Anaerobic Treatment of Winery Wastewater and Energy Recycling Using New Anaerobic Filter Process

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Abstract: The investigation was conducted to examine the effectiveness of a double-media anaerobic filter (AF) process for the biogas production and chemical oxygen demand (COD) degradation rate from grape winery wastewater. The experiment was carried in three identical filters, which were a soft and hard packing double- media (SHM) AF, a soft packing single- media(SM) AF, and the hard packing single-media (HM) AF. The results show that the SHM AF for COD removing rate is the best when hydraulic retention time (HRT) is 4days and volume organic loading rate (OLR) is 1.86 kgCOD/m^3.d. Meanwhile COD degradation rate is 87.46%, 72.06%, and 75.32% in three filters; biogas production is 0.43/m^3/kgCOD$_{removed}$, 0.35/m^3/ kgCOD$_{removed}$, 0.32/m^3/kgCOD$_{removed}$ respectively; COD degradation rate is 90.95% in SHM AF when OLR is 1.86 kgCOD/m^3.d and HRT is 7days. However, if we extend the HRT, COD degradation rate has no significant change, and gas production is lower than before.

Keywords: COD degradation rate; Biogas yield; Anaerobic filter; soft and hard packing double-media; Winery wastewater

1. Introduction

With the improvements of living standards, red wine has become popular. There is an increasing demand for red wine. Lots of production of red wine brings the numerous emissions of organic wastewater [1]. At present, the physical-chemical methods for treatment of red wine wastewater have been employed in abroad [2-4], while the up-flow anaerobic sludge bed (UASB) method is adopted in China. However, the studies on this are few [5-7]. When we adopt anaerobic technology process not only does it degrade COD of wastewater, but also recycles the biogas. Finally, we reach the aim of sewage purification and energy recycling. AF is the abbreviation of anaerobic filter. Because the structure of AF is simple, AF causes low power consumption; capacity of resisting sludge burthen is better, suspended solids (SS) for outlet is low, and outlet water quality is good. AF is applied to sewage treatment, which has a broad application prospect [8-9].

But the AF reactor often encounters the problems of clogging and channeling, in particular when the AF is packed with high specific surface media and is used for the treatment of wastewaters with high levels of SS [10]. So we have to develop new technology. Under the condition that the cost increases little, we change hydraulic behaviors, enhance mixture in AF, cut down the logjam of AF, and enhance treatment efficiency. This is significant for wastewater treatment. This paper applies complementation of soft packing media and hard packing media to develop new soft and hard packing double-media AF technology process. However, it is not clear whether such a double-media AF has superior performance of COD degradation rate and fully recycle biogas than a single-media AF of wastewater treatment. Therefore, the research was carried to examine the effectiveness of new AF process. Studying new AF and determining the parameter are important, which has practical guidance significance and applies value to the engineering practice.

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2. Experimental materials and methods

2.1. Experimental materials

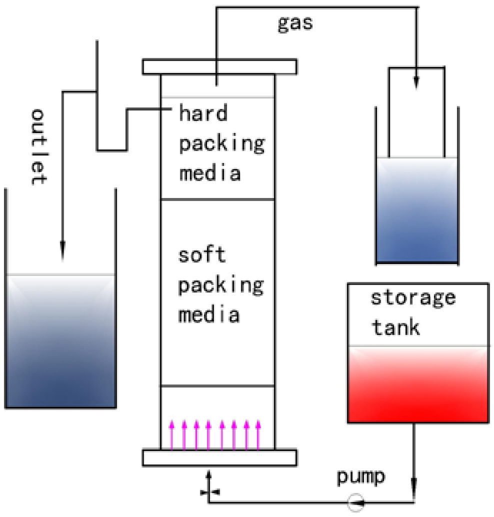
Grape winery wastewater is taken from a local red wine factory in Kunming, the characteristics of raw wastewater are given in Table 1. According to the experimental requirement, after the wastewater was diluted, COD are 1274.36mg/L, 2115.23mg/L,3112.67mg/L. In order to meet the demand of PH is 7.0±0.5; we used 0.5mol/L $NaHCO_3$ to adjust.

Table 1Characteristics of raw winery wastewater

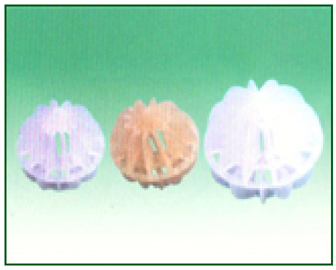
item	COD(mg/L)	SS(mg/L)	TP(mg/L)	PH
content	18500-20000	415	0.88	2.89

2.2. Reactors and packing media

The three column reactors are made of Plexiglas. Except for types and placement of packing media, all other operating conditions are the same. Biogas is collected by draining off water. Schematic of reactor is given in Fig.1. Description of reactors is given in Table2.



(a)



(b)

Fig.1. Schematic diagram of the reactor
(a) Schematic diagram of the reactor; (b) Image of the hard packing media.

