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Research Article

RESEARCH ON A SBR FOR TREATMENT OF SUGAR FACTORY WASTEWATER AND ITS DESIGN

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ABSTRACT

A sequencing batch inner loop three-phase fluidized bed biofilm reactor for aerobic treatment of cane sugar factory wastewater has been investigated by using bagasse as carriers, and the derivation of the bio-reaction time t and the effective volume of the reactor V_R, in the design of the sequencing batch reactor (SBR), was carried out. The experiments showed that, with the initial COD, NH_3-N and TP concentrations of 578.9~876.8 mg/L, 39.9~55.7 mg/L, 3.61~5.60 mg/L, respectively, after the aeration time of 2~3.5 h, the effluent COD and NH_3–N were lower than 120 and 10mg /L, which achieved the national primary discharge standard, and the highest removal rates of COD, NH_3-N and TP reached to 97%, 91.39% and 99.21%, respectively. The bio-reaction time is obtained as:

$$t=-\int_{C_{so}}^{C_s}\frac{dC_S}{(-r_S)}=-\int_{C_{Sso}}^{C_s}\frac{dC_S}{r_{\max}C_S/(Km+Cs)}=\frac{1}{r_{\max}}[K_m\ln(C_{so}/C_s)+(c_{so}-c_s)]$$

And the effective volume of the reactor V_R:

$$V_R=\frac{V_0(t+t')}{1-\varepsilon_g}$$

The SBR had better performance of wastewater treatment. And the work could be utilized for the design of the SBR for sugar factory wastewater treatment.

Keywords: *Sequence, Inner Loop Three Phase Fluidized Bed Bioreactor, Wastewater Treatment, Sugar Factory, Design*

INTRODUCTION

Sugarcane grows mainly in south and southwest of China, specially in Guangxi,Yunnan, Fujian, and Guangdong. Guangxi province is the largest producer of cane sugar in China. With more than 2.6 million farmers in Guangxi for sugar cane plantation, the planted areas and sugar yields take up over 50% nationwide, and its quantities of cane sugar production and marketing account for 70% through the whole country. The sugar industry is as a traditional pillar industry, and plays an important role in ensuring Guangxi' socioeconomic development. But one of the main problems of sugar factories in Guangxi are large water consumption and serious water pollution due to the low level of science and technology, which has become the substantial bottleneck of the economic development of Guangxi sugar industry. With the growth in sugar production, the environmental problems associated with sugar factories are also increased.

In the sugar factories of Guangxi, the traditional wastewater treatment methods, such as lagoon, activated sludge process and simple bio-film methods, which have disadvantages of low efficiency, long time, large space, high treatment costs, have been used. In industry as well as in research, three-phase fluidized bed biofilm reactors have received much attention due to their high efficiency, and low capital and operating costs. In this type of reactor a high concentration of biomass is maintained inside, because microorganisms are attached to support particles. The main advantages of the reactor are the large biofilm liquid interfacial area, high interfacial velocities, good mass transfer characteristics, the lower hydraulic retention time and the small size of equipment required, higher operational flexibility(Xiao-guang Chen *et al.*, 2005 and Yuan-an Wei *et al.*, 2004)

With granular porous carriers made of high polymer, a laboratory scale inner loop three-phase fluidized bed biofilm reactor for aerobic treatment of cane sugar factory wastewater was investigated in our Lab(Chang-yi Jin *et al.*, 2012). The reactor had high operation flexibility and the ability to resist shock loading. This treatment method of cane sugar factory wastewater had the advantages of simple operation, economy and high efficiency. And based on the work, we have studied a sequencing batch three phase fluidized bed biofilm reactor for cane sugar wastewater treatment by using bagasse as carriers and its design. In the design of the sequencing batch reactor, the derivation of the bio-reaction time t and the effective volume of the reactor V_R was carried out.

