Reducing sludge production by using swim-bed technology as an innovative attached-growth process

Yingjun Cheng, student member, Graduate school of Science and Technology, Kumamoto University
Daisuke Yazaki, non-member, Graduate school of Science and Technology, Kumamoto University
Toichiro Koyama, non-member, NET Co. Ltd.
Kenji Furukawa, member, Faculty of Engineering, Kumamoto University

1 Introduction

Forming large amounts of sludge in the wastewater treatment process represents more investment, especially more operating costs. Usually, in anaerobic wastewater process, excess production is considerably lower than that in the aerobic treatment. However, in practice the application of anaerobic process is more restricted compared to the aerobic process. It is valuable to find a good way in aerobic process to reduce the excess sludge production. To maximize and encourage the growth of microorganisms, which locate in the higher position of food chain, is an effective way to reduce the sludge production[1]. Swim-bed technology involving the novel biofringe (BF) material can allow a longer food chain forming due to the attachment of a large amount of biomass on a flexible matrix in a fixed position. A high and stable organic pollutant removal rates, with low sludge yields, were achieved by using a single vessel BF reactor in the present study.

2 Materials and methods

Experimental set-up

The reactor used in this study was 21.6L and constructed of acryl resin, having downdraft and updraft sections in a parallel upright arrangement as shown in Fig.1. Influent was introduced deeply within the updraft section using a peristaltic pump. Air was also introduced near the bottom of the updraft section, which served to mix and oxygenate the wastewater while circulating it through the reactor.

Feed wastewater

The influent solution was mainly composed of peptone and bonito fish-meat. The 5-day biochemical oxygen demand (BOD) was 74% of the chemical oxygen demand (COD) for influent solutions. $KHCO_3$ solution was also added into it as a buffer solution.

Analytical methods

Influent and effluent were measured by the closed reflux colorimetric method according to Standard Methods[2], with filtration samples using 0.45 μm filter paper to remove undissolved components. BOD was measured using a respirometer (BOD Track; Hach Co., Ltd., Loveland, CO). The MLSS concentrations in reactor and SS concentrations in effluent were determined according to the Standard Methods. Sludge attached on the BF was observed frequently using the microscope.

Operational conditions

The experiments were divided into four runs depending on the COD volumetric loading rates applied. Table 1 gave an overview of the main operational characteristics of the whole experiments. When one run of study was finished, stopped the operation of the reactor, drawn out the BF and measured the biomass attached on it, cleaned the reactor and determined the dispersed biomass in the cleaned water, respectively. And then, the experiment was re-started immediately, using the biomass detached from the BF as the seed sludge and increasing to a higher COD volumetric loading rates.

Table 1 Operational characteristics

Run	I	II	III	IV	
HRT(h)	10.8	10.8	10.8	10.8	
COD loading rate(kg-COD/m^3/d)	1	2	3	4	5
Influent COD(mg/L)	450	900	1350	1800	2250
Duration(d)	30	20	16	6	16

Nevertheless, for run IV, the experiment was first operated on COD volumetric loading rates of 4 kg-COD/m^3/d and then increased to 5kg-COD/m^3/d continually. In order to get the effluent sludge production, the effluent was collected every day.

3 Results and discussions

Pollutant removal performance

The degradation of organic constituents was evaluated by COD removals as shown in Fig. 2. The COD removal rates were kept consistently throughout the entire range of the testing and 80% COD removal efficiencies were obtained even at the COD volumetric loading rates of 5kg-COD/m^3/d.

The MLSS concentrations in reactor and effluent SS concentrations changed with the subsequently increasing the COD loading rates as shown in Fig. 3. MLSS concentrations were not stable although under the operation of one loading rate, which should be related to the metabolism cycle of the biofilm. The average SS concentrations in the collected effluent varied from 10.3mg/L to 238.2mg/L with the COD loading rates increased.

Sludge yields

The sludge yields were calculated according to the following equation in every run.

$$Y = \frac{g\text{-}SS_{end} - g\text{-}SS_{start}}{g\text{-}COD_{removed}} \quad (1)$$

$$g\text{-}SS_{end} = SS_{BF} + SS_R + SS_E \quad (2)$$

Where $g\text{-}SS_{start}$ was the total amount of seed biomass presented at the initial of each run. $g\text{-}SS_{end}$ represented the sum of the biomass at the end of the experiment , which included the biomass attached on the biofilm(SS_{BF}), dispersed bacteria contained in the cleaned water of the reactor(SS_R) and the sum of the biomass(SS_E) in every day's collected effluent. The term of $g\text{-}COD_{removed}$ means the total COD removed in every run.

