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COD REMOVAL BY LAB-SCALE MEMBRANE ACTIVATED SLUDGE PROCESS FROM LEACHATE OF GO CAT LANDFILL IN HOCHIMINH CITY

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ABSTRACT

This study examined characteristics of leachate from Go Cat landfill in Hochiminh city, Vietnam and the performance of a lab-scale bioreactor equipped with microfiltration unit (membrane bioreactor; MBR) for leachate treatment. The COD concentration of leachate was 39.6-59.8 g l^{-1} and 1.1-4.0 g l^{-1} in the dry season (Nov 2003, Apr 2004) and the rainy season (May, Aug 2004), respectively. This means that intensive precipitation in summer of the monsoon climate promotes leachate generation and changes in its quality due to the enhanced degradation and the increased dilution. The BOD/COD ratio over 0.68 through the year suggested biological wastewater treatment processes are promising ones for leachate treatment. The MBR was operated for 90 days at volumetric loading rates of 1.9-4.2 mg-COD l^{-1} d^{-1}. The microfiltration membrane successfully kept the sludge concentration high in the MBR. The specific loading rate was maintained at 0.097 to 0.616 g-COD g-VSS^{-1} d^{-1} owing to the high MLVSS concentration. The MBR showed high COD removal of 84-97% throughout the experimental period. Those results suggested that the effluent COD standard of 100 mg l^{-1} will be probably achieved in the rainy season but some post-treatment processes would be needed especially for the dry season.

KEYWORDS
Landfill leachate; membrane bioreactor; Hochiminh city

INTRODUCTION

Hochiminh city (HCMC) with a population over 6 million in 2004 is the most crowded city in Vietnam. The municipality manages about 5,000 tons d^{-1} of unclassified solid wastes containing about 60% biodegradable organic fraction, which are generated from residential and commercial areas (PCHCMCity, 2002). In order to deal with the rapid development of HCMC, several landfill sites have been constructed near the city. Leachate generated from such landfill sites is not always satisfactorily treated although applicability of several treatment processes has been studied (Ishigaki *et al.*, 2002). One of the reasons for difficulty in the treatment is that characteristics of leachate highly depend on precipitation. In HCMC 80-85% of the precipitation at 1,800 mm $year^{-1}$ usually comes down in the rainy season (May-Oct) (PCHCMCity, 2002). Such landfill leachates in the monsoon climate should be intensively studied (Fan *et al.*, 2005; Tränkler *et al*, 2005), however

characteristics of leachate in Vietnam have been rarely studied.

Leachate generated from young acidogenic landfills is generally characterized as high concentrations of chemical oxygen demand (COD), biochemical oxygen demand (BOD), and several toxic/hazardous compounds. The high BOD/COD ratio in young landfill leachates requires biological treatment processes (Inanc *et al.*, 2000; Timur *et al* ., 2000). It is generally suitable to use a biological treatment process when the BOD/COD ratio is higher than 0.5 (Chain, 1977). Although several biological treatment processes have demonstrated high performance for leachate treatment, some problems have been detected depending on the leachate characteristics such as the variations of the flow rate and the complex composition. To solve the problems, the membrane bioreactor (MBR) is a state-of-the-art technology for landfill leachate treatment (Ahn *et al.*, 2002; Robinson, 2005; Tarnacki *et al.*, 2005; Vasel *et al.*, 2004). The advantages of MBRs are the accumulation of a large amount of biomass, high volumetric loading rates (VLR), and a high quality of the effluent.

The objectives of this research were to survey the leachate characteristics of Go Cat landfill in HCMC in the dry and rainy seasons and to evaluate the performance of a lab-scale MBR for the leachate treatment. Possibility and limitation of the MBR for the leachate treatment in Vietnam were discussed on the basis of the national effluent standard for COD.

MATERIALS AND METHODS

Leachate sampling at Go Cat landfill

Go Cat landfill at a distance of 15 km from the center of HCMC is a young landfill operated since 2001 by CITENCO (City Environmental Company). This anaerobic open landfill has an area of 25ha and a capacity for receiving 2,000 tons d^{-1} of commingled solid wastes (ODAP Newsletter, 2001). A layer of high-density polyethylene material covers on the side slopes and the bottom of the dumping yards for leakage prevention. The wastes are disposed and pressed everyday in the yards. Vertical gas collecting wells and leachate collecting pipes were installed in the landfill.

