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Function of anaerobic portion in a conventional sequencing batch reactor

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Abstract——The performance of SBRs treating two kinds of wastewater (synthetic wastewater containing polyvinyl alcohol and effluent from a coke-plant wastewater treatment system) was investigated in this study, in order to examine the exact function of anaerobic portion in a conventional SBR. The set up of 4- or 8- hour anaerobic mixing period in a SBR's cycle did not benefit for PVA degradation. While an anaerobic reactor seeded with anaerobic sludge could partly hydrolyse and acidify PVA into readily-degradable intermediates. During the anaerobic fill period of an SBR treating the effluent from a coke-plant wastewater treatment system, the organic concentration was reduced to certain extent due to the adsorption of activated sludge and dilution of the mixed liquor from the previous cycle. Parts of readily-degradable organics in the influent were utilised by denitrifiers as carbon source. The biomass in a conventional SBR was alternatively imposed to aerobic and anaerobic conditions in its operating cycle, the environmental conditions needed for anaerobic hydrolization and acidification of refractory organics could not occur in such an SBR.

Keywords: sequencing batch reactor (SBR); anaerobic (aerobic) fill; polyvinyl alcohol (PVA) degradation; coke-plant wastewater.

1 Introduction

The sequencing batch reactor (SBR) has received considerable attention and has been used to treat municipal wastewater and a wide variety of industrial wastewaters since Irvine and his co-workers identified a lot of advantages of the SBR (Irvine, 1979; 1989; Ng, 1989). The SBR is able to complete the roles of primary setting, biodegradation and secondary settling as well as nitrogen and phosphorus removal within a single reactor (Ng, 1989). In addition, the SBR can also effectively control activated sludge bulking and be operated with great flexibility to accommodate for variations in operating conditions (Irvine, 1989).

The SBR process has also been found to be effective for treating hazardous wastewaters. Herzbrun *et al.* (Herzbrun, 1985) conducted a laboratory-scale studies on treatment of both

leachates from industrial landfills and industrial wastes shipped either in bulk or drums in conventional SBRs. The results indicated that the SBRs was able to achieve acceptable effluent quality. In a similar investigation by Ying *et al.* (Ying, 1986), SBRs were also used to treat landfill leachate. It was found that because of high feed TOC (180 mg/L), a high MLSS ranging from 8000 to 13000 mg/L was required to achieve satisfactory treatment of at least 90% removal in TOC and COD. High treatment efficiencies could be maintained when hydraulic retention time(HRT) dropped from 10 days to 1 day by increasing the MLSS level. Brenner *et al.* (Brenner, 1992) demonstrated that, too long anoxic period in a time sequence led to accumulation of poorly-degradable intermediates and resulted in a decrease in reduction of phenol, cresols and dimethylphenols in SBRs. But, under tested conditions, effluent COD was ranging from 30 to 52 mg/L, which was much lower than influent COD level of 7750 mg/L. The degradation profiles of phenol, 2-chlorophenol and 2,4-dichlorophenoxyacetic acid in an SBR were studied by Lawadowski *et al.* (Lawadowski, 1986), it was found that the SBR was very effective for these organics removal.

Based on the experimental results of the treatment of toxic and biorefractory wastewaters with SBRs, Irvine and Ketchum(Irvine, 1989) suggested that, the SBR was uniquely suited for the selection and enrichment of desired microbial populations because of the ease with which a diverse array of operating strategies and selective pressures could be implemented. This has led to the conclusion that the SBR process is an appropriate technology for treating toxic and biorefractory wastewaters.

There are three fill modes for an SBR: anaerobic, aerobic and partly aerobic. In most cases, anaerobic fill mode is preferred to aerobic and partly aerobic fill modes, because a SBR with anaerobic fill has many merits. These include: simultaneously removing organic carbon, nitrogen and phosphorus, effectively preventing filamentous bulking of activated sludge and saving operating costs due to reduction in aeration time (Herzbrun , 1985; Hsu, 1986). In the investigation by Herzbrun *et al.* (Herzbrun, 1985), anaerobic fill mode was implemented as an energy-saving protocol, and the SBR was operated with up to 6 hours of anaerobic feed with very favorable results. As a result, the SBR with anaerobic fill has been commonly used, particularly for treating municipal wastewater and domestic sewage(Yu, 1994).

