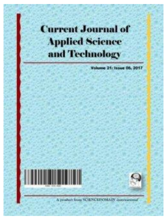

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Research on a Sequencing Batch Three Phase Fluidized Bed Biofilm Reactor for Treatment of Sugar Factory Wastewater

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Authors' contributions

The work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

With bagasse as carriers, a sequencing batch three phase fluidized bed biofilm reactor for cane sugar wastewater treatment has been investigated. 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. Considering both the treatment performance and energy consumption, the optimum air flow rate was determined as 40~80 L/h, and the favorable pH range was found to be 5~8.Bagasse, as carriers in the sequencing batch reactor, had better characteristics of the bio-film attachment and performance of wastewater treatment. Using bagasse as carriers could achieve the purposes of reducing cane sugar wastewater treat-cost and contamination of the environment.

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Keywords: Bagasse; carrier; sequence; three phase fluidized bed bioreactor; wastewater treatment; sugar factory.

1. 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 is 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 [1-3].

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 [4]. The reactor had high operational 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. Bagasse (the dry, fibrous residue remaining after the extraction of juice from the crushed stalks of sugar cane, usually used as a source of cellulose for some paper products) used as carriers had better characteristics of the bio-film attachment and performance of wastewater treatment, and could achieve the purposes of reducing treat-cost and contamination of environment.

2. EXPERIMENTAL PROCEDURES

2.1 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: <1~2 mm, the length: 0.5~25 cm, and the carriers required: > 60 mesh) 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.

2.2 Experimental Setup

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

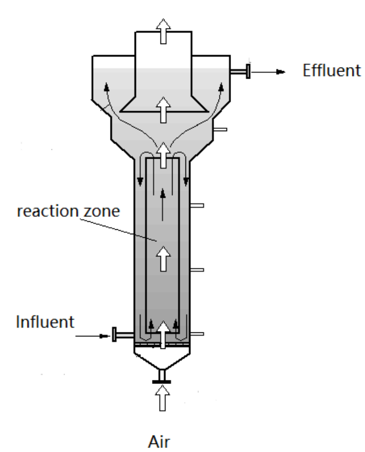


Fig. 1. Schematic diagram of the apparatus

3. 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 pH, COD, ammonia nitrogen (NH_3–N), total phosphorus (TP) [5], and dissolved oxygen (DO) were analysed as per cycle detailed in Standard. Methods Determination of dissolved oxygen in Water was by iodine method [6]. COD was determined by dichromate method according to GB 11914-89 [7]. The ammonia nitrogen (NH_3–N) was measured by using Nessler's reagent colorimetric method according to GB 7479-87 [6].

4. RESULTS AND DISCUSSION

4.1 Characteristics of Carriers

Carriers (support medium, numerous types) are used for attachment of a film of biomass. The carriers may be made of different materials (examples include but are not limited to wood chips, gravel, ceramics, alloy, plastics, rubber, recycled tyres). Carriers such as sand or gravel have the advantage of their low or zero cost, but also they have a series of considerable disadvantages. The most important one is that the finer particles may escape from the reactor, contaminating the water. Besides, their density is in general superior to that of the water, and the friction caused by the collisions of the particles splits up the bio-film. It is for all these reasons that artificial supports are being developed. In order to reduce treat-cost of cane sugar wastewater, the carriers were made of bagasse in this work. The Digital photos of carriers are shown in Fig. 2. It indicates that the carriers are porous and coarse, which is useful for inoculation. Bagasse contains sugar, having good microbial growth conditions. Besides, the wet bulk density of carriers is with similar densities to that of water, making them float more easily. And since bagasse is a by-product of sugar factories, the wastewater treatment cost can greatly be reduced.

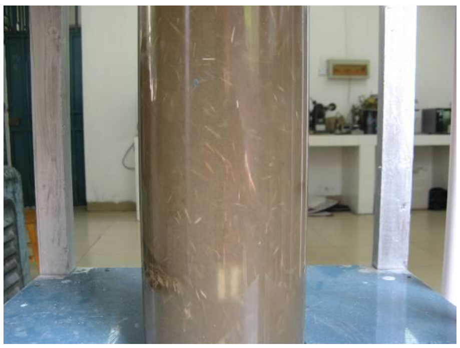
4.2 Inoculation

The microorganisms responsible for the conversion of organic material or nutrients are coated on the support particle by incubating it along with the culture media for few days (attached growth process). The organic and inorganic materials present in the waste water acts as the substrate for the

Fig. 2. Digital photos of bagasse

metabolic activity of the microorganism. The development of the biofilm is determined by the balance between the growth and detachment of the cells.

In the study, the microorganisms were incubated by maintaining HRT: 4-5h and dissolved oxygen (DO): 3-3.5 mg/L with carriers. In the experiments, it was observed if microorganisms were attached to support particles. The process continued for 7 days until the steady-state biomass loading on the carriers was achieved. Inoculation experiments of the three-phase fluidized bed reactor are shown in Fig. 3. It indicates that, in the initial stages of inoculation, the three-phase mixtures are muddy. With the increase of inoculating time until day 7, the water in the reactor becomes clear, and the microorganisms are successfully attached to bagasse.



