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Start-up strategies of UASB reactor for treatment of pharmaceutical wastewater

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Abstract: Two start-up strategies of upflow anaerobic sludge blanket (UASB) reactor for treatment of pharmaceutical wastewater were investigated. The results showed that both of them were workable. Compared with the strategy that started up the reactor directly using chloromycetin wastewater, the strategy that started up the reactor first using mixed wastewater and then using chloromycetin wastewater could save time by 23%. When the latter strategy was adopted the development of sludge activity fluctuated more largely and its final activity was lower, but the sludge grew faster in the course of start-up.

Keywords: start-up; toxic wastewater; UASB

Introduction

The upflow anaerobic sludge blanket(UASB) reactor has been successfully applied to the treatment of various types of organic wastewaters all over the world(Lettinga, 1991). However, the difficulty of start-up is still a widespread problem(Barnes, 1987; Lettinga, 1995) especially when the process is used to treat toxic wastewaters such as pharmaceutical wastewater.

The start-up of UASB reactor depends largely on the activity and amount of inoculum sludge(Zheng, 1993), but both of them are scarcely satisfied in practical use(Zhou, 1996). The key to the question is to promote the bacterial growth and to raise the sludge activity through proper operation of the reactor.

In the view of microbiology two different strategies can be adopted. One is that all the inoculum bacteria are firstly enriched and then adapted to toxic wastewater, the other is that only the expectant bacteria are selectively enriched directly using toxic wastewater. The two strategies are compared in the present study.

1 Meterials and methods

1.1 Synthetic wastewater

Table 1 Some physical and chemical properties of chloromycetin wastewater*

Item	Range	Average
COD, mg/L	29858 – 49613	30648
BOD_5, mg/L	6542 – 9813	7719
TS, mg/L	65500 – 68500	66500
VS, mg/L	45500 – 47000	46000
Chloride, mg/L	13450 – 17495	15473
NH_4^+-N, mg/L	1058 – 1422	1264
TKN, mg/L	2254 – 2308	2280
TP, mg/L	1.8 – 2.5	2.3
pH	1.4 – 1.8	1.6

* It was diluted before use.

The synthetic wastewater was composed of (g/L): sucrose 27.5; yeast extract 0.3; NH_4Cl 7.3; KH_2PO_4 2.5; $K_2HPO_4 \cdot H_2O$ 1.3; $NaHCO_3$ 33.0. The stock solution was diluted before use.

1.2 Chloromycetin wastewater

The sample of chloromycetin wastewater was taken from a chloromycetin factory in China. Some physical and chemical properties are listed in Table 1.

1.3 Sludge inoculum

There were several anaerobic digesters for the treatment of excessive aerobic activated sludge in Hangzhou Sewage Plant, China. Sludge from one of the digesters served as the source for biomass. Before use, large particles were removed by passing the sludge through a sieve. Some physical and chemical properties of inoculum sludge are listed in Table 2.

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1.4 UASB reactor system

The laboratory-scale UASB reactor was made of Plexiglas with total volume of 1.50L, height of 0.60m and internal diameter of 0.06m. A gas-liquid-solid separator was installed at the top and five sampling ports were evenly distributed over the height of the reactor. The flow diagram of the reactor system is shown in Fig. 1. The influent was pumped in to the bottom of the reactor and flowed upwards through the sludge bed. The treated effluent passed the gas-liquid-solid separator and was then collected in the effluent tank. The biogas was led off to a gas-container after passing a gas-meter.

Table 2 Some physical and chemical properties of sludge inoculum

Item	Value
TS, mg/L	49800
VS, mg/L	26100
VS/TS	0.52
Co-enzyme F_{420}, mmol/g	0.14
Dehydrogenase activity, mg/(g·h)	6.49
pH	6.91

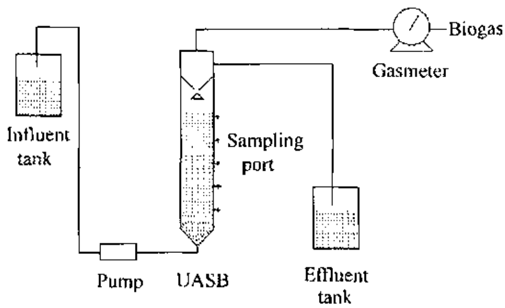

Fig.1 The UASB system and its flow diagram

Two UASB reactors were inoculated with the same amount of inoculum sludge(1L) and were run in parallel at around 30℃.