Table 2 Sludge yields for every run

Run	SS_{start}(g)	S_{end}(g)	$COD_{removed}$(g)	Y(kg-MLSS/kg-$COD_{removed}$)
I	23.33	99.78	563.76	0.136
II	18.56	138.16	743.04	0.162
III	23.84	167.27	881.28	0.162
IV	15.03	313.02	1833.4	0.163

It was well known that the sludge production would increase with enhancing the organic loading rates[3]. While in the case of BF process, there was only a slight increasing when the COD loading rates increased. The sludge yields obtained in this study were about less than 50% of those typically conventional aerobic processes. It should be contributed to the long food chain of the BF process and was verified by the microscopic observation shown in Fig.4

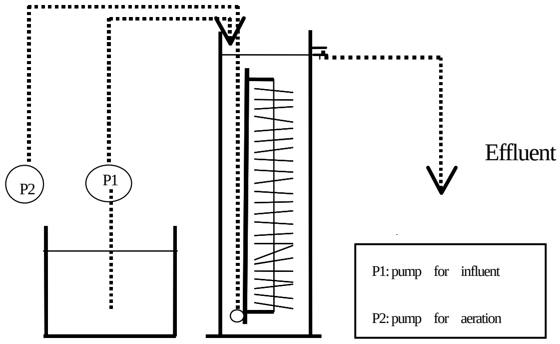


Fig.1. Schematic diagram of experimental set-up

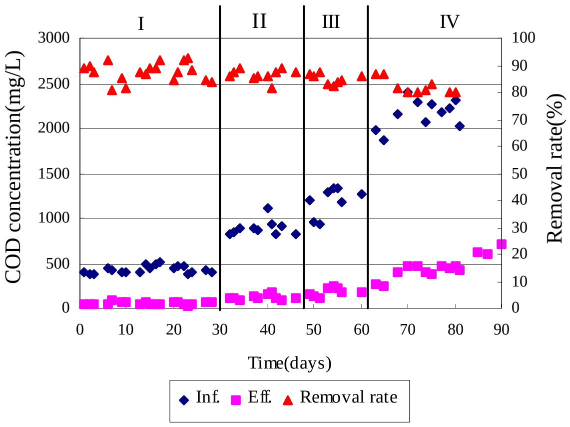


Fig.2. Changes in COD removal efficiencies

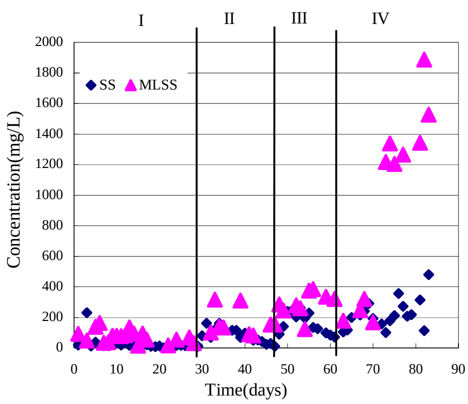
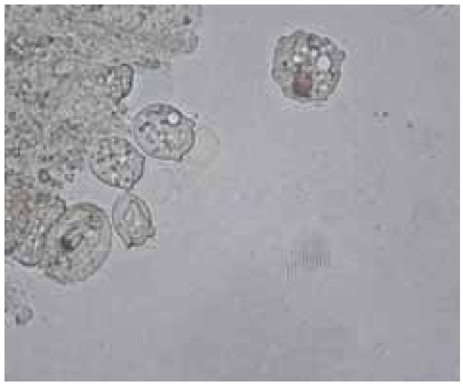
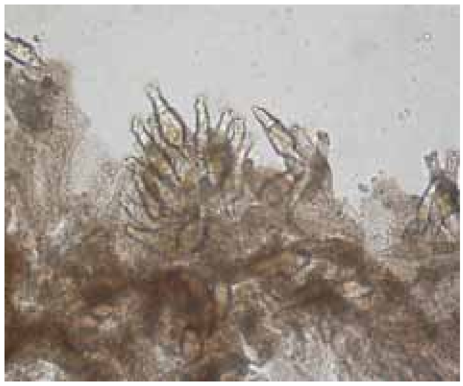


Fig.3. Changes in effluent SS and MLSS concentrations



(a)



(b)

Fig.4. Microscopic photographs of biomass attached on the biofringe: (a) taken on the after 14 days, (b) taken after 69 days

4 Conclusions

Swim-bed technology using the novel biofringe attachment material demonstrated a promising technique of treating wastewater. Consistent pollutant removal efficiencies were achieved throughout the entire range of the testing and 80% COD removal efficiencies were obtained even under the volumetric loading rates up to 5kg-COD/m^3/d. The sludge yields can be reduced considerably, which were about less than 50% of those typically conventional aerobic processes.

References

[1] W. Ghyoot and W. Verstraete, Reduced sludge production in a two-stage membrane-assisted bioreactor, Wat.Res., 1999, 1(34):205-215

[2] Clesceri L. S., et al., Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association, Washington, D. C.

[3] Natuscka M. et al., Reducing sludge production in aerobic wastewater treatment through manipulation of the ecosystem. Wat.Res., 1996, 8(30):1781-1790