行政院國家科學委員會專題研究計畫 成果報告

利用沉浸式薄膜生物反應槽程序處理實際製藥廢水之研究
研究成果報告(精簡版)

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計畫主持人：張家源
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計畫參與人員：此計畫無參與人員：無

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行政院國家科學委員會專題研究計畫成果報告

利用沉浸式薄膜生物反應槽程序處理實際製藥廢水之研究

Treatment of pharmaceutical wastewater by submerged membrane bioreactor process

計畫編號：NSC 95-2211-E-041-009

執行期限：95 年 8 月 1 日至 96 年 7 月 31 日

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一、中文摘要

本系統係現場建構一沉浸式好氧薄膜生物反應系統(Submerged Aerated Membrane Bioreactor, SAMBR)之模廠，收集處理製藥廠之廢污水，系統以好氧生物槽與好氧薄膜生物槽為處理主體，將廠區之製程廢水與預鑄式生活污水系統之放流水收集統一處理，探討水質處理效果，系統耐突增負荷程度及本處理系統對製藥廢水之適用性。COD 去除效果皆達 95.9%以上、BOD 去除效率皆達 99.3%以上、SS 去除率達 100%，其平均去除效果符合行政院環保署放流水標準之藥品製造業放流標準(COD＜100 mg/L、BOD＜30 mg/L、SS＜30 mg/L)。本研究期間共計 114 天，放流水污泥密度指數(SDI)值均在 6.4 以下，顯示放流水質良好，於系統操作第 219 天再進行程序評估，系統操作與出流水質相當穩定。由本研究結果得知，SAMBR 系統對於製藥廢水水質之改善，具有極佳之處理功效，可作為製藥業製程廢水回收再利用之參考方案。

關鍵詞：薄膜生物反應槽、製藥廢水、黏滯度、掃描式電子顯微鏡

Abstract

A pilot-scale study of pharmaceutical wastewater treatment by a membrane bioreactor (MBR) process in southern Taiwan is presented in this paper. A 10 m^3/day capacity MBR plant consisting of an aeration tank and a membrane bioreactor was installed to remove organic matter (measured in terms of chemical oxygen demand (COD)). The performance of the MBR was monitored for a period of 140 days. The removal of COD was on average over 95%. The effluent did not contain any suspended solids. During the 140 days of operation, manual cleaning was carried out twice and chemical cleaning was carried out once. A natural logarithmic evolution of the viscosity with TSS concentration was observed. The results of SEM and EDX demonstrated that the fouling on the membrane outer surface was mainly due to microorganisms and/or the sludge physiological properties. The results indicated that the MBR system has potential as a means of treating high-strength and fluctuating strength wastewater with consistent performance.

Keywords: Membrane bioreactor; Pharmaceutical wastewater; Viscosity; Scanning electron microscope

1. Introduction

The existence of pharmaceutical substances in the aquatic environment and their possible effects on living organisms are a growing concern [1].

The treatment of pharmaceutical wastewater to the desired effluent standards has always been difficult due to the wide variety of the products that are produced in a drug manufacturing plant. Variable wastewater composition and fluctuations in pollutant concentrations cannot be treated by conventional treatment plants. Activated sludge process is a well-known process for removing various organic contaminants and organic carbon. However, the substances synthesized by pharmaceutical industries are organic chemicals that are structurally complex and resistant to biological degradation [2].

The use of membrane bioreactor (MBR) in wastewater treatment is becoming increasingly important, because they offer several advantages, i.e. high biodegradation efficiency, smaller footprint, and less sludge production [3].

Recent literature shows that MBR can be effective in removing these emerging contaminants. During the last three years research results were published in this particular area, reflecting the growing number of MBR applications for treatment of specific chemical compounds, such as pharmaceuticals, fragrances and endocrine disrupting compounds. However, various aspects of practical applications still received little or no attention to date [4,5] and the application of the MBR in treatment of pharmaceutical wastewater is still in its infancy. While there are many similarities in the design parameters for municipal plants, industrial plants show considerable variations in design, control and operational performance.

This paper presents the results of a pilot-scale MBR performance used in the treatment of pharmaceutical wastewater in Southern Taiwan Science Park (STSP).

