Entrapped Mixed Microbial Cell Process for Biological Wastewater Treatment/Reuse

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INTRODUCTION

Currently, the issues of wastewater reuse require the development of biological treatment technologies in order to protect environmental quality, conserve limited water resources, and avoid public health problems. Agricultural and domestic wastewater problems have existed for many years. The development of in-time technology for potential reuse/disposal of agricultural and domestic wastewater is required.

EMMC (Entrapped Mixed Microbial Cell) technology developed at the University of Hawaii at Manoa for some years (Yang et al 1995-2007). The EMMC process is considered to be one of the most effective ways to remove organics and inorganics for the land limited condition. In this conference, it will be presented the requirement of using EMMC carrier reactor, carrier selection, application for wastewater treatment, and comparison of MBR (Membrane Bioreactor).

METHODS AND PROCEDURES

Preparation of EMMC-biobarrel carriers

The EMMC-biobarrel carriers were prepared by following the procedure of making a EMMC carrier developed by Yang et al., (1994), with a minor revision. Cellulose triacetate (CTA), a water-permeable polymer, is used as gel material to confine the migration of microorganisms. The advantages of employing CTA for carrier-making, such as simpler preparation and better mechanical strength have been demonstrated by Yang, et al., (1988). The mixed microbial cells used in this study were obtained from the dewatered sludge in East Honolulu Wastewater Treatment Plant (EHWTP), Honolulu, Hawaii.
A mixture of 100ml of 10%(w/v) cellulose acetate using methelene chlorides as a solvent was mixed with dewatered sludge containing about 90% of water. After mixing uniformly, the biobarrel rings were added. The biobarrel rings were coated with or filled the mixture of gel and cells for carrier shaping. The well-coated and filled biobarrels were then firmed in 100% toluene solution. The hardened carriers were washed with tap-water and then packed in the reactor for further experiments. The organic solvents (methelene chloride and toluene) can be recovered by a combination of freezing and distillation methods (Zhang, 1995) if needed.

System set-up and operation

Laboratory scale systems of the EMMC-biobarrel with both single-layer and double layer configurations were set up. For the single-layer system, the carriers were randomly packed in the reactor, forming one layer by gravity. The liquid volume occupied by the carrier was about 1L with a packing ratio of 20% based on the total effective volume of 5L. For the double-layer system, the EMMC-biobarrel carriers were separated into two layers with an overall packing ratio of 13% based on a total effective volume of 18.9L. Initial biomass concentrations in the single- and double-layer systems were estimated as 8g/L and 5.2g/L of total effective volume, respectively.

An HRT of 9h with intermittent aeration of 1 hr on/2 hrs off was applied as a start operational condition, which was then followed by a switch of aeration schedule to continuous aeration. Further HRT reduction of 6h was applied in order to observe the impact of the loading rate on the systems' performance. The operational conditions are summarized in Table 1. The airflow rate was maintained at 1.2L/L void volume (total volume-carrier volume)/min. The system was operated at room temperature (25±2) and the pH ranged from 7.3~8.5.

Table 1 Operational conditions

System	HRT (hrs)	Aeration Schedule	Packing Ratio (%)
Single-layer system I	6	Intermittent	10%
Single-layer system II	6	Continuous aeration	20%
Double-layer system III	6	Continuous aeration	13%

Feed characteristics

The synthetic wastewater simulated to the domestic sewage was prepared daily using sucrose as a carbon source. The COD/N ratio was maintained at 5. The COD and NH_4^+-N concentrations of the synthetic feed incorporated in this study was about 200 mg/L and 40 mg/L, respectively. The phosphate buffer was incorporated to maintain a stable pH during operation.

RESULTS AND DISCUSSIONS

Requirement and Selection of EMMC Carriers

Immobilized microbial cells systems have been widely used for biological wastewater treatment through the attachment of mixed microbial cells. The attached cell process method has the disadvantages of falling off due to period back washing or high flow rate impact. On the contrary, the EMMC (Entrapped Mixed Microbial Cell) technology entraps mixed microorganisms inside a gel. The EMMC technology will allow the diffusion of substrates to the cells and products to be away from the cells. Materials which have been successfully used for cell entrapment include agar, agarose, kappa-carrageenan, collagen, alginates, chitosan, polyacrylamide, polyurethane, cellulose, and cellulose triacetate. Among these materials, cellulose triacetate was selected as an EMMC carrier because of its mechanical strength. Based on our previous studies (Yang et al 1995-2007), it provides the following advantages over the existing technology:

(a) High density of microbial cells.
(b) Various species/types of microbial cells can be co-entrapped in a bioreactor.
(c) Durability; without any loss of activity and dissolution of the carriers.

