Effect of Temperature on Treating Low Strength Wastewater in an Anaerobic Immobilized Bio-plates Reactor

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Abstract
An anaerobic immobilized bio-plates reactor (14.5 L, packing ratio of 27.5% and 7 compartments) was applied to treat low strength wastewater (400 mg COD/L) with non-fat dry milk (NFDM) as carbon source. The two substrate concentrations of NFDM were treated with a hydraulic retention time of 16 h at 35°C. Afterward, the reactor was steadily reduced to 25°C. At the various substrate concentrations of NFDM, temperatures and with a hydraulic retention time of 16 h, chemical oxygen demand (COD) removals were 87% or higher and effluent concentrations of COD and volatile fatty acids (VFA) were 50 mg/L and 6 mg/L or lower, respectively. No significant negative impacts under 25°C on organic removal were found. The CH_4 contents were higher 76% and overall methane yields were 0.21-0.27 L/g $COD_{removed}$ in steady state. The low energy required for system operation was 4E-06 kWh/m^3 of requiring one influent pump. The immobilized anaerobic reactor demonstrated good treatment performance when the operating temperatures were 25 and 35°C.

Keywords
Low strength wastewater; anaerobic immobilized bioreactor; anaerobic treatment; immobilization

Introduction

Anaerobic biologic treatment offers merits of energy saving, low sludge production and methane generation in comparison to conventional aerobic activated sludge process. However, due to its relative problems such as slow growth of anaerobic bacteria, washing out of biomass, time and temperature dependent biochemical reaction, the application of anaerobic treatment for the low strength wastewaters (COD < 700-1000 mg/L) was fairly limited. In addition, low strength wastewater was often treated at ambient temperatures but anaerobic biologic treatment were commonly preferred to be operated under mesophilic condition (30-35°C) for high rate efficiency treatment, which resulted in higher energy operating costs. In this study, we developed immobilization biotechnology to entrap anaerobic bacteria in the form of bio-plates which could maintain high anaerobic sludge concentration with low suspended biomass concentration and achieve simultaneous removal of carbon and nitrogen within a single through-put process for the treatment of low strength wastewaters. Thus, the treatment performance and effect of temperatures on the anaerobic immobilization biotechnology for the treatment of low strength wastewater were investigated.

Materials and methods

In this study, a 14.5-L immobilized bio-plates reactor consisted of standing baffles which divided into 7 compartments was set up to investigate for low strength wastewater (400 mg COD/L) treatment. The immobilized reactor was prepared per Yang et al. (1997), and having a packing ratio of 27.5%. The reactor had a MLSS of 58 g/L and operated at the SRT of 350-600 d. The reactor was fed with synthetic wastewater containing non-fat dry milk (NFDM) as carbon source with substrate of 425 ± 7 mg COD/L (NFDM: 91.8 mg/L; sodium acetate: 439 mg/L) under the temperature of 35°C at a HRT of 16 h (OLR: 0.6 g COD/L-d) for start-up period. After the two months of start-up periods (COD removal more than 80%), the two substrate concentrations of

NFDM were treated with a HRT of 16 h at 35℃ as stage Ⅰ and Ⅱ and the pH was controlled at 7. The temperature in the reactor was stepwise decreased from 35 to 25℃ as stage Ⅲ by a water jacket and a water bath. All the experiments were analyzed with the TCOD, SCOD, gas composition, gas production, VFAs and dissolved methane to evaluate their treatment performance.

Results and discussion

The operating condition and the treatment performance for the anaerobic immobilized bio-plates reactor from stage Ⅰ to Ⅲ are showed in Table 1. The results from stage Ⅰ (NFDM: 183.6 mg/L; sodium acetate: 299 mg/L) to stage Ⅱ (NFDM: 275.4 mg/L; sodium acetate: 149.4 mg/L) showed the COD removal efficiencies and methane contents were slightly decreased from 91 to 88% and 82.9 to 78%, respectively and the effluent COD concentrations, VFA concentrations (mainly acetic acid) and carbon dioxide content were increased from 38 to 47 mg/L, 1 to 3 mg/L and 2.2 to 6%, respectively. To degrade a complex mixture depended on the K values of the methanogens and the limitations of mass transfer (Langenhoff and Stuckey, 2000) which resulted in gas production decreased and dissolved methane increased to 21-22.4 mL CH_4/L of water from stage Ⅰ to Ⅱ. As for the stage Ⅲ, the temperature reduced from 35 to 25℃ by decreasing 1℃/d. The results showed the effluent TCOD, SCOD and VFA concentration were slightly increased from 47 to 50 mg/L, 41 to 46 mg/L and 3 to 6 mg/L, respectively; with achieving 87, 76.4% and 5.4% of COD removal efficiency, methane content and carbon dioxide content, respectively. It was observed that the reduction of gas production and dissolved methane increased to 30 mL CH_4/L which is 102% of the statured value (0.021 g gas/kg water at 25℃) when the temperate decreased to 25℃. It could be attributed to non-well mixing at lower temperature, and lower gas production and limitation of mass transfer could lead to poor contact between biomass and substrate. The immobilized reactor had an overall methane yield of 0.26-0.27 L CH_4/g $COD_{removed}$ at 35℃ while it only produced 0.21 L CH_4/g $COD_{removed}$ of methane yield at 25℃. The methane yield reported in this study was similar as (Kayranli and Ugurlu, 2011), who reported that production of about 0.2111 L CH_4/g $COD_{removed}$ was found in an ASBR treating low strength wastewater (500 mg COD/L containing NFDM as carbon source) with a HRT of 15 h at 25℃. VFA accumulation in the system would negatively impact the performance, however low VFA value in the effluent was measured (6 mg COD/L), and suggested that VFA inhibitory effect was insignificant during these three stages. Lastly, the immobilized anaerobic reactor demonstrated good treatment performance when the operating temperatures were 25 and 35℃. The low energy required for system operation was 4E-06 kWh/m^3 of requiring one influent pump.

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Table 1. Operating conditions and average performance in steady state for the anaerobic immobilized bioplate reactor

Stage	Ⅰ	Ⅱ	Ⅲ
HRT (h)	16	16	16
OLR (g COD/L-d)	0.6	0.6	0.6
Temperature (℃)	35	35	25
Operating period (d)	83	110	30
Substrate (mg/L)			
NFDM	183.6	275.4	275.4
Sodium acetate	299	149.4	149.4
Influent (mg/L)			
TCOD	425 ± 7	425 ± 7	425 ± 7
SCOD	365 ± 25	316 ± 10	316 ± 10
Effluent (mg/L)			
TCOD	38 ± 9	47 ± 8	50 ± 10
SCOD	31 ± 8	41 ± 7	46 ± 8
VFA	< 1	3 ± 1	6 ± 1
Removal (%)			
TCOD	91 ± 3	88 ± 5	87 ± 5
Gas composition (%)			
CH_4	82.9 ± 1	78 ± 1	76.4 ± 1
CO_2	2.2 ± 0.2	6 ± 0.7	5.4 ± 0.7
N_2	14.9 ± 2	16 ± 2	18.2 ± 1
Methane yield (L CH_4/g $COD_{removed}$)*	0.26	0.2	0.13
Gas production (L CH_4/L)	2-2.3	1.4-1.7	0.8-1.2
Dissolved methane (mL CH_4/L)	-	21-22.4	~ 30

* Methane yield for gaseous methane