MATERIALS AND METHODS

SBR for Aerobic Treatment of Sugar Factory

Experimental procedures

Materials

Synthetic wastewater with a ratio of COD/N/P=100/5/1, which was composed of glucose, NH_4Cl and K_2HPO_4, was used as liquid phase in the three phase fluidized bed biofilm reactor. Modest nutrient salts like $MgSO_4$, $CaCl_2$ and $NaHCO_3$ were added into the wastewater for better growth of the microorganisms. Activated sludge from Nanning municipal wastewater treatment plant was used as inoculum. The carriers (the diameter: <1~2mm, the length: 0.5~25cm, and the carriers required: > 60mesh) used in the experiments were made of bagasse, which was obtained from local sugar factories in Guangxi. For determination of COD, NH_3–N and TP analytical reagents were used.

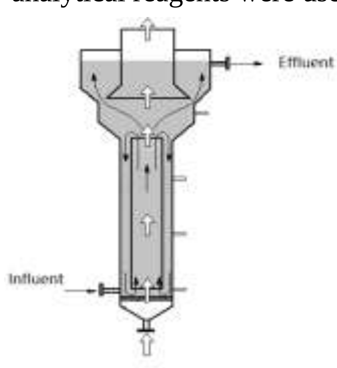


Fig.1 Schematic diagram of the apparatus

Experimental setup

The laboratory scale sequencing batch reactor used in this work to treat wastewater is schematically shown in Figure 1. The reactor consisted of a perspex column with a working volume of 3.37L. The internal diameter of the down-comer was 70mm.The riser was 580mm in height, had an internal diameter of 40mm.

Experimental procedure

Inoculation

To the inner loop three-phase fluidized bed bio-film reactor filled with 0.6L activated sludge and 2.6~3.2g (per liter reactor volume) carriers, the synthetic wastewater (COD: 200-300mg/L; COD : N : P: 100:5:1; Trace element: $MgSO_4$, $NaHCO_3$, $KHCO_3$, $CaCl_2$) was added with a pump, and the liquid flow rate was controlled by using a rotameter which was of range 0.45 -0.56L/h. Then air was sparged using a compressor and the flow rate was controlled by rotameter which was of range 25 -50L/h. The inoculation was carried out by maintaining HRT: 4-5h and dissolved oxygen (DO): 3-3.5mg/L. After a few days, steady biofilm was formed on the carriers. The carriers with biofilm would be used for the experiments of wastewater treatment.

Wastewater treatment

The sequencing batch three phase fluidized bed biofilm reactor had five basic operating steps / operations including, fill, react, settle, draw and idle, which together encompassed one complete SBR cycle. The reactor was operated in 2 cycles of day each. One cycle consisted of 10~30 min influent addition, 2~5h aeration, 10~20 min settling, 5~10 min effluent withdrawal and 5~10 min idling. With maintaining the air flow rate 40~80 L/h, wastewater treatment was performed. The performance parameters such as COD, ammonia nitrogen (NH_3–N), total phosphorus (TP)(Zhang Xuehong *et al.*, 2008), and dissolved oxygen (DO) were analysed as per cycle detailed in Standard. Methods Determination of dissolved oxygen in Water was by iodine method. COD was determined by dichromate method according to GB 11914-89 (Peking 1989). The ammonia nitrogen (NH_3–N) was measured by using Nessler's reagent colorimetric method according to GB 7479-87 (Peking1987).

RESULTS AND DISCUSSION

After the inoculation, the wastewater bio-treat was carried out to investigate the performance of the sequencing batch bioreactor under the conditions of air flow rate 20-140L/h and aeration 2~5h. Effects of air flow on COD, NH_3-N and TP are shown in Figure 2. It shows that with the increase of air flow (from 20 to 140 L/h), the concentrations of COD, NH_3-N and TP are reduced at the same aeration time, whereas the removal rates of COD, NH_3-N and TP are increased. It is because activity of aerobic microorganisms is low under the aeration conditions of low air flow. With the increase of aeration, fluidized bed circulation increases, causing mixing increase, hence aerobic microbial growth and metabolism activity accelerate, so does COD is removed. However, increasing air flow will increase power consumption. The experimental results indicate that the COD removal is slow when the air flow is 20L / h, the COD removal is faster when the air flow is larger than 40 L / h. Therefore, the optimum air flow rate was determined as 40~80 L/h, considering both the treatment performance and energy consumption.