Application of Biological Wastewater Treatment

A laboratory study for EMMC technology was investigated for the comparison of single and double layers of EMMC carriers for the simultaneous removal of carbon and nitrogen at HRT of 6 hrs and continuous aeration. As shown in Figure 1 and Table 2, the process performances of each system are presented. It is apparent that at an HRT of 6 hrs all the systems achieve a comparable organic removal. Although the nitrification efficiency of system III is slightly lower than the other systems, the total nitrogen removal of system III is higher than system I and comparable with system II.
Introducing double layer design to EMMC-biobarrel process is considered as an approach to improve system mass transfer. One of the most important factors affecting mass transfer efficiency is the interfacial surface area. For a packed-bed system, to a certain extent, reducing packing density (the number of the media in unit volume) can result in higher mass transfer efficiency because lower packing density can avoid surface overlapping, i.e., the waste of specific area. With a similar concept, EMMC carriers were divided to double-layer in order to improve the interfacial area between carrier and incoming oxygen and substrate and, consequently, the treatment efficiency.

Comparison and Integration of EMMC and MBR Processes

Performance of single-stage MBR processes for domestic wastewater treatment has been investigated for decades. In general, single-stage MBR process is able to achieve high organics and SS removal efficiencies. Regarding the nitrogen removal, the MBR process has been shown to provide complete nitrification (>99%) and partial denitrification of municipal wastewater, resulting in low ammonia and organic nitrogen concentrations but high nitrate concentration (Fan et al. 1996). As shown in Table 2, the performance comparison between a typical single-stage MBR and EMMC-biobarrel processes is presented.

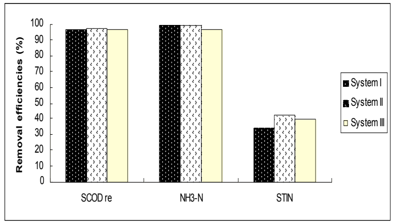

Figure 1 Performance comparison of the system I, II and III at HRT of 6h with continuous aeration

Table 2 Process performance of MBR (Fan et al., 1996) compared with the EMMC-biobarrel process

Parameters	Unit	Single stage MBR	Double-layer EMMC-biobarrel*
TCOD loading rate	kg/m^3/day	1.32	0.86
TN loading rate	kg/m^3/day	0.17	0.15
TCOD/N		7.7	5.7
TCOD reduction	%	96	86
NH_3-N reduction	%	>99	96.6
TN reduction	%	17	39.6
TSS reduction	%	>99	---
Aeration schedule		Continuous	Continuous

As shown in Table 2, both of the single stage MBR and the EMMC-biobarrel processes demonstrate advantages and disadvantages. On one hand, the single-stage MBR achieves about 10% higher TCOD removal efficiency than that of EMMC-biobarrel process. This is because the ultrafiltration (UF) membrane is able to completely prevent the suspended solid from being washed out and, consequently, leads to a lower TCOD concentration. On the other hand, because the concurrent aerobic/anoxic conditions can be well developed in the EMMC-biobarrel process due to the presence of the carrier, EMMC-biobarrel process achieves about 23% higher total nitrogen removal efficiency than that of single stage MBR even at a lower influent COD/N ratio.
MBR process is a high cost process due to membrane purchasing, fouling remediation, and energy consumption. It seems that the EMMC-biobarrel is more cost effective than MBR due to its simple configuration, easy operation, and maintenance.

CONCLUSION

EMMC-biobarrel processes with single-layer and double-layer configurations were investigated simultaneously for carbon and nitrogen removal from synthetic-domestic wastewater. Continuous aeration was proved to be more suitable for the systems for achieving complete nitrification and improved denitrification. At the COD loading rate of 0.75 kg/m^3/day and NH_3-N loading rate of 0.16 kg/m^3/day, more than 96% of SCOD /NH_3-N removal and about 40% of STIN removal were obtained from all systems. Long SRTs of about 200 days could be achieved by the single-layer system with a packing ratio of 20% and double-layer system with a packing ratio of 13% due to the effective entrapment of biomass in the systems (Zhu, 2006).

XVIIth International Conference on Bioencapsulation, Groningen, Netherlands ; September 24-26, 2009

EMMC-biobarrel process is strongly recommended for land limited/small wastewater treatment due to its small space requirement, high performance, and simple operation and maintenance.
Integrating the MBR-EMMC-biobarrel system is strongly recommended because it may be a “break-through” for solving the membrane fouling problem and in improving the effluent quality for further advance treatment if reuse is required.

Acknowledgement

Funding for this research was provided by the College of Tropical Agriculture and Human Resource, University of Hawaii at Manoa, Honolulu, Hawaii, USA. Ms. Jia Zhu is now associated with GMP International Inc. as an environmental engineer.

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