up.

The reactors were fed with the same synthetic wastewater, which was Anammox nutrient medium (Van de Graaf et al., 1996; Strous et al., 1999). The MBR was continuously fed with the synthetic wastewater by the peristaltic pump and the same

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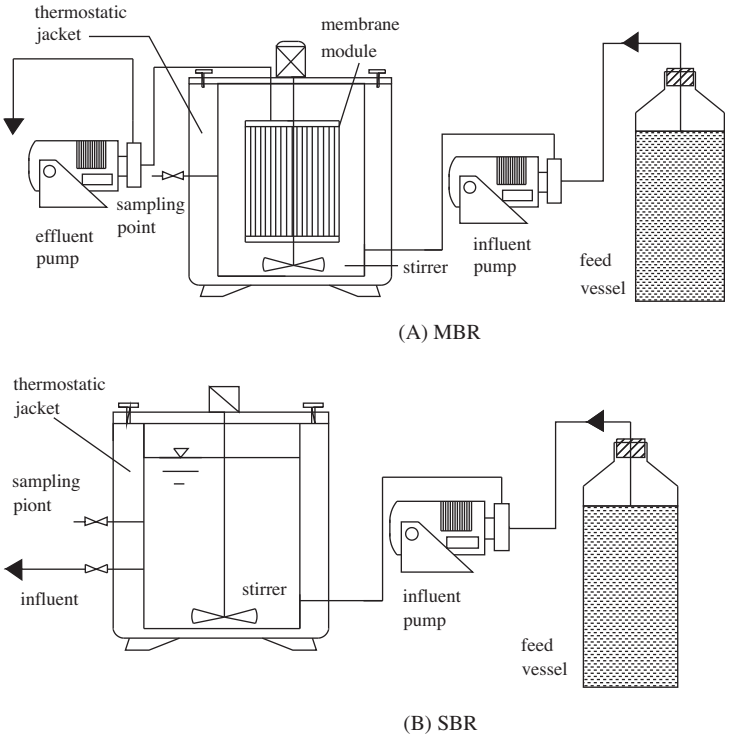

Fig. 1. Scheme of the reactors for the start-up of Anammox: (A) MBR and (B) SBR.

way permeate was sucked up via the hollow fiber membrane module. The MBR was operated in the mode of constant flux. The stirrer in the MBR worked at speed of 100 rpm to keep biomass suspended as free cells. The SBR worked in cycles of 12 h: feed and react 10.5 h, settle 80 min, discharge 10 min. A fixed exchange percentage of 25% was employed. In feed and react phase, the stirrer worked at speed of 100 rpm for homogeneous distribution of substrate and biomass. Both the MBR and the SBR were operated at the following conditions: hydraulic retention time (HRT) of 2 days, temperature of 35 °C, pH was controlled at around 8.0. Initially, the medium concentrations of $(NH_4)_2SO_4$ and $NaNO_2$ were both set to around 50 mg N L^{-1} and the N-loading rate was increased by increasing the concentrations of $(NH_4)_2SO_4$ and $NaNO_2$ in the feed vessel. The synthetic wastewater was replaced daily to avoid the changes in feed composition due to biological activity or other influencing factors.

Ammonia and nitrite, MLSS, MLVSS and SV% were measured according to the standard methods (APHA, 1998). The pH was determined with a digital portable pH meter. The DO level was measured with a digital portable DO meter (YSI, Model 55, USA). In the stationary phase of Anammox reaction, FISH analysis and phylogenetic analysis were done on mature sludge (Schmid et al., 2000; Lakay et al., 2007). Membrane fouling in the MBR was preliminary investigated by monitoring the evolutions of transmembrane pressure.

3. Results and discussion

3.1. Start up

The MBR and the SBR were inoculated with the same sludge and operated in parallel. The reactors were all fed with synthetic wastewater. The pH and DO concentration in the reactor was controlled at 7.8–8.2, <0.05 mg/L, respectively, in order to satisfy the strict requirement of Anammox growth and metabolism, while HRT was set at 2 days, initially. Anammox process may be inhibited when concentrations of Nitrite-N are higher than 70 mg/L (Jetten et al., 1999). During the experiments of both MBR and SBR, the effluent concentrations of Nitrite-N were below 30 mg/L, indicating that nitrite in the reactors could not inhibit Anammox process.

As Fig. 2 describes, the start-up process of Anammox could be divided into three phases in both the MBR and the SBR. During Phase 1 and Phase 2, no Anammox activity was detected, even though the total nitrogen loading rate was maintained at a low level of around 55 mg N L^{-1} d^{-1}. Phase 1 and Phase 2 altogether lasted for 19 days in the MBR, while the two phases lasted for 49 days in the SBR. So, the first two phases in the MBR appeared to be much shorter than that in the SBR, which were beneficial to quick start-up of Anammox. This can be explained by two aspects: (1) the feed mode between MBR and SBR was absolutely different: for MBR, the continuous feed mode was employed, so that Anammox bacteria could be at slowly growing phase and gain stable growth and enrichment; but for SBR, the high-flux periodical feed mode with a fixed exchange ratio was employed, so that Anammox bacteria underwent the process from the nutrient-rich period to the nutrient-deficient period and (2) MBR could achieve the complete retention of biomass to reduce the loss of Anammox bacteria.

In Phase 3, the MBR and SBR both exhibited a clear Anammox activity, characterized by the occurrence of synchronized removal of NH_4^+ and NO_2^-. In the experiment, simultaneous achievements of 125 mg N L^{-1} d^{-1} $NRR_{NH_4^+}$ and 150 mg N L^{-1} d^{-1} $NRR_{NO_2^-}$ were used as the provisional criterion of the successful Anammox start-up. The Anammox process was successfully started up in the MBR after 59 days and in the SBR after 101 days, respectively. The max $NRR_{NH_4^+}$ and $NRR_{NO_2^-}$ were 159.8 mg N L^{-1} d^{-1} and 185.4 mg N L^{-1} d^{-1} in the MBR, while they were 130.3 mg