2. Materials and methods

2.1 Experimental setup and operation

Fig. 1 shows the MBR plant constructed to treat wastewater from a pharmaceutical company. The company is located at Southern Taiwan Science Park (STSP). Regulation requires the COD of the wastewater should be reduced to below 450 mg/L in order to be discharged into a tertiary treatment plant in the STSP Administration which has an effluent COD limit of 50 mg/L.

The system consisted of two tanks with a total volume of 20 m^3. The first tank is a biological tank (10 m^3) and the second tank has a dual function of biological reaction with solid-liquid separation. The hollow fibre membrane used in this plant was manufactured by MOTIMO Company in China. Table 1 shows the characteristics of the membrane. The hollow fiber membrane was immersed in the membrane tank, where the air was supplied at the bottom of the membrane units to supply of oxygen for biological treatment and to create a turbulence which helps reduce membrane fouling.

The membranes were operated at an intermediate suction and were backwashed periodically using permeate. Prior to day 40 of operation, several operating modes including the suction-relaxation and coarse bubble aeration duration were evaluated with the aim of reducing the fouling of membranes. On day 41, the operation mode was fixed as follow: during the continuous operation mode, the suction pump was stopped for 30 seconds after 4 minutes of filtration to allow membrane relaxation. Two modules of membrane were employed in the second tank to alternatively accommodate the pumping and relaxation mode exchange operating mode. For each membrane, 54 minutes of membrane operation (12 cycles of suction-relaxation) was followed by 6 minutes of backwash by permeate.

After 30 days of seeding and start-up, the MBR plant was monitored continuously for 140 days. The HRT of the aerobic tank and MBR tank were set at the same value of 24 hours. The re-circulation rate of the mixed liquor was set at 500% of the average influent flow rate.

2.2 Wastewater characteristics

The influent to the MBR system consisted of real pharmaceutical manufacturing wastewater and septic tank effluent. The plant has intermittent and fluctuating wastewater flow with variable wastewater composition depending on the production regime. The characteristics of the wastewater are indicated in Table 2.

2.3 Control, analysis and monitoring

DO, pH, ORP, temperature and flow rates were recorded daily using the in-line controllers. Dissolved oxygen (DO) was monitored with a DO analyzer and maintained higher than 3.0 mg/L in the aerobic and membrane tanks. The influent and effluent of each tank were sampled two to three times per week. The analysis including chemical oxygen demand (COD), biochemical oxygen demand (BOD), mixed liquid suspended solids (MLSS), mixed liquid volatile suspended solids (MLVSS) and turbidity were performed in accordance with the standard methods (APHA, 1993) and the corresponding instrument instruction manuals. The mixed liquor viscosity was measured by a TVC-5 type viscometer (Toki Sangyo Co., Ltd., Japan)

The surface morphologies of the nascent and fouled membranes were characterized by scanning electron microscope (SEM) and energy dispersive X-ray analyzer (EDX) with a Hitachi S-3000 system. The samples were fixed with 4.0% glutaraldehyde in 0.1M phosphate buffer at pH 7.2 and dehydrated with ethanol, gold-coated by a sputter and observed in SEM.

Table 1

Characteristics of hollow fiber membrane

Characteristic parameter	Membrane module
Material	PVDF
Internal/outter diameter（μm）	650/1000
Wall thickness（μm）	180
Pore size (μm)	0.1
Specific membrane area（m^2/g）	12.1
Fiber length（cm）	90
Number of the hollow fibers	4220

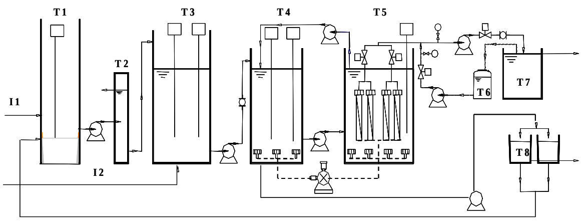


Fig. 1. Schematic diagram of the MBR system for pharmaceutical wastewater treatment. I1 influent from pharmaceutical manufacturing processes I2 influent from septic tank effluent T1 wet well T2 solvent-liquid separation T3 equalization tank T4 biological tank T 5 membrane bioreactor T6 backwash tank T7 effluent tank T8 sludge drying bed

