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Low flux submerged membrane bioreactor treating high strength leachate from a solid waste transfer station

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HIGHLIGHTS

- SMBR was utilized to treat real high strength leachate from a transfer station.
- SMBR was operated at low fluxes of 1.2; 2.4; 3.8 and 5.1 LMH.
- Slower fouling rate observed at lower flux.

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ABSTRACT

A submerged membrane bioreactor was employed to treat high strength leachate generating from a solid waste transfer station. The reactor was operated at low fluxes of 1.2; 2.4; 3.8 and 5.1 LMH. The organic loading rate (OLR) ranged from 2 to 10 kg COD/m^3 day. Results show that 97% removal efficiency of COD at flux of 2.4 LMH. The highest removal of ammonia nitrogen and total nitrogen was 92.0 ± 1.5% and 88.0 ± 2.0% respectively at flux of 3.8 LMH. Fouling rates were observed to be 0.075; 0.121; 3.186 and 6.374 kPa/day for the fluxes of 1.2; 2.4; 3.8 and 5.1 LMH, respectively. Membrane fouled very slowly at low flux operation. The sustainable flux was identified to be less than 2.4 LMH for treating high strength leachate. It reveals less fouling was able to achieve for high strength wastewater by reducing the membrane flux.

1. Introduction

Leachate is highly loaded, toxic and is bad for the sanitation of wastewater (Bodzek et al., 2006). It causes serious pollution to water resources if directly discharged. It contains large amount of biodegradable organic matters, refractory compounds (humic and fulvic acids), high ammonia concentrations and numerous other pollutants. Another associated difficulty is the enormous variations in composition and flows that depends on many parameters such as waste type, composition, disposal technique, etc. To reduce pollution content in this kind of wastewaters, complex treatment processes are designed from physical/chemical techniques to biological treatments and/or several combinations of them.

Membrane bioreactors (MBRs) are innovative technology in which gravity settling of the activated sludge process (ASP) is replaced by a module of membrane such as microfiltration (MF) or ultrafiltration (UF). Furthermore, the development of submersible suction membranes has reduced the energy consumption as low as 0.46 kWh/m^3 (Liu et al., 2012), and has expanded its presence in various industrial and domestic wastewater treatment applications. Besides, MBR is a system that combines biological degradation with a membrane for physical filtration to separate the liquid component from the mixed liquor. It offers numerous advantages over conventional activated sludge processes such as water reuse, less space requirement due to elimination of settling tanks, and independence of process performance from filamentous bulking or other phenomena effecting settleability (Brindle and Stephenson, 1996). MBRs are utilized to treat leachate wastewaters effectively. The removal efficiencies for COD and ammonia nitrogen were 99% and 58.5% with influent concentration of 1000–3500 mg COD/L and 281–700 mg N/L, respectively (Galleguillos, 2011). The removal efficiencies were 82.4% and 98.3% for COD and BOD_5 respectively (Bodzek et al., 2006). While both BOD_5 and ammonia removal efficiencies were 97% at influent concentration

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of 1240 mg COD/L and 210 mg N/L, respectively (Laitinen et al., 2006).

However, membrane fouling is a major drawback of this technology. Decreasing in the performance of membrane filtration due to fouling has hindered the widespread application of membrane process for wastewater treatment. A number of studies have been conducted to elucidate the effect of various factors on membrane fouling. Other than the intrinsic properties of the membrane material, these factors can be categorized two main groups, namely operation- and sludge-related factors. Operation-related factors, such as operation flux (Le-Clech et al., 2006), solids retention time (SRT) (Ahmed et al., 2007), dissolved oxygen concentration (Psoch and Schiewer, 2006). Sludge-related factors include sludge viscosity (Meng et al., 2006), carrier based biomass (Thanh et al., 2012), extracellular polymeric substances (EPS) concentrations (Drews et al., 2006; Johir et al., 2012).

Most of solid waste transfer stations in the Ho Chi Minh city in Vietnam have small area and their leachate wastewaters contain high amount of organic matters and suspended solids. Therefore, membrane based wastewater treatment systems are priority consideration because they offer space saving and high treatment efficiencies. MBRs can operate in long sludge retention time (SRT) of 5–50 days with high MLSS and low F/M ratio. Nitrification in MBR could be higher than conventional activate sludge processes (CASP) because the SRT required for nitrifying bacteria is longer. Carbon and nitrogen removal efficiencies in MBRs are higher than that of CASP. The F/M ratio in the MBRs often ranged from 0.05 to 0.15 day^{-1} (Brindle and Stephenson, 1996; Visvanathan et al., 2000; Pollice et al., 2005). In addition, the MLSS concentrations are up to about 20,000 mg/L maintained during domestic wastewater treatment (Rosenberger et al., 2002). The good treated wastewater quality is not a doubt for MBR technology. However, the membrane fouling is a concerned issue to be emphasized in real application. Le-clech et al. (2006) showed that trans-membrane pressure (TMP) increased proportional to flux. Membrane fouling at higher flux is faster than at low flux. Liu et al. (2012) also postulated that permeate flux plays a critical role on the stable operation of membrane bioreactor (MBR) system for municipal wastewater treatment. Thus, operation of MBR at low flux range could be an effective fouling control treating high strength wastewater like leachate from a solid waste transfer station. This study aims to evaluate the treatment performance and fouling of MBR treating leachate from a solid waste transfer station at four low fluxes.