1.5 Analytical procedures

COD, BOD_5, TS, VS, NH_4^+-N, TKN, TP and chloride were determined using the standard method issued by the Environmental Protection Agency(EPA) of China(1997). VFA(volatile fatty acid) and methane content were determined as described by the Institute of Biological Science, China(1984). pH was determined using glass electrodes connected to pHS-10C pH-meter. Content of co-enzyme F_{420} and dehydrogenase activity were determined as described by Yu *et al*.(Yu, 1987). The maximal specific methane production was determined as described by Wu *et al*.(Wu, 1985).

2 Results and discussion

2.1 Performance of Reactor 1

Reactor 1 was firstly fed with synthetic wastewater(SW), then mixture of synthetic wastewater and chloromycetin wastewater(MSC) and finally chloromycetin wastewater(CW). When it was fed with SW at COD concentration of 4500 mg/L, its performance improved quickly within the first 10 days. The average COD removal, volumetric COD loading rate and volumetric biogas production were 97.2%, 4.50 g/(L·d) and 2.18 L/(L·d), respectively(Table 3).

From day 11 on, MSC instead of SW was pumped into Reactor 1. Hydraulic retention time(HRT) was prolonged to 2 days and then shortened step by step to 1 day. Following this, the ratio of SW to CW was gradually reduced from 2:1 to 1:2. The influent COD concentration was set at 4779 mg/L. The average COD removal, volumetric COD loading rate and volumetric biogas production reached 84.5%, 4.78 g/(L·d) and 2.01 L/(L·d), separately(Table 3).

On day 49, Reactor 1 began to be fed with CW. During 30-day operation, the average influent COD concentration(4786 mg/L) and volumetric COD loading rate(4.79 g/(L·d)) were near to those above while the COD removal(78.0%) and volumetric biogas production(1.82 L/(L·d)) were slightly lower (Table 3).

Table 3 Performance changes of reactor 1 during start-up

Type of influent		COD, mg/L Influent	COD, mg/L Effluent	COD removal, %	COD loading rate, g/(L·d)	Biogas production, L/(L·d)	HRT, d	Operation time, d
SW		4500	125	97.2	4.50	2.18	1	1 - 10
MSC	SW:CW = 2:1	4511	478	89.4	4.51	2.01	2	11 - 16
		4667	710	84.8	4.67	1.95	1.5	17 - 22
		4833	685	85.8	4.83	2.08	1	23 - 28
	SW:CW = 1:1	4995	688	86.3	5.00	2.16	1	29 - 38
	SW:CW = 1:2	4779	742	84.5	4.78	2.01	1	39 - 48
CW		4791	1034	78.4	4.79	1.82	1	49 - 58
		4765	1072	77.5	4.77	1.78	1	59 - 68
		4801	1046	78.2	4.80	1.85	1	69 - 78

2.2 Performance of Reactor 2

Reactor 2 was fed directly with CW to acclimate the sludge inoculum. HRT was set at 1 day. The influent COD concentration was progressively increased from 915 to 4805 mg/L. Accordingly the volumetric COD loading rate was raised from 0.92 to 4.81 g/(L·d) and volumetric biogas production was raised from 0.38 to 1.88 L/(L·d). On day 69, the performance parameters of Reactor 2 approached the level of Reactor 1. The average influent COD concentration was 4762 mg/L, COD removal 77.7%, volumetric COD loading rate 4.76 g/(L·d) and volumetric biogas production 1.84 L/(L·d)(Table 4).