Table 2
Characteristics of the raw wastewater

Characteristic items	Range
Temperature (℃)	18.5 ~ 25.1
pH	6.6 ~ 9.4
SS (mg/L)	60 ~ 360
COD_{Cr} (mg/L)	800 ~ 11800
BOD_5 (mg/L)	100 ~ 6350

3. Results and discussion

3.1 Performance of MBR system

Fig. 2 illustrates the influent and effluent quality of the MBR in terms of COD. COD effluent was remarkably stable and with a highest removal efficiency of 96%. This result may be attributed to the mass loading in MBR tank which was generally low and in the range of 0.003~0.079 kg CODkgMLVSS^{-1}d^{-1}. Moreover, COD organic loading to the biological tank was in the range of 0.099~6.844 kg CODm^{-3}day^{-1} and 0.011~0.408 kg COD m^{-3}day^{-1} to the membrane tank.

Besides, it was found that an additional 5% COD removal was observed in the membrane effluent compared to that in the final membrane tank.

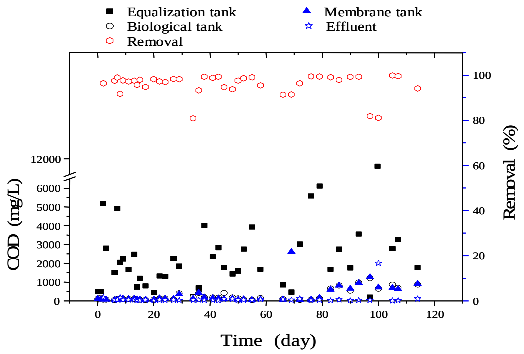


Fig. 2. Variations and removal of COD

Fig. 3 demonstrates the process performance on BOD_5 removal. As shown in Fig 3, the influent concentration of BOD_5 fluctuated. However, BOD_5 concentrations in the effluent were at, or close to, the laboratory detection limits. The average BOD removal was more than 99% and the highest BOD removal efficiency of 100% was achieved.

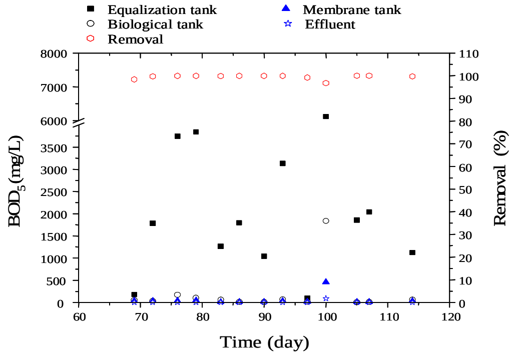


Fig. 3. Variations and removal of BOD

3.2 Variation of MLSS and flux

Fig. 4 shows that the plant can be operated with a high biomass concentration by using membranes for sludge separation. MLSS concentration in MBR tank was maintained in the range of 6000~17000 mg/L and excess sludge was wasted in accordance with the sludge growth rate (average SRT > 40 days). As shown as Figure 4, the variation of MLSS could be classified into two stages. The trend in the MLSS growth rate during the first stage (day 1 to day 60) was slowly raising followed by a sharp increase during the second stage. This is partly attributed to the influent COD concentration during stage 2 being on average higher than during stage 1. Further stage 1 and 2 could have corresponded respectively (i) to a stage of adaptation and acclimation of the biomass to the operating conditions and (ii) to a stabilized stage where the biomass can be considered as acclimated to the operating conditions

The average sludge production during stage 1 and 2 were 0.035 kgSS/kgCOD and 0.072 kgSS/kgCOD respectively, which is much less than the conventional activated sludge process (0.2~0.3 kgSS/kgCOD).

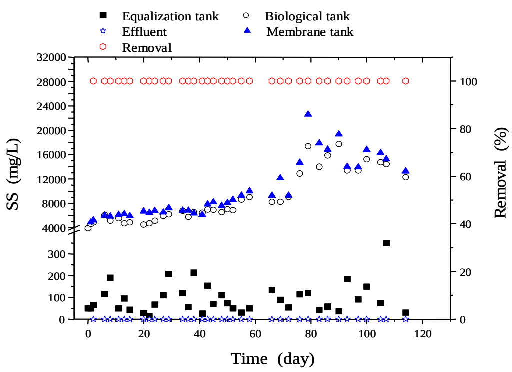


Fig. 4. Variations of MLSS and SS

Besides, the effluent SDI value is between 4 to 6 over the period of operation. It revealed that further treatment should be adopted if the effluent is to be used as the feed water to a RO system for recycling purposes. Otherwise, a membrane with a smaller pore size such as NF could be employed to improve the SDI index.