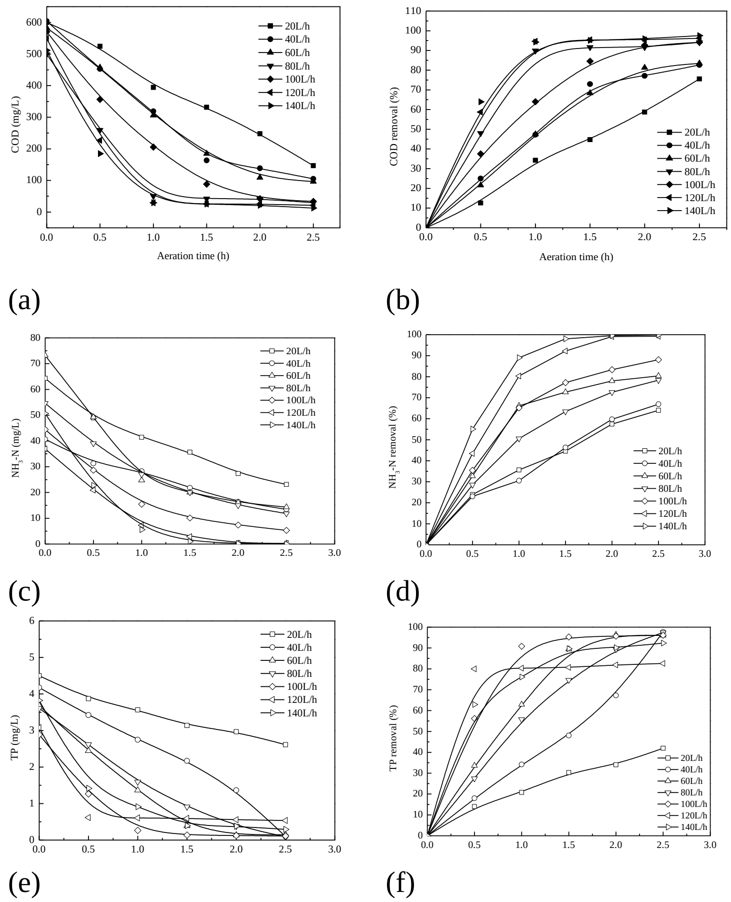
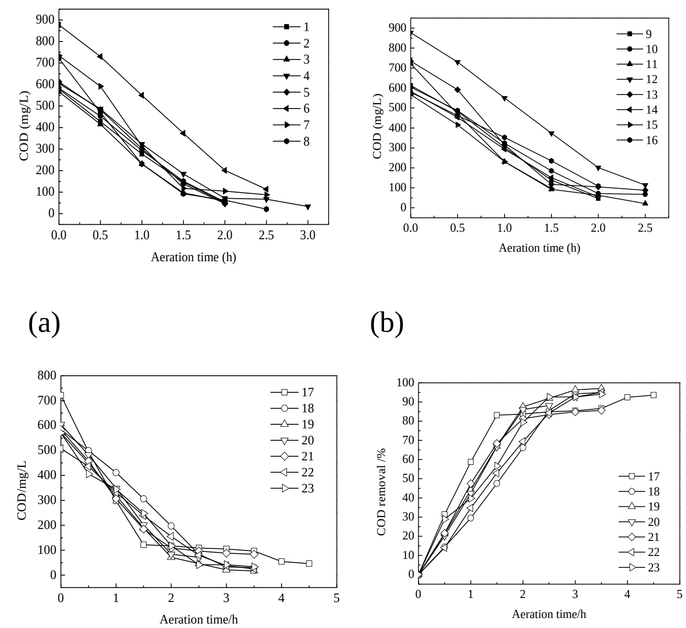