Precipitation and average temperature in HCMC from Oct 2003 to Nov 2004 are shown in Fig. 1 (Statistical Office in HCMC, http://www.pso.hochiminhcity.gov.vn/). The leachate samples were collected from the landfill in the dry season (Nov 2003, Apr 2004) and the rainy season (May, Aug 2004). The samples were regularly collected in 20-litter plastic carboys from two ponds of Go Cat landfill, and transported to the laboratory. The samples were reserved in a refrigerator at 4°C and analyzed within 2 days. Table 1 shows leachate quality of the landfill.

Laboratory-scale MBR

A scheme flow of the lab-scale MBR, Aerobic Digester W11 (Armfield Co., Ltd, UK), was shown in Fig. 2. The apparatus consists of a 10-liter reactor vessel, a liquid feed pump, air supply blower, and instruments for monitoring and controlling the process. The cylindrical inner wall made from a porous plastic material with a pore size of 25μm has about 200mm outside diameter and 300mm height. This microfilter had a responsibility for retaining the suspended solids while allowing treated water to pass through to the outer, annular exit chamber. The pump delivered leachate to the reactor through a transparent lid. The transmembrane pressure (TMP) was monitored by the head loss of water inside and outside of the cylindrical wall. Air was supplied at a measured rate by the blower into the base of the reactor via a spider-arm dispenser, designed to prevent blockages as well as to produce sufficient bubbling for stirring and reaction. The water volume inside the cylindrical membrane was maintained at 6.3-7.4 l. The permeate was discharged by gravity to a floor-standing tank.

Operational conditions of the MBR

Seed sludge was sampled from a conventional activated sludge process in a wastewater treatment plant in HCMC. The sludge was cultivated in the MBR by the daily fill and draw operation with leachate of the initial COD concentration of 25,000-30,000 mg l^{-1}. The start-up period was three weeks for obtaining COD removal higher than 70%.

The MBR trial was divided into 3 phases: Run 1, Run 2, and Run 3 with different sludge retention time (SRT) and VLR in the continuous treatment mode under ambient condition. Table 2 presents the experimental conditions for three runs. In Run 1 COD removal and sludge production at VLR of 2.0 g-COD l-1 d^{-1} were evaluated without intentional sludge withdrawal from the MBR except for measuring the mixed liquor suspended solids (MLSS) concentration. In Runs 2 and 3, a certain amount of excess sludge was intermittently discharged from the bioreactor to maintain the

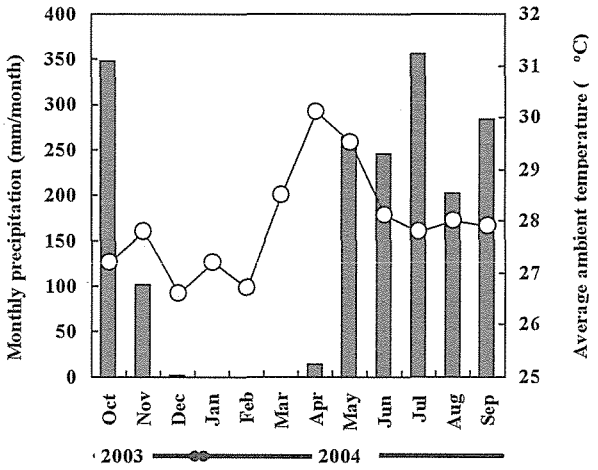

Figure 1 Precipitation and average temperature in HCMC from Oct 2003 to Sep 2004. Leachate generated from Go Cat landfill was sampled in the dry season (Nov 2003, Apr 2004) and the rainy season (May, Aug 2004).

Table 1 Seasonal variations of leachate composition of Go Cat landfill

Sampling date	Dry season				Rainy season			
	Nov 2003		Apr 2004		May 2004		Aug 2004	
Pond	Pond1	Pond 2	Pond1	Pond2	Pond1	Pond 2	Pond 1	Pond 2
pH	4.8	6.2	5.6	6.5	7.6	7.9	7.8	8.6
TDS(g l^{-1})	7.3	12.2	18.3	20.7	9.1	11.1	9.4	16.1
Hardness(g-$CaCO_3$ l^{-1})	5.8	9.7	5.7	8.1	1.5	1.9	0.6	1.5
SS(g l^{-1})	1.8	4.3	0.8	6.7	0.2	0.2	0.1	0.2
BOD(g l^{-1})	30.2	48.4	39.0	48.5	1.0	1.9	0.8	2.7
COD(g l^{-1})	39.6	59.8	50.6	57.3	1.4	2.7	1.1	4.0
BOD/COD	0.76	0.81	0.77	0.85	0.70	0.70	0.73	0.68
T-N (mg l^{-1})	560	900	980	1800	400	550	300	380
Org-N(mg l^{-1})	250	410	300	790	30	160	50	140
NH_4-N(mg l^{-1})	250	430	580	1550	370	390	230	320
NO_2-N(mg l^{-1})	0	2	0	2	0	2	0	2
NO_3-N(mg l^{-1})	0	5	0	5	0	5	0	5
T-P (mg l^{-1})	12.5	17.1	29.3	32.9	4.7	9.5	5.2	12.0