Fig. 5 illustrates the variations of TMP and flux during the monitoring period. The membrane module was withdrawn for cleaning on days 43 and 92 to remove clogging. Chemical cleaning was carried out on day 102 by inside-out type washing (as shown in Figure 5). It was found that the clogging occured periodically within about 40 days. It can be seen that there was an abrupt raise of TMP from 10 to 38 kPa prior to the second manual cleaning and the same phenomena was observed before the first manual cleaning. The TMP varied from 9 to 55 kPa with the flux change from 16-64 $Lm^{-2}h^{-1}$. However, the TMP kept within a range of 10-25 kPa over most of the period of operation. It demonstrated that less power consumption is needed for the immersed membrane system than for the pressure driven type of membrane.

Some studies reported that fouling was independent of MLSS concentration until a very high value was reached. Yamamoto et al. [6] reported that the critical MLSS concentration was about 30–40 g/L, but it varied with operating conditions. Ross et al. [7] also found that a dramatic increase in membrane fouling, i.e., a sharp decrease in permeate flux, occurred after a stable performance of up to 40 g/L of MLSS concentration. Based on the field observations in this study, a cake layer formed around the membrane fibres and seemed to contribute to the main part of membrane fouling even where the range of MLSS concentration investigated here was lower than the critical values reported in literature [6,7].

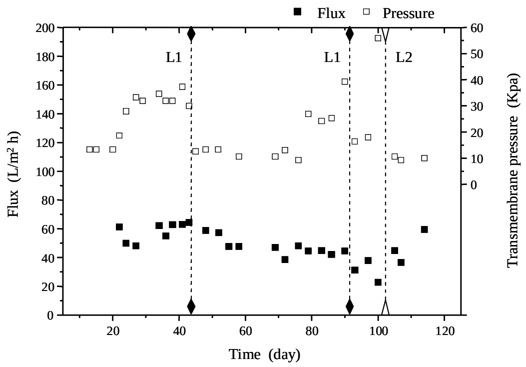


Fig. 5. Variations of flux, TMP and the cleaning of membrane (L1 manual cleaning, L2 chemical cleaning)

Fig. 6 shows the variation in viscosity during the period of operation. Similar to the trend observed with MLSS, three stages of variation in viscosity was observed. In the initial stage (up to day 50), the viscosity was low in a range between 8–13 mPa s, followed by a sharp increase from day 50 to day 69, and finally achieving the higher viscosity in the range of 64 - 79 mPa s.

The relationship between viscosity and MLSS is shown in Fig. 7. The result showed that the mixed liquor viscosity increased logarithmically as the MLSS concentration increased. It indicates a decreasing influence of higher solid concentrations on viscosity.

Previous results often demonstrated the plot of viscosity versus suspended solids with power or exponential laws, resulting in curves having upward concavity [8,9]. According to Sanin [10], exponential pattern can explain the stronger non-Newtonian behavior of the sludge with increasing solid concentration.

The exponential evolution of the viscosity with MLSS concentration for MBR systems was also observed others [11,12]. Trussell et al. [11] reported the relationship followed an exponential law at different MCRT (mean cell retention time) conditions. Pollice et al. [12] interpreted the plot of viscosity versus suspended solids with exponential laws but had a downward concavity similar to our work.

In fact, the dependence of viscosity with MLSS could be related to the sludge composition, the floc size and shape, the nature of the interactions between particles and to the quantity of bound water. The other parameters such as extracellular polymeric substances (EPS) and soluble microbial products (SMP) could also affect the variation of viscosity [8-10].