On the other hand, some research results have shown that, the anaerobic acidogenic-aerobic process is an efficient and cost-effective technology for treating wastewater containing refractory compounds(Qian, 1994; Zou, 1994). This process takes advantage of microorganisms involved in the anaerobic fermentation and acidification and their strong tolerance to high concentration inhibitory organics and unfavorable environmental stresses. The main function of the anaerobic acidogenic step is partial scissions of polycyclic and heterocyclic rings, cleavage of long chains and degradation of refractory compounds through anaerobic hydrolization and acidification. The intermediates converted from the refractory compounds in the effluent of the acidogenic reactor are easily degradable in the subsequent aerobic treatment. This enables the process to meet effluent discharge standards in terms of these compounds. The laboratory-and full-scale experiments have been conducted on the

treatment of textile wastewaters containing polyvinyl alcohol (PVA) and coke-plant wastewater through the anaerobic acidogenic-aerobic process (Qian, 1994; Zheng, 1988). The results have demonstrated that the combined process is able to effectively decompose PVA, dyes and other biorefractory compounds in the wastewaters.

In view of the mentioned-above, some researchers (Qiao, 1987; Jin, 1988; Zhou, 1993) thought that, some refractory organics might be hydrolysed and acidified during the anaerobic portion in an SBR's cycle, this would result in the improvement of their biodegradability and lead to that they could be easily decomposed in the subsequent aerobic react period. If such an option were correct and the anaerobic portion really played an important role in removal of refractory organics within SBR's, it would be expected that an operating protocol which incorporated the increase in the anaerobic operating time and correspondingly the decrease in the aerobic time during the SBR's cycle could adopted . This strategy is able to save energy for aeration and simultaneously increase removal efficiency for biorefractory organics.

In this study, a parallel experiment was carried out at bench-scale with SBR's treating two kinds of biorefractory wastewater (synthetic wastewater containing PVA and effluent from a coke-plant wastewater treatment system), in order to examine the exact function of the anaerobic portion in conventional SBRs.

2 Materials and methods

2.1 Reactor

Three identical plexiglas columns with a total liquid volume of 4 L were used as the SBR's. Each reactor was 8 cm in diameter and 10.4 cm in height. Humidified air was introduced through porous diffuser stones. Magnetic stirrers were used for mixing. Feed pumps, decant pumps, magnetic stirrers and aerators were automatically controlled by use of program timers. Three SBRs were operated at ambient temperatures ranging from 20 to 28℃.

2.2 Wastewater and seed sludge

2.2.1 Synthetic wastewater containing PVA

PVA is a typical biorefractory organic polymer. One gram PVA is equivalent to 0.016 g of BOD_5 or 1.76 g of COD, so its ratio of BOD_5/COD is approximately 0.011 (Nishikqwa, 1975). Its biodegradability is very poor. In this study, commercial-grade PVA (Product of Xinghua Chemical Co. China) was dissolved into hot tap water to form synthetic wastewater with addition of inorganic compounds. The saponification value and molecular weight of used PVA is 99% and 75000 respectively. This type of PVA is commonly used in taxitile industry (Nishikqwa, 1975; Suzuki, 1973). The original composition and concentrations of these compounds in the synthetic wastewater are detailed in Table 1. The synthetic wastewater could be diluted with tap water based on actual requirements.

Table 1 Composition of PVA—containing wastewater (mg/L)

PVA	NH_4Cl	K_2HPO_4	$MgSO_4$	$CaCl_2$	$FeSO_4$	$NaHCO_3$
1000	180	50	50	30	50	300

2.2.2 Effluent from a coke-plant wastewater treatment system

The tested wastewater was obtained from the effluent tank of an existing biological treatment facility at Shanghai Coke Plant, China. The existing system was an ordinary extended aeration activated sludge process. The wastewater strength was categorised as low range and contained ammonia as well as some refractory compounds. This tested wastewater is referred to as coke-plant wastewater below. The composition of the wastewater is shown in Table 2. $NaHCO_3$ was added into the wastewater to compensate for the decrease in alkalinity caused by nitrification.