predetermined SRT. After discharge of half of the sludge in the MBR at the end of Run 1, it was operated at VLR of 2.0 g-COD l^{-1} d^{-1} and SRT of 50days in Run 2. The MBR was operated at the various VLR with SRT of 100days in Run 3 with starting mixed liquor volatile suspended solids (MLVSS) concentration of 8,300 mg l^{-1}. In Runs 1 and 2, the inflow rate was regulated depending on the influent COD concentration to maintain the predetermined VLR values as represented in Fig.3.

The membrane module was taken out from the bioreactor when TMP increased up to 60 -75 kPa, and was cleaned with tap water and then 0.5% NaOCl and 5% HCl solutions to remove the foulants on the membrane surface. The membrane was washed once a week in the first two weeks in Run 1, after then 2-3 times a week.

Analytical methods

The following parameters were measured by probe type DO-, pH- and total dissolved solids

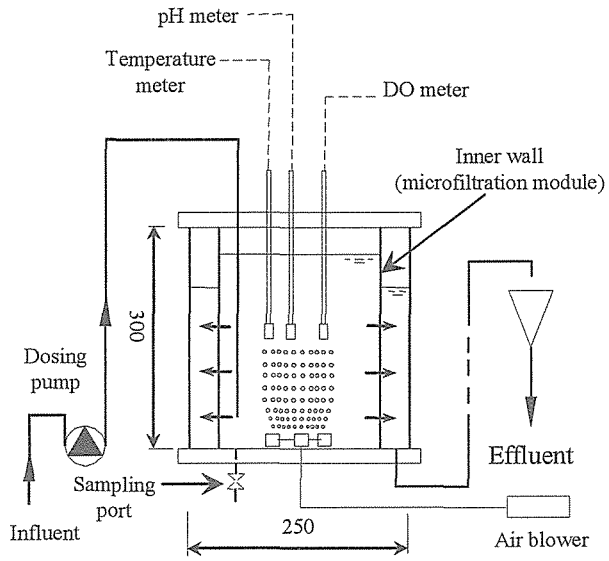

Figure 2 Schematic diagram of the MBR for leachate treatment. Permeate is obtained as the process effluent through the inner cylindrical wall (microfiltration).

Table 2 Experimental conditions for leachate treatment by the MBR

	Run 1	Run 2	Run 3
Operation period	Day 0-48 (48days)	Day 49-66 (18days)	Day 67-90 (24days)
SRT (day)	∞ *1	50	100
Flow rate (l d^{-1}) *2	0.4-1.5	0.9-1.7	2.5-3.5
Volumetric loading rate (g-COD l^{-1} d^{-1})	2.0	2.0	1.9-4.2
Specific loading rate (g-COD g-VSS^{-1} d^{-1})	0.097-0.44	0.231-0.328	0.209-0.616
Influent temperature (^{0}C)	20-25	20-25	20-25
DO in bioreactor (mg l^{-1})	4-5	4-5	4-5
pH	6.5-8.5	6.5-8.5	6.5-8.5
KH_2PO_4 solution added to COD/P ratio	150	150	150

*1 Without sludge withdrawal except for MLSS measurement

*2 Flow rate was regulated according to the influent COD concentration to maintain the predetermined VLR (see Fig. 3).

(TDS)-meters. COD_{Cr}, BOD_5, MLSS, MLVSS, nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonium nitrogen (NH_4-N), organic nitrogen (Org-N), total Kjeldahl nitrogen (T-N), and phosphate concentrations and hardness were analyzed according to the standard methods (APHA-AWWA-WPCF, 1995).