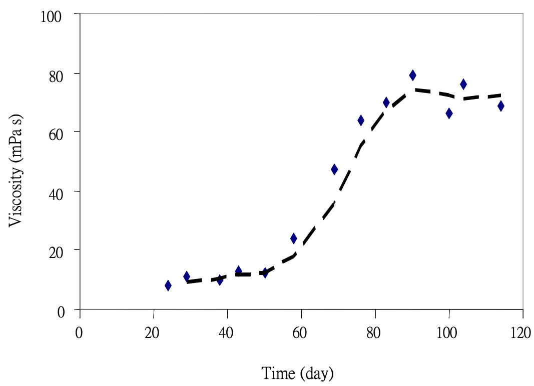


Fig. 6. Viscosity variation

In this study, the evolution of the viscosity with MLSS concentration based on field data followed a natural logarithmic variation and is different from the results of other studies. It implies that further study could be carried out to clarify this finding.

3.3 SEM and EDX

SEM was used to examine the morphology of foulants on outer and inner surface of fouled membrane. As can be seen in Fig. 8 (a), the outer surface has a huge deposit of foulants. On the other hand, the inner surface has less accumulation and the foulants have an irregular shape.

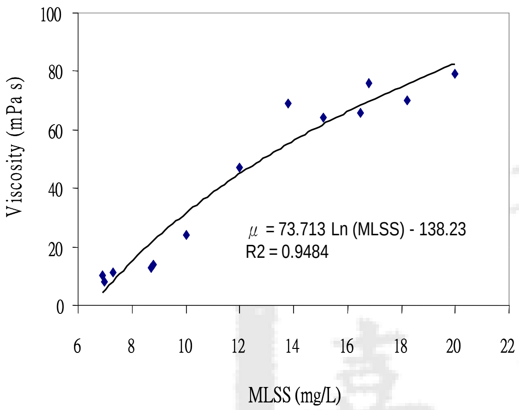
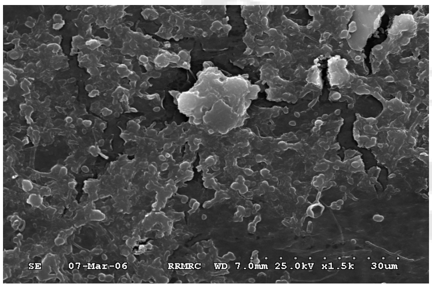
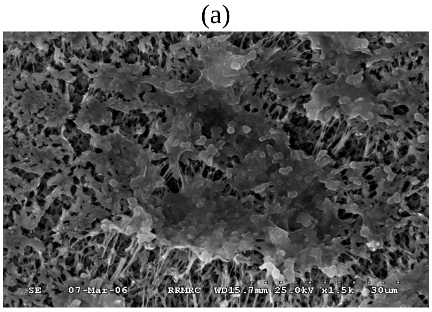


Fig. 7. Relationship between viscosity and MLSS.



(a)



(b)

Fig. 8. The SEM of fouled membrane (a) outer surface (b) inner surface

The results of EDX spectra indicated that nitrogen was not detected on inner surface and two kinds of cations, Rb and Pr, were deposited on the outer surface. However, Al can pass through the membrane and accumulate on the inner surface.

The results of SEM and EDX demonstrated that the fouling on the membrane outer surface was mainly due to microorganisms and/or the sludge physiological properties, such as EPS. The EDS results showed that cations on the outer surface of membrane were with higher diversity and quantity compared with the results of inner surface. It indicated that most of the cations were rejected by the biotic absorption and/or adsorption.

4. Conclusion

This study demonstrates the field operation of pharmaceutical wastewater treatment by MBR. It was demonstrated that the MBR system is capable of removing 95% and 99% of COD and BOD_5 respectively. The results indicate that the MBR system has a great potential in treating this type of wastewater with stable operation and satisfactory removal performance.

References

[1] T. Heberer, Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data, Toxicol. Lett., 131 (2002) 5–17.

[2] M. Carballa, F. Omil, J. M. Lema, M. Llompart, C. Garcia-Jares, I. Rodriguez, M. Gomez and A. Ternes, Behavior of pharmaceuticals, cosmetics and hormones in a sewage treatment plant, Water Res., 38 (2004) 2918–2926.

[3] F. Fan, H. Zhou and H. Husain, Identification of wastewater sludge characteristics to predict critical flux for membrane bioreactor processes, Water Res., 40 (2005) 205–212.

[4] M. Clara, B. Strenn, O. Gans, E. Martinez, N. Kreuzinger and H. Kroiss, Removal of selected pharmaceuticals, fragrances and endocrine disrupting compounds in a membrane bioreactor and conventional wastewater treatment plants, Water Res., 39 (2005) 4797–4807.

