摘要

近年文獻中指出，在低溶氧環境(如 DO: 0-1 mg/L)下，生物好氧硝化及缺氧脫硝之兩階段反應同時完成，稱為同時硝化脫硝(Simultaneous nitrification and denitrification, SND)。SND 程序可以解決傳統程序中好氧段及缺氧段操作上之衝突，而 SND 反應過程中亦不會產生潛在性危害的中間產物。本研究的主要目的是在循序分批式濾膜生物反應槽(Sequencing batch membrane bioreactor, SBMBR)中利用線上監控參數(如 ORP，pH 與 DO)監控同時硝化脫硝現象並使用從 Nernst equation 推導的模式來模擬之，並且探討應用 SBMBR 放流水來當做回收用水的可行性。結果顯示高碳氮比(TCOD/NH_4-N = 11.0)與低溶氧環境(DO = 0-1 mg/L)可加強 SND 現象，線上監控的圖形也可以指出反應的終點，並且在模式模擬下也有相當良好的結果。台灣水資源短缺，水回收再利用的議題已經逐漸受到重視，故本研究之 SBMBR 放流水在經過 0.4 μm 的中空纖維濾膜過濾之後，只需要再經過加氯消毒或是臭氧化步驟即可用作各類型用途之回收水，例如噴灑用水(灌溉用水與冷卻用水等)、景觀用水(洗車用水)與廁所沖洗用水，尚須注意經過消毒處裡之後不能接觸人體的原則，並且不能儲存需立即使用。

關鍵字：同時硝化脫硝；循序分批式濾膜生物反應槽；氧化還原電位(ORP)；
即時控制策略；Nernst 模式；回收水

Abstract

Nowadays, some scholars reported that nitrification and denitrification can occur concurrently in one reactor under low DO condition (ex. DO: 0-1 mg/L), this is so-called simultaneous nitrification and denitrification (SND). SND reaction can solve the problems for alternating oxic and anoxic period in conventional process. The intermediates, which are potentially harmful to human health, were not accumulated during SND reaction. The objective of this study is to analyze SND phenomenon in sequencing batch membrane bioreactors (SBMBRs) with online monitoring parameters, and discuss the feasibility of the effluent from SBMBR as recycle water. The results show high C/N ratio (TCOD/NH_4-N = 11.0) and low-DO (0-1 mg/L) condition can enhance SND phenomenon; online monitoring profiles (ORP, pH and DO) can point out the end-point of reactions. The model developed from Nernst equation can fit satisfactorily in all runs. The shortage of water resource in Taiwan is a serious domestic problem, thus, water recycling issue gradually becomes a great cooncern. In this study, the effluent from SBMBR, which was filtrated with the hollow fiber membrane of 0.4 μm porous size, may be used as recycle water

with additional disinfection process of ozonation or chlorination, such as sprinkling water (irrigation and cooling water), landscape water (car washing water) and toilet flushing water. However, it should be noticed that the water after disinfection process can not contact with human body and be storaged.

Key words: simultaneous nitrification and denitrification (SND); sequencing batch membrane bioreactor (SBMBR); oxidation-reduction potential (ORP); real-time control strategy; Nernst model; recycle water

Index

Chapter 1 Introduction.....1

Chapter 2 Literature review.....3
2-1 Simultaneous nitrification and denitrification (SND) process 3
2-2 Sequencing batch membrane bioreactor (SBMBR) system.....8
2-2-1 SBMBR.....8
2-2-2 Hollow fiber membrane (HFM).....11
2-2-2-1 Porous size and materials of HFM.....11
2-2-2-2 Clogging problem in membrane filtration.....13
2-3 Online monitoring parameters and Nernst equation modeling 15
2-3-1 Online monitoring parameters……15
2-3-2 Nernst equation modeling……..16
2-4 Objectives.....19

Chapter 3 Experimental methods and equipment.....20
3-1 Experimental equipment and monitoring systems in SBMBR 20
3-1-1 Experimental equipment.....20
3-1-2 Monitoring systems.....21
3-2 SBMBR system and operation.....22
3-2-1 Synthetic stock feed.....22
3-2-2 System operation procedure.....23
3-3 Analytical methods.....28

Chapter 4 Results and discussion.....29
4-1 SND phenomenon in SBMBR system.....29
4-1-1 SND phenomenon.....29
4-1-1-1 System with limited carbon case: Run 1 (C/N = 8.0) 29
4-1-1-2 System with excess carbon case: Run 2 (C/N = 11.0) 34
4-1-2 The alkalinity profiles in SND process.....39
4-1-3 System performance.....41
4-2 Real-time control strategies and modeling.....45

4-2-1 Real-time control strategies.....45
4-2-1-1 ORP profile.....45
4-2-1-2 pH profile.....46
4-2-1-3 DO profile.....47
4-2-1-4 Real-time control of SND phenomenon.....49
4-2-2 SND model.....50
4-2-2-1 System with limited carbon case: Run 1 (C/N = 8.0) 51
4-2-2-2 System with excess carbon case: Run 2 (C/N = 11.0) 52
4-3 Membrane operational characteristics.....55
4-3-1 Clogging problem of membrane filtration.....55
4-3-2 Feasibility of SBMBR effluent reusing.....58