RESULTS AND DISCUSSION

Leachate from Go Cat landfill in rainy and dry seasons

Table 1 shows leachate quality of Go Cat landfill in HCMC, Vietnam. As shown in Fig. 1, there were large precipitations in the rainy season in HCMC. Although the water balance in the landfill has not been exactly elucidated, Go Cat landfill produces leachate about 400 m^3 d^{-1} in average and much more in the rainy season (ODAP Newsletter, 2003). The COD concentration in leachate dropped drastically from 39.6-59.8 g l^{-1} in the dry season to 1.1-4.0 g l^{-1} in the rainy season, while the BOD value also did between 30.2-48.5 and 0.8-2.7 g l^{-1}. The BOD/COD ratio that is an indicator of the proportion of biodegradable organic matter to total organic matter showed a slight decrease from 0.76-0.85 in the dry season to 0.68-0.73 in the rainy season, indicating enhanced biodegradation in the landfill in the rainy season.

pH increased from 4.8-6.5 in the dry season to 7.6-8.6 in the rainy season. This means that the large precipitation in the rainy season dissolved alkalinity of the cover soil in the landfill into leachate.NH_4-N and Org-N were major components of the nitrogenous compounds in leachate. T-N and Org-N concentrations in the rainy season were apparently lower than those in the dry season. However, NH_4-N concentrations stayed at the same level through the year, presenting the enhanced ammonification of organic compounds in the rainy season. NO_2-N and NO_3-N concentrations were negligible in the young leachate, suggesting the nitrification process does not proceed significantly in the anaerobic landfill. Total phosphorus concentrations also declined from 12.5-32.9 mg l^{-1} in the dry season to 4.7-12.0 mg l^{-1} in the rainy season. It is noted that low phosphorus concentrations are an important limiting factor for subsequent aerobic biological treatment of leachate.

Although there is a little information on the effect of the climate on the leachate composition and generation (Fan *et al.*, 2005; Tränkler *et al*, 2005), it was confirmed that intensive precipitation in summer of the monsoon climate promotes leachate generation and changes in its quality due to the enhanced degradation and the increased dilution as shown in Table 1. If quantitative and qualitative variations of leachate were not considered into the design and operation of the leachate treatment process, it would be occasionally overloaded in practice due to high discharges in the rainy season and high concentrations in the dry season.

Performance of MBR for COD removal

The lab-scale MBR was operated for treatment of Go Cat landfill leachate, which has BOD/COD ratios higher than 0.5. Phosphorus as KH_2PO_4 solution was added to leachate for retaining the COD/P ratio = 150. The operational conditions and the performance of the MBR are shown in Fig. 3. The inflow rate in Runs 1 and 2 was set as expressed in Fig. 3A to maintain the high predetermined VLR of 2.0 g-COD^{-1} l d^{-1} while conventional activated sludge processes are usually applied at VLR of 0.4-0.8 g-COD l^{-1} d^{-1}.

In Run 1, the MBR was operated without intentional sludge withdrawal. According to the variation of the influent COD concentration in a range of 35,000-9,000 mg l^{-1} during 48 days, the inflow rate was regulated at 0.4-1.5 l d^{-1}. The MLVSS concentration increased from 4,600 mg l^{-1} on day 0 to 15,000 mg l^{-1} on day 46. After day 3, the effluent COD concentration was maintained around 1,000-1,500 mg l^{-1}. In Run 2, the MBR was controlled at SRT of 50days. Owing to the sludge

withdrawal, the MLVSS concentration dropped from 8,200 mg l^{-1} on day 49 to 4,500 mg l^{-1} on day 64. The effluent COD concentration was 870-1,300 mg l^{-1} during day 55-63. In Run 3, the MBR was operated at SRT of 100 days at various VLR of 1.9-4.2 mg l^{-1} d^{-1} as shown in Fig. 3B. The influent COD concentration was relatively low between 4,000 and 10,000 mg l^{-1}, while the inflow rate was regulated very high in a range of 2.5-3.5 l d^{-1}. The MLVSS concentration increased from 8,300 mg l^{-1} on day 67 to 14,000 mg l^{-1} on day 90. The effluent COD concentration was 65-830 mg l^{-1} in spite of the high VLR.