[5] K. Kimura, H. Hara and Y. Watanabe, Removal of pharmaceutical compounds by submerged membrane bioreactors (MBRs), Desalination, 178 (2005) 135–140.

[6] K. Yamamoto, M. Hiasa, T. Mahmood and T. Matsuo, Direct solid–liquid separation using hollow fiber membrane in an activated sludge aeration tank, Water Sci. Technol., 21 (1989) 43–54.

[7]W. R. Ross, J. P. Barnard, J. Roux Le and H. A. Villiers De, Application of ultrafiltration membranes for solids-liquid separation in anaerobic digester systems: The ADUF

process, Water SA, 16 (1990) 85–91.
[8] L. H. Mikkelsen, The shear sensitivity of activated sludge relations to filterability, rheology and surface chemistry, Colloids Surf. A: Phys. Eng. Aspects, 182 (2001) 1–14.
[9] N. Tixier, G. Guibaud and M. Baudu, Towards a rheological parameter for activated sludge bulking characterization. Enzymes Microb. Technol. 33 (2003b) 292–298.
[10] F. D. Sanin, Effect of solution physical chemistry on the rheological properties of the activated sludge, Water SA, 28 (2002) 207–211.
[11] R. S. Trussell, R. P. Merlo, S. W. Hermanowicz and D. Jenkins, Influence of mixed liquor properties and aeration intensity on membrane fouling in a submerged membrane bioreactor at high mixed liquor suspended solids concentrations, Water Res., 41 (2007) 947–958.
[12] A. Pollice, C. Giordano, G. Laera, D. Saturno and G. Mininni, Physical characteristics of the sludge in a complete retention membrane bioreactor, Water Res., 41 (2007) 1832–1840.

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

95 年 10 月

<table>
<tr><td>報告人姓名</td><td>張 家 源</td><td>服務機構及職稱</td><td>嘉南藥理科技大學
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<tr><td>會議時間地點</td><td>2006 年 9 月 10 日至 14 日
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<tr><td>會議名稱</td><td colspan="3">(中文) 2006 第五屆世界水大會
(英文) The 2006 IWA Beijing World Water Congress</td></tr>
<tr><td>發表論文題目</td><td colspan="3">(中文) 利用兩階段缺/好氧薄膜生物反應槽系統處裡 ABS 廢水之研究
(英文) Anoxic/aerobic Treatment of Acrylonitrile-Butadiene-Styrene Resin Manufacturing Wastewater in a Two-stage MBR System</td></tr>
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一、參加會議經過

水資源與其相關議題是影響 21 世紀全球發展的關鍵因素，世界水大會提供展示和傳播最新科技理念的機會，解決地區和全球性的多變且複雜的水問題。同時藉由水大會博覽會的同時進行，世界先進的產品、技術及管理策略得以展示及推廣；國際水協會（International Water Association, IWA)及中國大陸建設部於 2006 年 9 月 10 日至 14 日共計 5 天於中國大陸北京市國際會議中心共同舉辦兩年一次之第五屆世界水大會（The 2006 IWA Beijing World Water Congress）及 9 月 15 日之現地技術考察，促使世界各地水專業及科學家、知名企業家、一流的技術人員、政府官員、公共事業代表及其他專家等共同交流和分享先進經驗的機會。

本次論文發表會議屬國際水資源與其相關議題研究方面極重要之會議，其論文議題所包含之範圍甚廣，廣獲全球水環境與相關領域專家、學者及實務技術人員之重視及參與，參加本次會議之人數達 2 千人以上，議場盛況空前。

本人發表之論文安排在 poster presentation 部份，為能全程參與盛會，提前一天抵達並完成註冊手續，會議之進行之時間為早上 9 點至下午 6-7 點，本人於會場進行壁報展示,每天一早開始到下午結束時間,參加會議的學者依舊熱情不減,吾人所參與之論文發表場次內容都相當精彩。由於會議係採多組同時進行之方式，有許多論文同時進行發表時給予人有難以取捨之感。

本人海報發表論文為「Anoxic/aerobic Treatment of Acrylonitrile-Butadiene-Styrene Resin Manufacturing Wastewater in a Two-stage MBR System」。發表期間有許多來自各國相同領域之專家、學者及實務技術人員提問討論，並相互討論交換研究心得，彼此均覺獲益良多，除此之外並互相留下通訊聯絡方法以便後續之學術研究成果交流。