Table 2 Description of reactors

No	1*	2*	3*
Total volume/L	3.2	3.2	3.2
Working volume/l	3.0	3.0	3.0
Ratio of dia-height	0.13	0.13	0.13
height/m	0.6	0.6	0.6
Packing media	Fibrous filler and multi-face hollow globule	multi-face hollow globule	Fibrous filler

2.3. Experimental start-up and operation

2.3.1. Experimental start-up

The experiment began at the ambient temperature of 13～22℃. The start-up was achieved by increasing the OLR and decreasing the HRT from 15to2 days in stepwise. After 50 days' start-up COD of inlet is about 1040mg/L and COD of outlet is stable between 198±50 mg/L, the start-up is successful.

2.3.2. Experimental operation

The experiment is conducted to examine COD degradation rate and biogas production rate in three reactors. And then we can conclude whether the superiority AF is the double-media AF when HRT and OLR are different; at the same time, we obtain the processing parameter of the lowest HRT and the highest OLR for grape winery wastewater treatment. The experiment is divided into 3 phases to be aware of that different HRT and OLR affect the results of experiment when we are in phase of experimental operation. In the first phase inlet concentration is1274～1280mg/L,OLR (0.80kgCOD/m^3.d) is the same and HRT increases from 1day to 5days; In the second phase inlet concentration is 2100～2120mg/L.OLR (1.65kgCOD/m^3.d) is the same and HRT increases from 1day to 5days; in the third phase inlet COD concentration is 3000～3300mg/L, OLR (1.86kgCOD/m^3.d) is the same and HRT increases from 1day to 7days.

2.3.3. Experimental record and test

Water and environmental temperature are tested in the course of conducting experiment. We should also test pH value. We record the biogas content every day or every hour, and then test methane, and COD of inlet and outlet. Test method as follows:

Table3 test item and brief introduction of methods

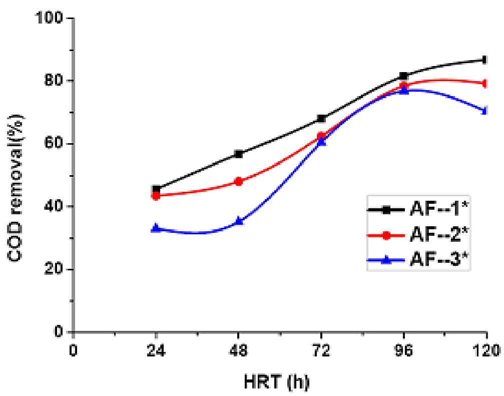
Item	T/℃	pH	CH_4/%	COD/mg/L
Method	Mercury thermometer	Glass electrode	AUS-GAS analysis	CODcr

3. Results and discussion

We set up the operating time for 7 days in order to insure experimental data reliability. We take average value after all groups of experiments remain stable. The experiment indicates that when the volume, environmental condition, organic loading rate, and HRT are the same, AF reactor with the different packing media has different COD degradation rate. SHM AF＞HM AF＞SM AF. The specific experimental data and its processing results are given in Fig.2.

3.1. COD degradation analysis

Fig. 2 indicates that when the start-up and operation condition are the same, operation efficiency of AF filled with soft and hard packing double-media is significantly higher than soft or hard packing single-media. When influent concentration keeps fixed, with the increase of HRT, the COD degradation rate obviously increases.



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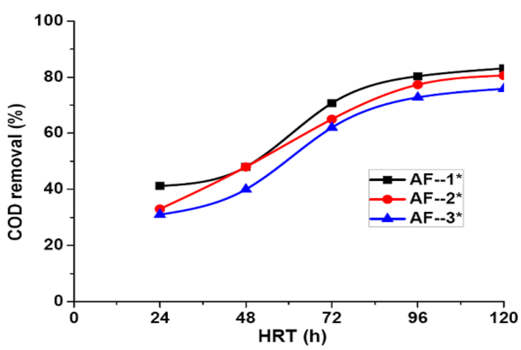

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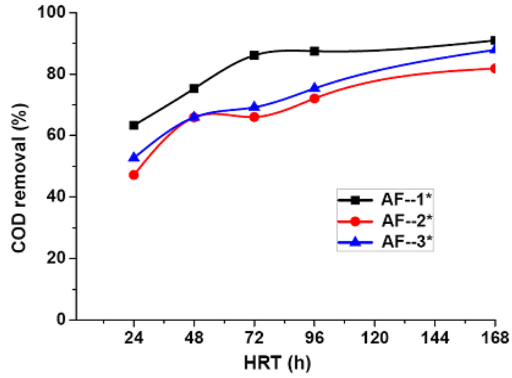