Table 2 Composition of the wastewater (mg/L)

COD	NH_3-N	NO_3-N	TN	SS
418—860	85—137	8—18	96—147	30—50

2.2.3 Seed sludge

The seed activated sludge obtained from Chueyang Municipal Wastewater Treatment Plant in Shanghai, China, was screened, settled and decanted in the laboratory. The pretreated sludge was cultivated in a 20-liter chemostat at a solids retention time (SRT) of 40 days. In order to make the seed sludge adapt to the respective tested wastewaters, the concentration of tested wastewater in the feed was increased stepwise. The activated sludge was considered acclimatized after approximately 50 and 60 days respectively. The mixed liquor was drawn from the chemostat and added into the SBRs.

2.3 Analyses

Standard methods (APHA, 1992) were used for analyses, including chemical oxygen demand (COD), suspended solids (SS), mixed liquor volatile suspended solids (MLVSS), mixed liquor suspended solids (MLSS), alkalinity, NH_3-N and NO_3-N. Organic constituents of the coke-plant wastewater were extracted by methylene chloride into acid, base and neutral fractions and qualitatively analyzed with a HP 5985-B GC/MS equipment (Hewlett Packard Corp. USA). PVA concentration measurement was conducted in accordance with the method described by Finley (Finley, 1961).

3 Results and discussion

3.1 Synthetic PVA-containing wastewater

3.1.1 Phase I

The effect of anaerobic mixing time on the degradation of PVA in SBRs was examined in phase I. The reactors were inoculated with the biomass that had been adapted to PVA. The synthetic wastewater was added into the reactors instantaneously. After fill was completed, the three reactors were operated with different modes. The first SBR, designated A1, was imposed with 4-hour anaerobic mixing followed by 14-hour aeration. The second SBR, designated B1, had 8-hour anaerobic mixing followed by 14-hour aeration. The third SBR, C1, was immediately aerated for 14 h after it received wastewater. So, three SBRs had identical

aeration time and different anaerobic mixing time. The average results obtained with influent PVA concentrations of 200 mg/L are presented in Table 3.

Table 3 The effect of anaerobic time on the SBRs

	PVA			COD			MLSS,	SVI,
	Inf.	Eff.	Removal.	Inf.	Eff.	Removal.	mg/L	ml/g
A1	200	40.0	80.0	348	86	75.2	4980	38
B1	200	39.6	80.2	348	80	77.1	4830	37
C1	200	43.2	79.3	348	88	74.6	5140	49

The data in Table 3 have shown that three reactors had almost identical reduction of PVA and COD. This suggested that set up of 4- or 8-hour anaerobic mixing period ahead of aeration period did not have a significant influence on PVA removal.

The PVA concentrations in mixed liquor of the reactors were measured at intervals of 2 h after the reactor received wastewater except the first sample, which was drawn just 5 mins after fill. Fig. 1 illustrates PVA concentration against operating time in the reactors.

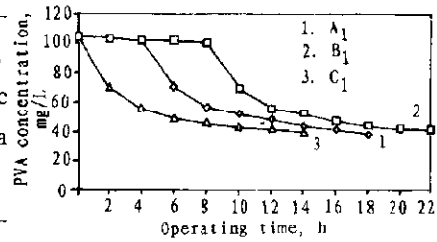

Fig. 1 PVA concentration against operating time

After wastewater was mixed with the activated sludge from the previous cycle, the PVA concentration in mixed liquor was approximately 104 mg/L. If only was dilution considered, the theoretical PVA concentration of the first sample should be approximately 118 mg/L. This showed that 14 mg/L of PVA was adsorbed by the activated sludge in 5 mins. As can be seen from Fig. 1, there had been extremely slight reduction of PVA during 4-or 8-hour anaerobic mixing period. Obviously, expected anaerobic hydrolization and acidification had not taken place. After aeration began, PVA had been degraded markedly, resulting in similar effluent PVA concentration of the three reactors.

3.1.2 Phase II

After the set up of anaerobic mixing periods was unable to increase PVA removal efficiency, set up of a separate anaerobic reactor in front of the SBR was designed to improve the performance of the SBRs in phase II. The influent PVA concentration PVA level was kept at 200 mg/L. The anaerobic reactor, designated D, was set up ahead of C2. The synthetic wastewater was first introduced into reactor D and anaerobically mixed for 8 h. The supernatant from D was subsequently aerated for 14 h in C2. So, this set was an anaerobic SBR for acidogenic reactor and an aerobic SBR for post-treatment in series.

