Anaerobic Treatment of Domestic Sewage using Novel Anaerobic Fluidized Bed Membrane Bioreactor underEnergy Recovery and Biofouling Control

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Abstract: Anaerobic membrane bioreactor (AnMBR) maintains highactive biomass by separating solid retention time (SRT) from hydraulic retention time (HRT). However, membrane fouling is still a primarychallenge as it reduces membrane lifetime and increases capital and operational costs. This study focuses on a novel staged anaerobic fluidized bed membrane bioreactor (AFMBR) with submerged membrane using fluidized granular activated carbon (GAC) and other particles to mitigate fouling. An AFMBR system was developed to treat domestic sewage with chemical oxygen demand (COD) averaging 250 mg/L. The system was operated continuously for one year at 25^{o}C with a concise hydraulic retention time (HRT) depending on the permeate flux applied. A membrane net flux of 22 L/m^2/h was achieved during continuous operation with only a periodic maintenance cleaning using hypochlorite solution and scouring effect of fluidized GAC without any adverse impact on organic removal. The extracellular polymer substance (EPS) was predominately proteinaceous and constituent of biofouling, resisting more to be removed by maintenance cleaning. The overall permeate COD of less than 30 mg/L were obtained with average organic removal efficiency of 93%. Operational energy requirement of AFMBR, 0.024 kWh/m^3, is only 10% of the electrical energy that could be generated with the methane produced.
Keywords: Anaerobic membrane bioreactor;Domestic sewage;Energy recovery;Membrane fouling

Introduction

Recent concerns over water scarcity, climate change and sustainability of wastewater-energy nexus have persuaded the domestic sewage more as a resource than a waste; for water, energy and fertilizing elements it contains. Anaerobic membrane bioreactor (AnMBR) is a promising technology thatis now actively employed intreating domestic wastewater. However, membrane biofouling is the most pressing problem as it reduces membrane lifetime and increases capital and operational costs. A new approach to control membrane biofouling, with much less energy expenditure than required by the conventional way in AnMBR (i.e., biogas sparging),was developed by Kim et al. (2011) using anaerobic fluidized bed membrane bioreactor (AFMBR). Authorsprevious study showed that fluidized granular activated carbon(GAC) as fluidized media in AFMBR has potential to improve organic removal efficiency while reducing membrane fouling thatis a long-standing problem in membrane technology(Aslam et al., 2014, 2017).However, elucidating activities of GAC particles and other media alternatives to GAC particles such as organic removal and biofouling control during thelong-term operation of AFMBR still require further research. A comparative study between various types of fluidized media will lead to better understanding and improvements in the design and operation of AFMBR to optimize the system performance in terms of biofouling and organic removal efficiency. Underthis presentation, our results on comparing receptive performance, biofouling behavior, membrane biofoulants characteristics,and microbial community during the operation of the AFMBR treating low-strength wastewater will be novel and valuable to both scientific and industrial communities.

Materialsandmethods

The AFMBR system having an effective volume of 1.5 L was developed as a polishing unit to treat effluent from the anaerobic fluidized bed reactor (AFBR) treating low-strength wastewater and operated at a constant temperature of 25°C. The feed to the AFBR consisted of sodium acetate and sodium propionate at equal soluble chemical oxygen demand(SCOD) concentration of 250 mg/L. In addition, it contained 0.096 g/L and 10 mL/L of anaerobic digester supernatant from a local wastewater facility as a source of nitrogen and micronutrients. A membrane with a nominal pore size of 0.5 μm with an effective surface area of 0.1 $m^2$was applied for the AFMBR. The 10x20 mesh GAC particles were fluidized in the AFMBR by recirculating bulk solution through the reactor. An alternative to GAC particles, polyethylene terephthalate (PET) beadswere selected as fluidized media for comparison. The size of GAC and PET bead was 1-2 mm,and 3±0.5mm and specific gravity was 2.3 and 1.3 respectively. A diffuser was installed at the bottom of the reactor to allow entrance of recirculating bulk suspension to fluidize both fluidized media beads to rise and cover the whole surface of the ceramic membranes. The 16s rRNA analysis was performed to characterize the microbial communities on GAC, PET beads,and reactor bulks. The membrane biofoulants from fouled membranes were also characterizedbythe microbialcommunitiesand extracellular polymer substances (EPS) for biofouling analysis.

Resultsanddiscussion

GAC and plastic PET beads were compared as fluidized media to examine membrane biofouling behavior, system performance, membrane biofoulants characteristics,and microbial communitiesin the long-term operation of the anaerobic fluidized bed ceramic membrane bioreactor (AFCMBR) polishing AFBR effluent. Results showed that both media provided effective tools to control membrane biofouling by mechanical cleaning action along the membrane surface. The hydrophilic membrane also provided a synergistic effect in fouling control as compared to the hydrophobic polymeric hollow-fiber membranes. Overall COD removal was somewhat lower with beads than observed with GAC particles (>90%) as fluidized media in AFMBR at the same operational condition.The electrical energy required for complete fluidization was0.024 kWh/m^3 with GAC fluidization, much less than that of an AFMBR combined with biogas sparging to control membrane fouling. The use of beads as media required less electrical energy than gas sparging to control membrane fouling, but the energy consumption for fluidization was higher than the GAC particles. Biofouling reduction efficiency, microbial community structure, biofoulants,and bulk characteristics varied considerably depending on thefluidized media applied in AFMBR system. GAC as porous fluidized mediaprovided a synergistic effect in biofouling mitigationand organic removal efficiency in comparison to the PET non-porous beads as fluidized media.

References

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