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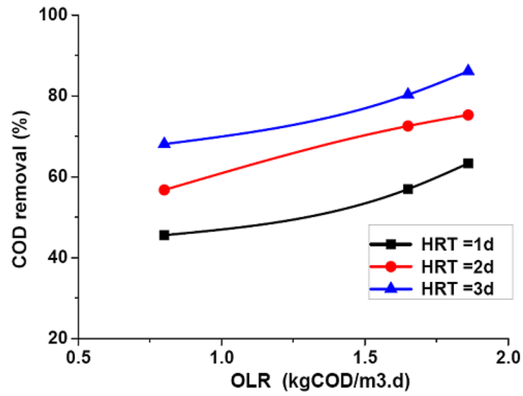

(d)

Fig.2.operation performance of 1*, 2*, 3* with different influent concentration and different HRT:

(a) Influent concentration is 1274.3, while 1*, 2*, 3* are under different HRT. (b) Influent concentration is 2115.3, while 1*, 2*,3* are under different HRT. (c) Influent concentration is 3112.2, while 1*,2*,3* are under different HRT. (d) 1* is under different OLR and HRT

However, when HRT is more than 7days, degradation rate of COD can't obviously increase any more. Therefore COD degradation rate is related to influent concentration in the same condition. Fig.2 (a) (b) (c) indicates that the best HRT is 4 days when we adopt single-media bed or double-media bed treatment red wine wastewater. When HRT is 4 days, soft and hard packing double-media AF is adopted, and inlet concentration is 1,274mg/L, COD degradation rate is 81.56% and outlet COD is 210~230 mg/L. When inlet concentration is 2,115mg/L, COD degradation rate is 80.3% and outlet COD is 240~250 mg/L. When inlet concentration is about 3112 mg/L, COD degradation rate is 87.46% and outlet COD is 281~310 mg/L. Fig. 2(d) suggests that organic loading rate of inlet and COD degradation rate increases when HRT is the same in SHM AF . HRT increases but COD degradation rate increases within limits when organic loading rate of influent is the same.

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Table 4 when HRT is 4 days, COD biogas production transforming rate in three different reactors

Item	Biogas yield /mL			COD biogas production transform rate /m^3/kgCOD$_{removed}$			Methane content（%）
Influent concentration mg/L	1*	2*	3*	1*	2*	3*	
							65～70
2115.32	640	590	460	0.38	0.35	0.30	
3112.22	1150	820	680	0.43	0.35	0.32	

3.2. Analysis of biogas production

When inlet concentration is about 1,200mg/L little biogas can be produced and methane content is lower than 45%, so we don't analyze it. When influent concentration is about 2,000~3,000mg/L, the biogas can be produced below in the Table 4.

Table 4 suggests that when HRT is constant, COD gas production transforming rate not only relates to inlet concentration but also the types of the reactor. When the type of reactor is the same, gas production increases with growth of OLR. Biogas yield relates to COD biogas production transforming rate. See as follows:

SHM AF ＞HM AF ＞SM AF

In order to research the relations of COD degradation and biogas production rate for winery wastewater in SHM AF, we adopt batch fermentation experiment in SHM AF. The result as follows:

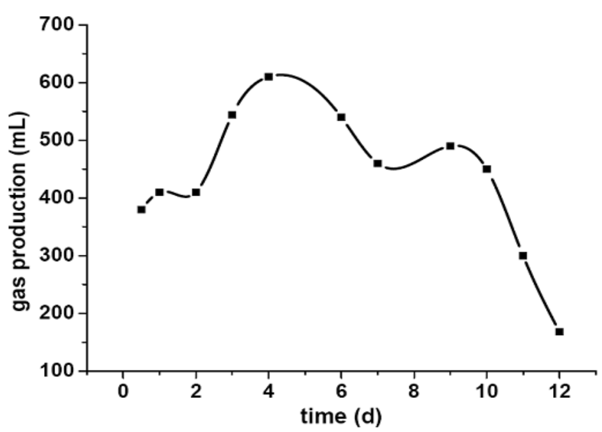

Fig.3. gas production curve of SHM AF

Fig. 3 suggests that when HRT is 4 days, biogas yield is the most productive and methane content is about 65%. After that, biogas yield decreases gradually. After 9 days biogas yield decreases rapidly. Biogas yield is about 100ml/d and methane content is lower than 50% after 12 days. So when we adopt SHM AF treatment red wine wastewater and HRT is 4 days, the biogas recycling is the highest. When HRT＞7 days the biogas recycling significantly decreases, so that the filter volume increases in practice. Consequently this will increase the cost of engineering.

4. Conclusions

(1)It is feasible to adopt anaerobic technology process brewing industry wastewater and SHM AF technology process treatment organic wastewater. When start-up and operation condition are the same and keep different packing media reactor of AF, COD degradation rate is different. COD degradation rate is stability and COD gas production rate is the best in SHM AF. The soft and hard packing double-media AF is proved to be more efficient than the single-media AF in terms of COD degradation efficiency and stability against hydraulic loading shocks.
(2)When inlet concentration is 3112mg/L at ambient temperature, the best HRT is 4days. The reactor produces biogas of 0.35～0.38m^3/kgCOD$_{removed}$ and methane yield is 65～70%; COD degradation rate is stable in 87.46% at least.

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