The 3-liter anaerobic reactor was seeded with anaerobic sludge from a lab-scale UASB for bean processing wastewater treatment and activated sludge wasted from the three reactors in Phase I. Synthetic wastewater and seed sludge were fed into the reactor and set in a temperature-controlled box with a constant temperature of 35℃. In order to make the anae-

robic bacteria adapt to PVA gradually, the proportion of PVA in the synthetic wastewater was increased by 10% every day. After acclimation, the PVA concentration of the feed was 200 mg/L.

Table 4 Performance parameters of D-C2 and B1

	PVA			COD			MLSS,	SVI,
	Inf.	Eff.	Removal.	Inf.	Eff.	Removal.	mg/L	ml/g
B1	200	39.6	80.2	348	80	77.1	4870	37
D—C2	200	16.4	91.8	348	48	86.4	4600	47

Table 4 presents the comparative results of D-C2 and B1. The data clearly showed that, under the conditions of identical influent PVA concentration and aeration time, D-C2 performed better than B1 in terms of the PVA and COD removals. The set up of a separate anaerobic reactor ahead of the aerobic SBR could significantly increase PVA and COD removals.

The effluent from C2 was filtered and ultraviolet scanned, it was found that there was an apparent absorption peak at a wave length of 254 nm. But there was no such an absorption peak for raw synthetic wastewater containing PVA. Fig. 2 presents the absorbency (A_{254}) of mixed liquor against operating time in reactor D.

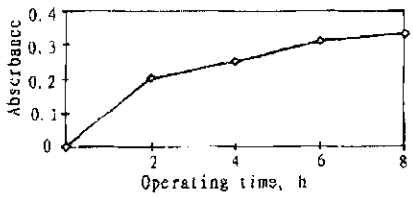

Fig. 2 Absorbance (A_{254}) against operating time in reactor D

As can be seen from Fig. 2, after synthectic wastewater was added into the reactor D and mixed with the anaerobic sludge, the absorbency (A_{254}) of the mixed liquor increased gradually and was in accordance with corresponding decrease in PVA concentration. It was likely that the UV absorption peak was caused by intermediates generated through anaerobic hydrolization and acidification of PVA. This implied that, the structure of PVA was changed through anaerobic hydrolization and acidification and some intermediates were yields, which were easily degraded in the subsequent aerobic SBR.

In order to verify the existence of anaerobic hydrolization and acidification of PVA in the anaerobic reactor, 300 ml anaerobic sludge was drawn from the reactor D and then deactivated through heating. The deactivated sludge was mixed with 100ml raw wastewater in an 1 liter flask. Another 1 liter flask was fed with the same amount of raw wastewater and the activeted sludge taken from the reactor C2. Both flasks with cover were set in a shaking thermostat for 8h. After settling, supernatants from both flasks were filtered and UV -scanned. However, there was no UV absorption peak for both samples. It confirmed the existence of anaerobic hydrolization and acidification of PVA in the anaerobic reactor.

There was an 8-hour anaerobic period in B1. During this period, PVA had been imposed to anaerobic condition, but no anaerobic hydrolization and acidification took place. While in

the reactor D, obvious anaerobic hydrolization and acidification had existed during 8 hour anaerobic mixing period. Apparently, such a distinct difference between two reactors in terms of PVA removal essentially resulted from the marked difference in character and composition of biomass in the two reactors. The biomass in the aerobic SBR was alternatively imposed to aerobic and anaerobic conditions in its operating cycle, the essential environment needed for anaerobic hydrolization and acidification of PVA did not occur in such an aerobic SBR.

3.2 Coke-plant wastewater

In this run, the coke-plant wastewater was manually added into reactors in 30 seconds. Three reactors were operated following the scheme shown in Table 5. R1 was aerated immediately after it received wastewater, whereas R2 and R3 were gently mixed after they received wastewater. 3 h and 6 h later, R2 and R3 started aeration respectively. Other operating parameters for the three reactors were kept at the same level. Therefore, effect of anaerobic time on the reactor performance could be evaluated in this run. The experiment results are summarized in Table 6.