與會期間，本人亦邀請澳洲 Vigneswaran 教授蒞台訪問。2005 年 11 月份澳洲 Vigneswaran 教授曾蒞台訪問，訪校期間針對 MBR、薄膜、高級氧化、吸附與混凝等技術，在水與廢污水處理與回收再利用之研究及相關工程實務上之應用深入探討；期間除參觀本人實驗室及 MBR 模廠外，並與本校、他校教師及產業界進行交流與座談，各方均深感台灣發展永續嶄新技術與水回收再利用之重要性與迫切性。

二、與會心得

本次會議除發表本人論文外，其餘時間於各會場聽取發表，亦收集許多相關領域有趣之文章，相信此一次會議之資料必能為日後之研究提供更多幫助。在眾多論文當中，吾人發現不乏實場操作之經驗與資料，此外會場上亦有廠商之展覽近年來新式之水處理設備，個人服務於技職教育體系，深感理論與實務結合之重要性，因此研究、科技與生活、實用的結合將是未來研究的另一思考與推動之重要方向

三、建議

個人參與本次會議中發現有許多國內學者亦受貴會補助出席發表論文,表示台灣在水處理研究上亦有是相當程度之努力與成果，吾人相信本次國內學者在貴會之襄贊之下踴躍出席盛會，對提升研究水準與能力將有莫大助益,因此希望國內相關單位能夠盡量在可能範圍內補助國內學者參加國際學術研討會。

主辦國際聯合會議對當地科技之推廣與知名度之宣導有莫大幫助。國內若能由前輩學者發起，爭取國際大型會議的主辦權，對我學術研究之國際化與學術知名度之提升將大有幫助。

四、攜回資料名稱及內容

研討會論文及與光碟各一份

五、其他

非常感謝貴會補助個人出席本次會議，除拓展國際視野外，亦為一次非常豐收的學術交流之行。

表 1　2006 年 9 月 11 日　星期一 技術議程

時間	會議內容																	
	主題發言																	
	中國水日	污水處理			飲用水處理		給排水系統運營與管理		污水再生利用與非傳統處理系統		城市水管理策略	水資源和流域綜合管理		健康與環境	專題研討會			
09:15-10:45		脫氮技術Ⅰ	工業廢水處理Ⅰ		消毒及消毒副產物Ⅰ	飲用水的感官指標			污水再生利用Ⅰ	替代衛生設施	效率管理	水資源綜合管理Ⅰ		有害物質	科技前沿：新興生物與納米技術及其應用	雨水收集利用	水價和水價結構：趨勢與案例研究	水系統資產管理策略，基準與績效評估指標
11:30-13:00		脫氮技術Ⅱ	工業廢水處理Ⅱ	污泥管理Ⅰ	消毒及消毒副產物Ⅱ				污水再生利用Ⅱ		需求管理	水資源綜合管理Ⅱ	氣候變化對水資源管理的影響	有害物質的檢測				
14:30-16:00		脫氮技術Ⅲ	工業廢水處理Ⅲ	污泥管理Ⅱ	消毒及消毒副產物Ⅲ				污水農用		漏滲管理	地下水管理策略		有害物質的生物降解Ⅰ		世界衛生組織：家庭用水處理與安全儲存	水價和水價結構：可持續的成本回收	
16:45-18:00		脫氮技術Ⅳ	工業廢水處理Ⅳ	污泥管理Ⅲ	消毒及消毒副產物Ⅳ	配水系統的延伸作用	配水系統中水的水質	污水收集系統的運營與管理			再生水和非傳統水源			有害物質的生物降解Ⅱ				
08:00-18:30	展覽開放																	