Fig. 2 Effects of air flow on COD, NH_3-N and TP

Under the conditions of air flow rate 60L / h, effects of aeration time on COD, NH_3-N and TP were investigated, the studies were conducted with 23 sequences with the initial COD, NH_3-N and TP concentrations of 578.9~876.8 mg/L, 39.9~55.7 mg/L, 3.61~5.60 mg/L, respectively, and the results are shown in figure 5-6. As can be seen in Figure 3-4, except the effluent COD is less than 120mg/L in run 6, 12 and 17 (with higher initial influent COD, the highest up to 876.87mg/L), and effluent NH_3-N is 12.3mg/L with a long aeration time of 4.5h in run 17, the effluent COD and NH_3–N are below 100 and 10 mg/ L after the aeration time of 2~3.5 h, which achieves the national primary discharge standards (Peking 1996). The highest removal rates of COD, NH_3-N and TP reach to 97%, 91.39% and 99.21%, respectively.

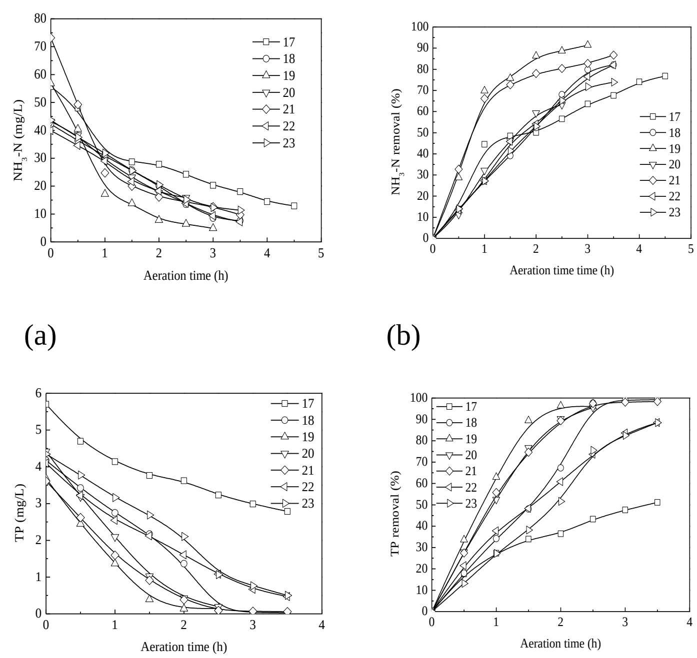
With bagasse as carriers, the sequencing batch three phase fluidized bed biofilm reactor had been operated for near six months, and it was not found that bagasse deteriorated or stinked. The application of a fluidized bed technique to biological wastewater treatment has brought a remark breakthrough. Treatment of industrial wastewaters requires a great deal of space when using systems based on activated sludge in which the retention time is many days. In the work, the biofilm reactor was capable of achieving treatment in low aeration time (2-3.5h), it could be because of the high biomass concentrations that can be achieved in the reactor. This wastewater treatment method had the advantages of simple operation, short aeration time, a low cost and high efficiency.



(a) (b)

(c) (d)

Fig.3 Effects of aeration time on COD



(a) (b)

(c) (d)

Fig.4 Effects of aeration time on NH_3-N and total phosphorus

DESIGN OF SBR

In the design of the sequencing batch fluidized bed reactor, the derivation of the bio-reaction time t and the effective volume of the reactor V_R was carried out.