Table 5 Reactor operating scheme

	R1	R2	R3
Working volume, L	4	4	4
Influent rate, L/d	2	2	2
SRT, d	40	40	40
Cycle time, h	24	24	24
Fill	0	0	0
Anaerobic mixing	0	3	6
React	16	16	16
Settle	2	2	2
Decant and idle	6	3	0

Table 6 Effect of anaerolc time on the reactor performance

Influent,		R1		R2		R3	
	mg/L	Effluent, mg/L	Removal, %	Effluent, mg/L	Removal, %	Effluent, mg/L	Removal, %
COD	623	251	59.7	243	61.0	234	62.4
NH_3-N	107	28	74.0	21	80.8	19	82.3
TN	118	87	26.5	79	—	40	—
MLSS, mg/L	—	3790		3820		3820	
SVI, mg/g	—	71		60		58	

From Table 6, it could be seen that, three reactors exhibited similar COD removal, but the duration of anoxic period had a significant influence on the removal of NH_3-N and particular total nitrogen (TN).

The organic constituents of influent, mixed liquor sampled from R3 were measured by use of GC/MS, in order to understand the removal history of organic compounds from the wastewater within the SBR. The sample 1 represented the influent, and sample 2 to 4 were drawn from the reactor 3 mins, 3h and 6h later after wastewater was added into the reactor and mixing began. The sample 5 was taken after 16-h aeration was terminated.

The individual compound concentration in the influent (sample 1) is referred as 100%, the relative amount of individual compound in all samples are listed in Table 7.

Table 7 Relative amount of individual compounds

	1	2	3	4	5
Phenol	100	73	22	18	0
O-cresol	100	52	26	24	2
3, 4-dimethyl phenol	100	59	57	57	23
Quinoline	100	54	68	77	68
Idol	100	50	48	46	30
Methyl quinoline	100	77	80	82	74
Quinoline alcohol	100	58	52	50	10
Isoquinoline	100	63	76	81	67

Since every sample was drawn at different time, the difference among them can show as follows:

(1) Sample 2 was drawn only 3 mins later after wastewater was added into the reactor. Obviously, there was hardly biodegradation of organic in 3 mins. Therefore, the difference in the amount of individual compound between sample 1 and sample 2 indicated the adsorption of activated sludge and dilution of resident mixed liquor from the previous cycle. As shown in Table 5, the concentrations of individual compound dropped to some extent. This suggests that the adsorption of activated sludge and dilution of resident mixed liquor could make their concentrations drop markedly and the reduction was not actually due to biodegradation.

(2) Three hours later after mixing began, sample 3 was drawn . During the 3-hour mixing period, NO_3-N concentration had been on decline and denitrification had occurred. Denitrifiers utilized some organic compounds as their carbon source. Thus, the difference between sample 2 and 3 mainly represented the degradation of organic by denitrifiers.

From Table 5, it was also found that some relatively readily - biodegradable organics, such as phenol and o-cresol, were utilized as carbon source. On the other hand, the concentration of quinoline, methyl quinoline and isoquinoline increased. This showed the desorption of some compounds adsorbed by activated sludge occurred.

(3) Sample 4 drawn after mixing was terminated and the aeration began. During the period between sample 3 and sample 4 were drawn, NO_3-N had almost remained unchanged. There was no significant difference between all figures of two samples.

(4) Sample 5 drawn after 16-hour aeration was completed. It could be found that 16-hour aeration led to substantial decrease in concentration of o-cresol, 3,4-dimethyl phenol and quinoline alcohol, while there was marked reduction in the concentrations of quinoline, methyl quinoline, idol and isoquinoline compared with the above-mentioned compounds. These compounds were hardly degraded in the SBR and were the main constituents of the final effluent from the reactor.