In all the runs, the specific loading rate (0.097-0.616 g-COD g-VSS^{-1} d^{-1}) was kept as low as that of conventional activated sludge processes in spite of the high VLR. This is caused by the high MLVSS concentration kept by the membrane. High COD removal of 84-97% was also achieved but the MBR performance was not always satisfactory for the national effluent standard type B as COD $\leq$100 mg l^{-1}. This standard is actually difficult to be achieved by any typical wastewater treatment process alone including the MBR technology. Fig. 4 shows a summary of the MBR performance, as the effect of the influent COD concentration and the inflow rate on the effluent COD concentration. If the influent COD concentration is comparable to that of leachate in the rainy season, i.e. less than about 4,000 mg l^{-1}, it was possible to achieve the effluent COD standard at the high inflow rate of about 3.5 l d^{-1}. On the other hand, the effluent COD concentrations were much higher than the standard when the influent COD concentrations were higher than 4,000 mg l^{-1} even at low inflow rates. This result suggests that leachate treatment by MBRs in the rainy season would be easier to achieve the environmental standard than that of in the dry season if an enough reactor volume is provided for preventing overflow.

In this study, possibility and limitation of the MBR for the leachate treatment were discussed on the basis of COD removal. Further studies on heavy metals, color components, and persistent organic pollutants in leachate will be needed. For constantly satisfying the environmental standards in Vietnam especially in the dry season, some post-treatment processes, such as coagulation, Fenton reactions, UV-TiO_2-H_2O_2 treatment (Ishigaki *et al.*, 2002), ultrafiltration, and nanofiltration, following MBRs as a main treatment process will be helpful although degradation of organic pollutants by Fenton reactions and UV-TiO_2-H_2O_2 treatment under some operating conditions results in generation of toxic intermediates.

CONCLUSIONS

Intensive precipitation in summer of the monsoon climate promotes leachate generation from Go Cat landfill and changes its quality due to the enhanced degradation and the increased dilution. The results of the leachate treatment tested by the lab-scale MBR suggested that the effluent COD standard in Vietnam would be probably achieved in the rainy season but some post-treatment processes would be needed especially in the dry season.

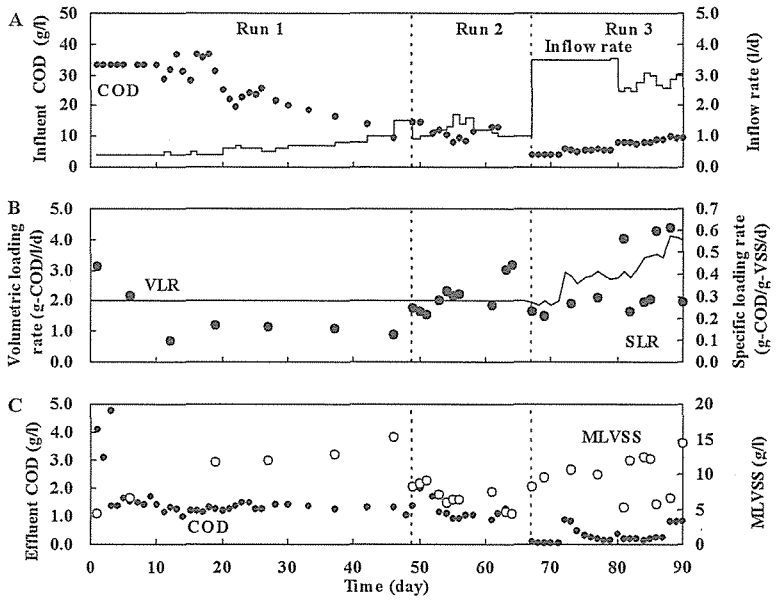

Figure 3 Operational conditions and performance of the MBR for Go Cat landfill leachate treatment. The influent COD concentration (●) and the inflow rate (—) (A), the volumetric loading rate (—) and the specific loading rate (●) (B), and the effluent COD concentration (●) and the MLVSS concentration (○) (C) are shown.

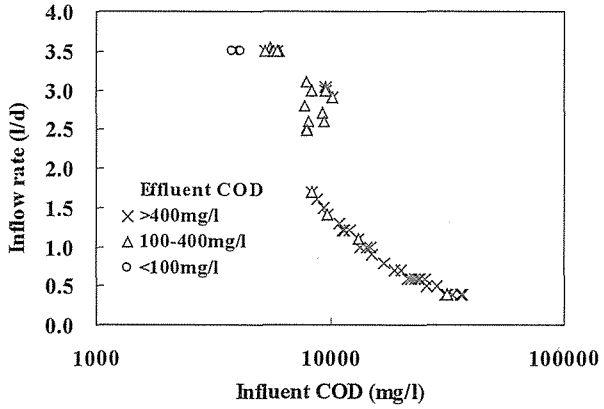

Figure 4 Effects of the influent COD concentration and the inflow rate on the effluent COD concentration of the MBR treating Go Cat landfill leachate.

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