Table 4 Performance of Reactor 2 during the start-up

Type of influent	COD, mg/L Influent	COD, mg/L Effluent	COD removal, %	COD loading rate, g/(L·d)	Biogas production, L/(L·d)	HRT, d	Operation time, d
CW	915	161	82.4	0.92	0.38	1	1 - 12
	1746	323	81.5	1.75	0.71	1	13 - 25
	2826	514	81.8	2.83	1.16	1	26 - 38
	3794	756	80.1	3.79	1.52	1	39 - 48
	4067	821	79.8	4.08	1.63	1	49 - 58
	4314	815	81.1	4.31	1.75	1	59 - 68
	4724	1062	77.5	4.72	1.82	1	69 - 78
	4805	1052	78.1	4.81	1.88	1	79 - 88
	4757	1075	77.4	4.76	1.83	1	89 - 98

2.3 Changes of characteristics of anaerobic activated sludge

2.3.1 Dehydrogenase activity

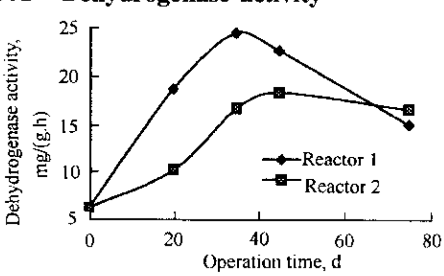

Fig.2 Changes of dehydrogenase activity during start-up of UASB

As shown in Fig. 2, the dehydrogenase activity of inoculum sludge in Reactor 1 was 6.49 mg/(g·h). It gradually increased at the beginning and reached its maximum(24.58 mg/(g·h)) on day 35. Then it went down to 15.03 mg/(g·h). The dehydrogenase activity in reactor 2 had a similar trend, but its maximum(18.41 mg/(g·h)) occurred on day 45 and the decrease was small (16.58 mg/(g·h)).

It was reported that dehydrogenase activity could reflect the ability of anaerobic activated sludge to oxidize organic substrates(Yu, 1987). So the results implied that CW beyond certain concentration(about 4800 mg/L) was inhibitory to anaerobic bioconversion and the anaerobic activated sludge in Reactor 2 tolerated the toxicity better than that in Reactor 1.

2.3.2 Co-enzyme F_{420} content

The F_{420} content of sludge inoculum in reactor 1 was 0.14 mmol/g. It went gradually up to its maximum (0.52 mmol/g) on day 35 and then went down to 0.32 mmol/g. The F_{420} content in Reactor 2 kept on increasing during the experiment with its maximum of 0.41 mmol/g on day 75 (Fig. 3).

Co-enzyme F_{420} is one of the special components of methanogenic bacteria (Zehnder, 1988). The difference of F_{420} content between reactor 1 and reactor 2 indicated that operation could largely influence methanogenic consortium.

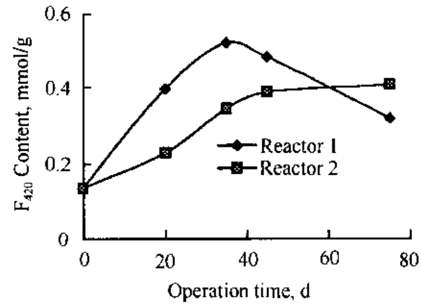

Fig.3 Changes of co-enzyme F_{420} content during start-up of UASB reactors

2.3.3 Methane production activity

As shown in Fig. 4, the specific activity of methane production of sludge inoculum in reactor 1 was 29.8 ml/(g·d). It gradually increased and reached its maximum (77.5 ml/(g·d)) on day 35. Then it went down from 77.5 to 40.3 ml/(g·d). The decrease was as large as 48%. The specific activity of methane production in Reactor 2 had a similar trend, its maximum (55.4 ml/(g·d)) occurred on day 45 and the decrease (from 55.4 to 45.8 ml/(g·d)) was far less (17%).