4 Discussion

The experimental results above clearly showed that, the set up of the anaerobic portion in a conventional SBR's operating cycle did not benefit for degradation of biorefractory compounds, and the anaerobic hydrolization and acidification of refractory compounds did not take place in the anaerobic portion. Whereas the anaerobic SBR seeded with anaerobic sludge and operated under strict anaerobic conditions could partly convert PVA into readily-biodegradable intermediates. However, based on the report about the treatment of paining process wastewater using an SBR by Zhou *et al.* (Zhou, 1993), considerable COD removal was obtained during the anaerobic portion in the SBR's cycle, over 55% of COD reduction could be got during the anaerobic portion. Then, it was concluded by the authors that the anaerobic portion played a very important role in degradation of organic. Jin *et al.* (Jin, 1988) reported that, 60% of aniline in the influent was removal during the 1-hour anaerobic fill period. There are other similar reports concerning the significant degradation in the anaerobic portion (Qiao, 1987). In our opinion, these wrong conclusions may result from over-estimating the anaerobic portion's function and neglecting the adsorption of activated sludge and dilution of mixed liquor remaining from the previous cycle, which are exactly the reason why there is a marked difference between the influent organic concentration and the organic concentration of the sample draw after the anaerobic fill is terminated.

In order to further understand exact function of the anaerobic portion, microbial characteristics of the SBR and basic requirements needed for anaerobic hydrolization and acidification of biorefractory compounds should be discussed.

The anaerobic iodegradation of refractory compounds is the result of either catabolic activity by a particular microbial species in the digester the concerted catabolism of consortia of various microorganisms (Azhar, 1994). For example, aromatic compounds generally undergo a ring reduction step in which anaerobes produce as a result of induction, a whole sequence of enzymes which convert aromatic substrates into an " ortho" or " para" cyclohexane carboxylic acid derivative, followed by cleavage of the ring. This is the critical step for the biodegradation of the aromatic compounds. These ring fission products are then funneled into the Krebes cycle through a variety of pathways depending on the organisms and culture

conditions (Berry, 1987). Stronach *et al.* (Stronach, 1986) have found that the reduction and cleavage of benzene nucleus is mediated by fermentative and acidogenic bacteria. As a result, the chemical structures of aromatic compounds are changed and biotreatability of the wastewater are improved through such an anaerobic fermentation and acidification step because of production of many mid-products which are readily degraded by microorganisms. Pre-treated wastewater can be further treated by either anaerobic organisms or aerobic ones. The acidogenic reactor takes advantage of microorganisms involved in the anaerobic fermentation and acidification and their strong tolerance to high concentration inhibitory organics and unfavorable environmental stresses. A schematic diagram of the anaerobic acidogenic-aerobic process is illustrated in Fig. 3.

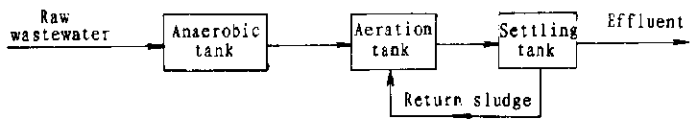

Fig. 3 The schematic diagram of the anaerobic acidogenic-aerobic process

It can be seen from Fig. 3 that activated sludge from the secondary settling tank is recycled into the aeration tank instead of the anaerobic tank. The anaerobic tank can be a UASB or an anaerobic filter with supporting media. The reactor is of high-strength anaerobic biomass and operated under anaerobic conditions. In such a combined process, aerobes and anaerobes are not mixed. This insures that subsequent aeration does not have any influence on the front anaerobic tank. The anaerobic fermentation of the facultative anaerobes in the anaerobic tank is not inhibited by dissolved oxygen and the obligate anaerobic are able to survival in the anacrobic tank. As a consequence, it can be guaranteed that some refractory compounds are hydrolysed and acidified into readily-degradable intermediates. In the course of anaerobic hydrolization and acidification, the obligate anaerobes perform more significantly than the facultative anaerobes, and the quantity of the former is approximately 100 times higher than that of the latter (Zheng, 1988). Therefore, the anaerobic hydrolization and acidification of refractory compounds are mainly completed by the obligate anaerobes. This also implies that, the necessary ecological environmental stresses for the anaerobic hydrolization and acidification of refractory organics are the presence of anaerobic environment in which there are large amount of obligate anaerobes. Anaerobic environment with just zero concentration of dissolved oxygen does not mean that the anaerobes hydrolysing and acidifying refractory compounds must be presented or the environmental conditions needed for anaerobic hydrolization and acidification can occur.

During the operating cycle of a conventional SBR, dissolved oxygen has been present for part of the cycle. Obviously, obligate anaerobes are unable to survive in such a reactor because they only live in absolute anaerobic environment and can be killed even under the conditions with very low-concentration dissolved oxygen (Stronach, 1986). As a consequence, there are no obligate anaerobes in the activated sludge in the intermittently aerated SBR.