Chapter 5 Conclusions and suggestions.....61
5-1 Conclusions.....61
5-2 Suggestions.....63

References.....64

Appendix.....71
Membrane washing……71

Figure list

Figure 2-1. Nitrogen transformations of nitrification, denitrification and "nitrite shunt" pathway.....5

Figure 2-2. Diagram of hollow fiber membrane.....12

Figure 2-3. Effect of upflow air on hollow fiber membrane washing 14

Figure 3-1. Schematic diagram of SBMBR is set with fixed time operation. 1. stirrer; 2. aeration stone; 3. valve; 4. aeration pump; 5. porous plat; 6. hollow fiber membrane; 7. peristaltic pump.....25

Figure 4-1. (a) Online monitoring parameters: ORP, pH and DO; (b) NH_4^+-N, NOx-N and SCOD profiles of SBMBR1 (airflow rate = 14.0 L/min) in Run 1 (C/N = 8.0). A: anoxic stage; O: oxic stage; D: drawing stage.....31

Figure 4-2. (a) Online monitoring parameters: ORP, pH and DO; (b) NH_4^+-N, NOx-N and SCOD profiles of SBMBR2 (airflow rate = 1.4 L/min) in Run 1 (C/N = 8.0). A: anoxic stage; O: oxic stage; D: drawing stage.....33

Figure 4-3. Triplicate tests of (a) Online monitoring parameters: ORP, pH and DO; (b) NH_4^+-N, NOx-N and SCOD profiles of SBMBR1 (airflow rate = 14.0 L/min) in Run 2 (C/N = 11.0). A: anoxic stage; O: oxic stage; D: drawing stage. A: anoxic stage; O: oxic stage; D: drawing stage.....36

Figure 4-4. Triplicate tests of (a) Online monitoring parameters: ORP, pH and DO; (b) NH_4^+-N, NOx-N and SCOD profiles of SBMBR2 (airflow rate = 1.4 L/min) in Run 2 (C/N = 11.0). A: anoxic stage; O: oxic stage; D: drawing stage.....39

Figure 4-5. Typical changes of alkalinity of SBMBR1 (high airflow rate) and SBMBR2 (low airflow rate) systems in Run 2 (C/N = 11.0). A: anoxic stage; O: oxic stage; D: drawing stage.....41

Figure 4-6. Model fit using Nernst equation of (a) high DO case (SBMBR1) and (b) low DO case (SBMBR2) in limited carbon case (Run 1, C/N = 8.0).....52

Figure 4-7. Model fit using Nernst equation of (a) high DO case (SBMBR1) and (b) low DO case (SBMBR2) in excess carbon case (Run 2, C/N = 11.0).....53

Figure 4-8. Variation of flux with operating cycles for high DO case (SBMBR1) and low DO case (SBMBR2) in Run 2 (C/N = 11.0). Each cycle takes 12 hrs to achieve, thus, two cycles per day. Water and chemical cleaning are done by jet water and NaOCl, respectively.....57
Figure 4-9. Membrane module (a) fouling and (b) after water or chemical cleaning procedure in all runs.....57

Table list

Table 2-1. SND efficiencies under various C/N ratios and systems.....7
Table 3-1. The properties of hollow fiber membranes……..20
Table 3-2. Composition of the synthetic stock feed in Run 1 (C/N = 8.0) and Run 2 (C/N = 11.0).....22
Table 3-3. Characteristics of the synthetic influent in Run 1 (C/N = 8.0) and Run 2 (C/N = 11.0).....23
Table 3-4. Operating conditions of SBMBR1 (high airflow rate, 14.0 L/min) and SBMBR2 (low airflow rate, 1.4 L/min).....26
Table 3-5. Characteristics of each operation stages.....27
Table 3-6. Analysis methods and instruments.....28
Table 4-1. Effluent qualities and removal ratios under various operating conditions.....43
Table 4-2. SND efficiencies and rates under various operating conditions. Compared to other studies for influent ammonia concentration of about 40 mg/L (C/N = 10.0)....44
Table 4-3. Real-time control strategies of ORP (breakpoints) at each batch operation stage of high DO (SBMBR1) and low DO case (SBMBR2) in Run 2 (C/N = 11.0).....46
Table 4-4. Real-time control strategies of pH (bending points) at each batch operation stage of high DO (SBMBR1) and low DO case (SBMBR2) in Run 2 (C/N = 11.0).....47
Table 4-5. Real-time control strategies of DO (breakpoints) at each batch operation stage of high DO (SBMBR1) and low DO case (SBMBR2) in Run 2 (C/N = 11.0).....48
Table 4-6. Typical SND control breakpoint of ORP, pH and DO profiles in high DO (SBMBR1) and low DO (SBMBR2) cases (Run 2) 49
Table 4-7. Nernst equation constants and R-square values of different operating conditions…….....54
Table 4-8. Comparison between recycle water and effluent from low DO case (SBMBR2) in Run 2 (C/N = 11.0).....60