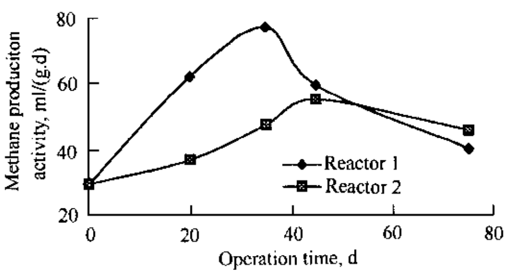

Fig.4 Changes of specific activity of methane production during start-up of UASB reactors

Methane production is the special ability of methanogenic bacteria (Wu, 1985). The changes of specific activity of methane production indicated that CW at high concentration was also inhibitory to methanogenesis and the methanogenic bacteria in Reactor 2 were more tolerant to the toxicity.

2.3.4 VS

In environmental engineering, VS is often used to stand for biomass (Yu, 1987). The VS concentration in both Reactor 1 and Reactor 2 increased during the whole experiment, and the former was higher than the latter (Table 5). This means that the anaerobic microorganisms in Reactor 1 grew faster than those in Reactor 2.

Table 5 Changes of VS and VFA concentration during start-up of UASB reactors

Type of influent		Operation time, d	VS, g/L		VFA, mg/L			
					Influent		Effluent	
R1	R2		R1	R2	R1	R2	R1	R2
SW	CW	1	20.4	20.4	493	18	293	61
MCS		20	25.7	21.5	431	37	145	48
MCS		35	27.5	22.8	301	29	186	34
MCS		45	30.1	24.6	297	24	205	35
CW		60	30.5	25.8	284	57	287	43
CW		75	30.9	26.1	303	51	303	45

2.3.5 VFA

In anaerobic digestion, organic substrate is firstly converted to VFA and then to biogas. There is no VFA accumulation in the effluent if the bioreaction progresses well. During the start-up of Reactor 1 and Reactor 2, the effluent VFA was kept at a level of 18 - 61 mg/L (Table 5), which was far lower than the reported inhibitory VFA concentration (Zhou, 1996). So the working state of both reactors was in good condition.

3 Conclusions

Both strategies seemed suitable to the start-up of UASB for treatment of pharmaceutical wastewater. Either of them could be chosen according to specific conditions.

Compared with the start-up directly using CW(88 days), that first using MSC and then using CW(68 days) could save time by 23%.

The development of sludge activity fluctuated more largely and its final activity was lower, but the sludge grew faster in Reactor 1 than its counterpart in the course of start-up.

References:

Barnes D, Fitzgeral P A, 1987. Anaerobic wastewater treatment processes[M]. Environmental Biotechnology(Forster *et al*. ed.). John Wiley & Sons. 57—106.

EPA of China, 1997. Analytical methods for water and wastewater[M]. Beijing: The Publishing House of Environmental Science and Technology of China.

Lettinga G, Hulshoff Pol L W, 1991. UASB-process design for various types of wastewaters[J]. Wat Sci Tech, 24(8): 87—107.

Lettinga G, 1995. Anaerobic digestion and wastewater treatment system[M]. Antonie Van Leeuwenhoek. 67:3—28.

The Biological Institute of the Chinese Academy of Sciences, 1984. General analysis of biogas fermentation[M]. The Publishing House of Science and Technology of Beijing.

Wu W M, Hu J C, Gu X S, 1985. Maximum specific methane production rate of anaerobic sludge and its measurement by beach test[J]. China Feedwater and Drain, 1(4):30—35.

Yu Y X, Wu G Q, 1987. Manual of microbial monitor in environmental engineering[M]. The Publishing House of Environmental Science and Technology of China.

Zehnder A J B, 1988. Biology of anaerobic microorganisms[M]. John Wiley & Sons.

Zheng P, Yu X E, Feng X S, 1993. Changes of characteristics of anaerobic activated sludge and their relation to reactor performance[J]. Acta Energiae Solaris Sinica, 14(2):128—137.

Zhou L, Zhang M Q, 1996. A new way to accelerate the start-up of UASB reactor[J]. Environ Sci, 17(2): 54—57.

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