Bio-reaction time

Make a material balance for S, which is a substrate COD or NH_3-N or TP for wastewater treatment. The inner loop three-phase fluidized bed bio-film reactor is batch operation. Under the condition of good circulation, the fluid flow of the reactor was presumed to be complete mixing. In the batch reactor, since the composition of S is uniform throughout at any instant of time, we may make the accounting about the whole reactor V_R. And as this reactor is unsteady operation, the material balance must be made for a differential element of time dt. The material balance for S

entry = leave + removal + accumulative

Noting that no fluid enters or leaves the reactor during bio-reaction, the material balance becomes

$$0 = 0 + (-r_S)V_R dt + dn_S$$

$$(-r_S)V_R dt = -dn_S \tag{1}$$

the equation (1) is usually expressed in the form of removal rate of substrate x_s

$$x_s = \frac{n_{s0} - n_s}{n_{s0}}$$

$$n_S = n_{S0}(1 - x_S)$$

$$dn_S = -n_{S0} dx_S$$

After the above relation is substituted,

$$(-r_S)V_R dt = n_{S0} dx_S \tag{2}$$

The reactor can be considered as an equal volume process. The equation integral,

$$t = -\int_{n_{S0}}^{n_S} \frac{dn_S}{V_R(-r_S)} = -\int_{C_{S0}}^{C_S} \frac{dC_S}{(-r_S)} \tag{3}$$

or

$$t = n_{S0}\int_0^{x_S} \frac{dx_S}{V_R(-r_S)} = C_{s0}\int_0^{x_S} \frac{dx_S}{(-r_S)} \tag{4}$$

Where: t-biochemical reaction time [min or h]

n_s- the amount of S at any moment [mg]

n_{s0}- the amount of S at the beginning of biochemical reaction[mg]

c_s- the concentration of S at any moment [mg/l]

c_{s0}-the concentration of S at the beginning of biochemical reaction [mg/l]

x_s-- removal rate of S

Michaelis-Menten equation

$$(-r_s) = -\frac{dC_s}{dt} = \frac{r_{max} C_s}{K_m + C_s}$$

Therefore, the Bio-reaction time

$$t = -\int_{C_{so}}^{C_s} \frac{dC_S}{(-r_S)} = -\int_{C_{Sso}}^{C_s} \frac{dC_S}{r_{max} C_S / (Km + Cs)} = \frac{1}{r_{max}} [K_m \ln(C_{so}/C_s) + (c_{so} - c_s)] \qquad (5)$$

Reactor volume V_R

Each cycle of the sequencing batch reactor has five basic operations, i. e. fill, react, settle, draw and idle. Therefore, the effective volume V_R of the reactor needed in treating a certain amount of wastewater is related not only to the biochemical reaction time t but also to the auxiliary time (non-biochemical reaction time) t´ and the gas holdup ε_g.

The volume of wastewater to be treated in each cycle is $V_o (t + t')$. If the volume of carrier is ignored (because the volume of carrier is very small relative to the volume of reactor), considering ε_g, the volume of gas-liquid compound in the reactor is as follows:

$$\frac{V_0 (t + t')}{1 - \varepsilon_g} \qquad (6)$$

Assuming that the density of three-phase mixtures is constant before and after aeration, the effective volume of the reactor is the volume occupied by the three-phase mixtures, therefore

$$V_R = \frac{V_0 (t + t')}{1 - \varepsilon_g} \qquad (7)$$

Where: V_R-the effective volume of the reactor, i. e. the volume occupied by gas-liquid-solid three-phase mixtures [m^3]

V_0-the average volume of wastewater treated per hour [m^3 / h]

t´-Auxiliary time (including fill, settle, draw and idle) [h]

ε_g- the gas holdup

CONCLUSIONS

The performance of the sequencing batch inner loop three-phase fluidized bed biofilm reactor in aerobic treatment of wastewater has been studied. A series of experimental runs were conducted using the synthetic waste, after the aeration time of 2~3.5 h, the effluent achieved the national discharge standard, and the highest removal rates of COD, NH_3-N and TP reached to 97%, 91.39% and 99.21%, respectively. This wastewater treatment method had the advantages of simple operation, economy and high efficiency. And the work can be considered as a useful tool for the design and operation of wastewater treatment equipment.

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