表 2　2006 年 9 月 12 日　星期二 技術議程

時間	會議內容																
	主題發言																
	市長論壇	污水處理			飲用水處理		給排水系統運營與管理	污水再生利用與非傳	城市水管理策略	水資源和流域綜合管理	健康與環境	專題研討會					
09:15-10:45		除磷技術Ⅰ	工業廢水處理Ⅴ	厭氧消化Ⅰ	膜過濾Ⅰ	水處理工程	水廠運行與系統管理		管理與監管	點源及面源污染Ⅰ	毒性評估及環境影響	漏滲評估及管理	非傳統水源開發：節水污水再生海水淡化雨水利用	世界衛生組織：水安全計劃	大型流域水管理：歐洲和美洲的案例	旅遊娛樂健身中的給排水	極端環境下城市水的創新管理
11:30-13:00		除磷技術Ⅱ	物化處理工藝進展Ⅰ	厭氧消化Ⅱ	膜過濾Ⅱ	常規處理工藝新進展Ⅰ	污水處理廠運行		水的社會管理	點源及面源污染Ⅱ	有毒物質及新問題						
14:30-16:00		廢水處理廠的設計、成本及規劃	物化處理工藝進展Ⅱ	厭氧消化Ⅲ	膜過濾Ⅲ	常規處理工藝新進展Ⅱ		小型污水系統Ⅰ	定價與融資	模型和決策支持系統Ⅰ	水安全計劃與導則			世界衛生組織：再生水安全利用	大型流域水管理：亞洲和澳洲的案例		應對和適應氣候變化的水規劃
16:45-18:00		活性污泥動力學	物化處理工藝進展Ⅲ	厭氧消化Ⅳ	生物處理工藝的應用	水廠污泥管理		小型污水系統Ⅱ	用戶管理	模型和決策支持系統Ⅱ	偏遠社區及應急供水						
08:00-18:30	展　覽　開　放																

表 3　2006 年 9 月 13 日　星期三 技術議程

時間	會議內容															
	主題發言															
	農村污水國際研討會	污水處理			飲用水處理		給排水系統運營與管	城市水管理策略	水資源和流域綜合管	健康與環境	專題研討會					
09:15-10:45		污水膜處理系統Ⅰ	污水中的有害物質Ⅰ	臭味及揮發性氣體控制	反滲透和納濾Ⅰ		給水處理廠	長期規劃	基于環境考慮的流量分配	水安全計劃	未來從業人員規劃	水環境聯合會：融資與定價	世界銀行：水及衛生設備的發展趨勢	國際水研究報告	城市水安全(第一部份)	未來的城市：城市的可持續發展與水
11:30-13:00		污水膜處理系統Ⅱ	污水中的有害物質Ⅱ	生物處理工藝進展Ⅰ	反滲透和納濾Ⅱ	吸附與離子交換Ⅰ		水系統的可持續管理	飲用水水源及取水口的保護	農村供水	水問題的協調：財務、環境和社會公平	水環境聯合會：管理				
14:30-16:00		污水膜處理系統Ⅲ	污水中的有害物質Ⅲ	生物處理工藝進展Ⅱ	反滲透和納濾Ⅲ	吸附與離子交換Ⅱ		資產管理	環境污染物Ⅰ		21世紀衛生：革新性衛生系統(第一部份)	水環境聯合會：能量回收	世界銀行：管理、規章和財政	污水處理廠的數學模型：當前的發展狀況	城市水安全(第二部份)	
16:45-18:00		污水膜處理系統Ⅳ	污水中的有害物質Ⅳ	生物處理工藝進展Ⅲ	氧化技術	吸附與離子交換Ⅲ		雨水管理	環境污染物Ⅱ			水環境聯合會：水再生利用				
08:00-18:30	展覽開放															

表 4　2006 年 9 月 14 日　星期四 技術議程

時間	會議內容														
	主題發言														
	污水處理			飲用水處理	給排水系統運營與管理	污水再生利用與非傳統處理系統	城市水管理策略	水資源和流域綜合管理	健康與環境	專題研討會					
09:15-10:45	廢水處理工藝模型Ⅰ	生物膜工藝Ⅰ			信息技術和設施管理	人工濕地Ⅰ		社區服務	與人體健康相關的生物體	網絡檢測前沿技術		21世紀排水溝系統：革新性衛生系統(第二部份)	地方融資策略	可持續性AGORA	水廠更新改造的創新技術
11:30-13:00	廢水處理工藝模型Ⅱ	生物膜工藝Ⅱ	顆粒分離	氧化技術Ⅲ		人工濕地Ⅱ			病患體及檢驗	網絡模型前沿技術	客戶服務與溝通				
14:30-16:00	閉幕式 (北京國際會議中心)														
08:00-18:30	展覽開放