2. Methods

2.1. MBR and operating conditions

A submerged membrane bioreactor had working volume of 22 L. The PVDF membrane module with a surface area of 1 m^2 and pore size of 0.2 μm were used. The system was controlled automatically by timers, solenoid valves and digital pressure gauges. Air diffusers were placed at the bottom of reactor and at the rear end of membrane module for aeration and air scouring. Dissolved oxygen concentration was maintained ranging from 3 to 5 mg/L, with the air supply of 70 L/m^3 min. The cyclic filtration and relaxation were 8 min and 2 min respectively. A digital pressure gauge recorded the trans-membrane pressure (TMP) indicating fouling propensity. The backwash process was operated automatically at the set-point TMP value of −40 kPa. The sludge retention time (SRT) was fixed at 30 days during operation. The operational fluxes were 1.2; 2.4; 3.8 and 5.1 LMH which corresponding to organic loading rate (OLR) of 2; 4; 6.4 and 9.3 $kgCOD/m^3$ day and HRT of 14.6; 7.3; 4.6 and 3.5 h, respectively.

2.2. Leachate wastewater

Leachate collected from the holding tank of a solid waste transfer station was used for this study. The concentrations of real leachate wastewater are in mg/L (except for pH): COD (4778 ± 1187), SS (1189 ± 409), TKN (144 ± 31), NH_4 + -N (68 ± 26), TP (45 ± 20) and pH (4.5–6.0). Then the wastewater was diluted with tap water to get the influent COD concentration of 1200–1400 mg/L. This assumed that the pretreatment by anaerobic process achieved about 70–80% COD removal efficiency.

2.3. Analytical parameters

Parameters of COD, TKN, NH_4–N, NO_2–N, NO_3–N, ultra violet absorbance (UVA_{254}), mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were determined according to standard methods (APHA, 1998). Polysaccharides (PS) were determined by the phenol–sulfuric acid method using glucose as standard described by Thanh et al. (2008). The samples for measuring PS and UVA_{254} were collected from MBR supernatant and permeate. The MBR supernatant was got by centrifuging the mixed sludge sample at 4000 rpm for 10 min. Trans-membrane pressure (TMP) was recorded daily and fouling rate (dTMP/dt) was determined through slope between TMP over time at the linear segment.

3. Results and discussions

3.1. Organic and nitrogen removal

Fig. 1 shows the COD removal efficiency at four fluxes of 1.2; 2.4; 3.8 and 5.1 LMH. The results show that the highest removal efficiency was 97.5 ± 0.5% at 2.4 LMH flux (HRT = 7.3 h). The SMBR shows good treatment performance in terms of COD removal; more than 90% of COD entering the system was removed. The COD in membrane permeate was lower than 50 mg/L complying with Vietnam national technical regulation (QCVN 25:2009/BTNMT, level A). Experimental results show a predominance of less shock loading in SMBR. Through the strong changes in applied OLR for the SMBR, the average COD concentrations in permeate were stable from 38 to 56 mg/L during the operation. The system not only adapted to the rapid increasing of flux proportion and organic loading rate but also played an important role in providing excellent and stable effluent quality, which was similarly reported by Brick et al. (2006). In this study, when flux was lower than 2.4 LMH, the specific substrate utilization rate (U) increased from 0.37 to 0.45 gCOD/gMLVSS d, respectively. When flux was higher than 2.4 LMH, U decreased to 0.22 gCOD/gMLVSS d. On the other hand, at 5.1 LMH flux U value was half-lower than that at 2.4 LMH flux. The highest U was 0.45 gCOD/gMLVSS d at flux of 2.4 LMH. The flux increased from 1.2 to 2.4 LMH, organic loading rate increased from 2 to 4 $kgCOD/m^3$ d respectively. Microorganisms increasingly adapted to high-loading operation, whereas U level decreased when the organic loading higher than 4 $kgCOD/m^3$ d (6.4–9.3 $kgCOD/m^3$ d).

The ammonia and TN removal efficiencies dropped from 55–88% to 56–85% respectively. Flux increased from 1.2 to 5.1 LMH, concentrations of ammonia and TN in membrane permeate ranged from 1.0–8.4 mg/L to 6.5–13.9 mg/L, respectively. The highest ammonia and TN removal performances were 92 ± 1.5% and 88 ± 1.8% at 3.8 LMH. When flux increased from 1.2 to 3.8 LMH, ammonia and TN removal efficiencies also steadily increased. However, at 5.1 LMH flux, ammonia and TN removal performances reduced. It can be explained that at this flux the HRT of 3.4 h is short to achieve complete nitrification at the high organic loading