Some facultative anaerobes may be presented in the SBR. But the anaerobic period during the cycle is not long, and is followed by the aerobic period. Introduction of oxygen can immediately inhibit the anaerobic fermentation of facultive anaerobes. This leads to that the anaerobic fermentation is quite limited and the concentration of fermentative products is very low. According to the investigation by Silverstein and Schroeder (Silverstein, 1983), less than 10 mg/L fermentation products accumulated in the SBRs during the anaerobic fill period, although the influent COD concentration exceeded 1000 mg/L and the wastewater was made of sucrose, bactopeptone and inorganic nutrients. Besides, under the conditions of co-existence of readily-biodegradable and refractory organic, the facultative fermentation-product-manufacturing microbes must utilize the readily degradable organics instead of the biodrefractory organics to conduct fermentation.

In the study by Herzbrun *et al.* (Herzbrun, 1985), phenol degradation during the anaerobic feed period was also studied. The phenol build-up in the SBR during 6 hour unaerated period was very close to calculated theoretical levels (if no biodegradation was assumed). During the anaerobic feed period, less than 1% of the phenol had been degraded. This result further confirms the conclusion mentioned-above.

In a word, a conventional SBR is intermittently aerated, the obligate anaerobes being involved in the anaerobic hydrolization and acidification of refractory organics are unable to survival in such an SBR. Therefore, the environmental conditions needed for anaerobic hydrolization and acidification of refractory organics can not occur. As a results, the anaerobic portion in an SBR's cycle may not be used to hydrolyse and acidify refractory compounds.

It should be noted that, if an SBR is used to treat ammonia-containing wastewaters and there are nitrification and denitrification in the SBR, some organic matter in the influent can be utilized by denitrifiers as carbon source during the anaerobic fill period, and there is biological degradation of organics during the anaerobic portion. However, under the conditions of co-existence of readily-biodegradable and refractory organics, the readily-degradable organic are favorably utilized by the denitrifiers as carbon source. Thus, it is still difficult for the refractory compounds to be degraded during the anaerobic portion.

5 Conclusions

The investigation with bench-scale SBRs treating two kinds of wastewater (synthetic wastewater containing PVA and effluent from a coke-plant wastewater treatment systems) was conducted, in order to examine the exact function of the anaerobic portion in SBRs' operating cycle. The conclusions drawn from this investigation are as follows: (1) The set up of 4 - or 8-hour anaerobic mixing period in SBR's cycle did not benefit for PVA degradation. While an anaerobic reactor seeded with anaerobic sludge and operated under strict anaerobic conditions could partly hydrolyse and acidify PVA into readily degradable intermediates. The anaerobically acidified wastewater was subsequently treated through 14-hour aeration in an SBR, total 91.8% of PVA reduction could be achieved.

(2) During the fill period of an SBR, the organic concentration was reduced to certain extent due to the adsorption of activated sludge and dilution of the mixed liquor from the previous cycle. Parts of readily-degradable organic in the influent, such as phenol and o-cresol, were utilized by denitrifiers as a carbon source. A 16-hour aeration significantly reduced the concentrations of o-cresol, 3,4-dimenthyl phenol and quinoline alcohol, but it hardly removed quinoline, isoquinoline, idol and methyl quinoline, which were the main constituents of the final effluent from the SBR.

(3) The set up of the anaerobic portion in an SBR's operating cycle did not result in the degradation of biorefractory compounds, and the anaerobic hydrolization and acidification of refractory compounds did not take place in the anaerobic portion. The biomass in a conventional SBR is alternatively imposed to aerobic and anaerobic conditions in its operating cycle, the obligate anaerobes being involved in the anaerobic hydrolization and acidification of refractory organics are unable to survival in such an SBR. Therefore, the environmental conditions needed for anaerobic hydrolization and acidification of refractory organics is unable to occur.

(4) In the view of making full use of purification function of the SBR during the fill period and avoiding possible build-up of toxic organics during the fill period, it is unnecessary to set up an anaerobic portion in the SBR's operating cycle when it is used for treating refractory wastewaters.

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