(a) Day 1

(b) Initial stages of inoculation (1)

(c) Initial stages of inoculation (2)

(d) Day 3

(e) Day 6

(f) Day 7

Fig. 3. Inoculation experiments of the three-phase fluidized bed reactor

4.3 Wastewater Treatment

After the inoculation, the wastewater bio-treat was carried out to investigate the performance of the sequencing batch bioreactor under the conditions of pH 4~10, air flow rate 20-140L/h, and aeration 2~5h. Effects of air flow on COD, NH_3-N and TP are shown in Fig. 4. 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 the 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 accelerates, so does COD remove. 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 faster when the air flow 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.

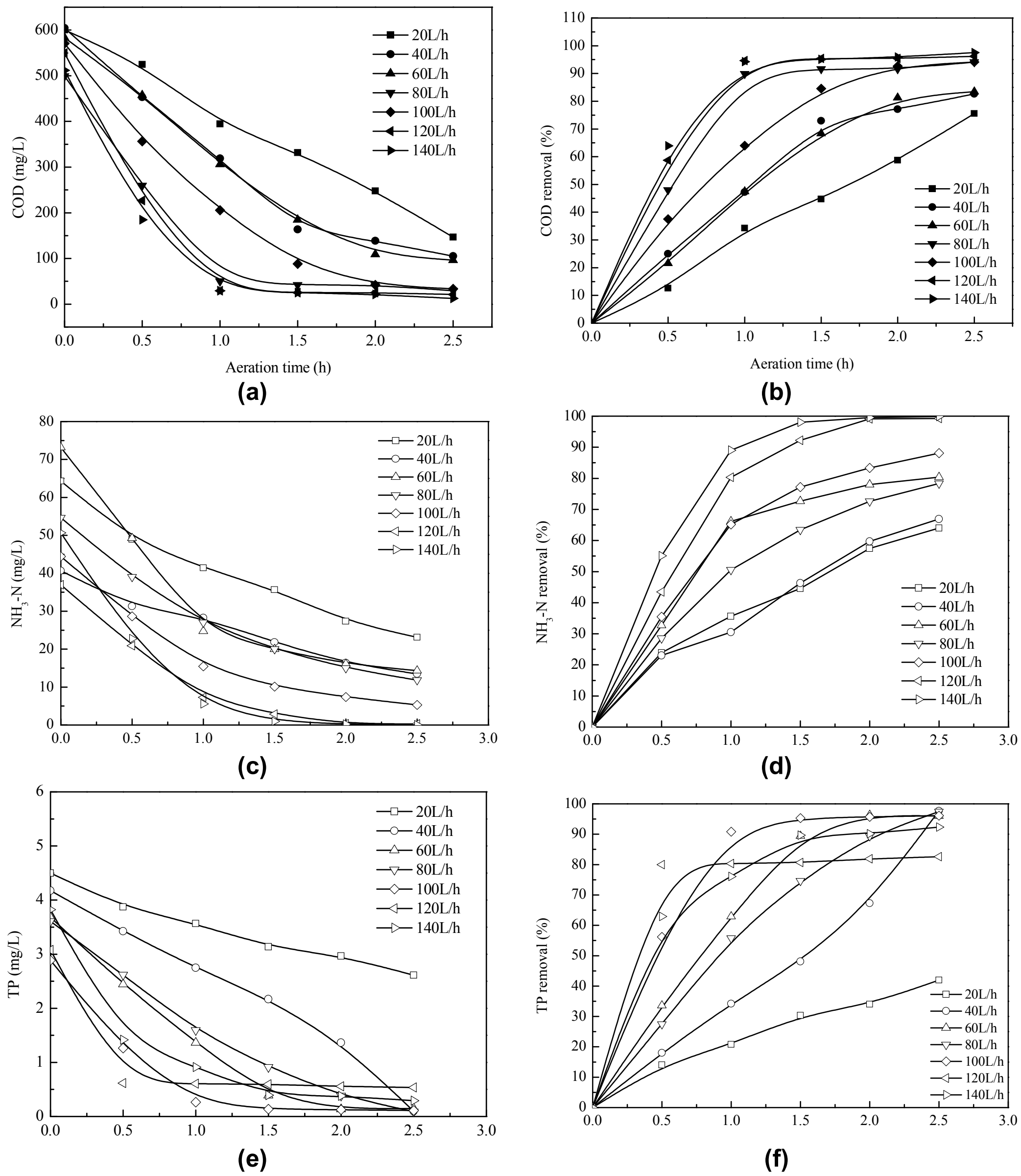


Fig. 4. Effects of air flow on COD, NH_3-N and TP

Under the conditions of air flow rate 60L / h and pH 7, 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 Figs. 5-6. As can be seen in Figs. 5-6, 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 [8]. The highest removal rates of COD, NH_3-N and TP reach to 97%, 91.39% and 99.21%, respectively.

In the work, we investigated effects of pH on COD and NH_3-N under the condition of air flow rate 60L / h. The results are shown in Fig. 7. It shows that when pH is equal to 4 or 10, with the aeration time of 3.5 h, the effluent COD is 268.52 mg/L or 239.15 mg/L, and the removal rate of COD is 56.16% or 64.37%, respectively, whose effluent is neither qualified nor meets the discharge standards. When pH is 5~9, COD is removed effectively (COD<100 mg/L, aeration 3.5H, removal rate 85%~94%) and it meets the discharge standards. And when pH is 4, 9 or 10, the removal effectiveness on NH_3-H is poor. The effects of the high strength of acids and alkalis on COD and NH_3-N are greater, making the removal of COD and NH_3-H reduce. The reasons may be that bagasse (film) shrinks in high acidity and alkalinity. It can be obtained by the experiments that the favorable pH range is found to be 5~8 for the waste treatment.

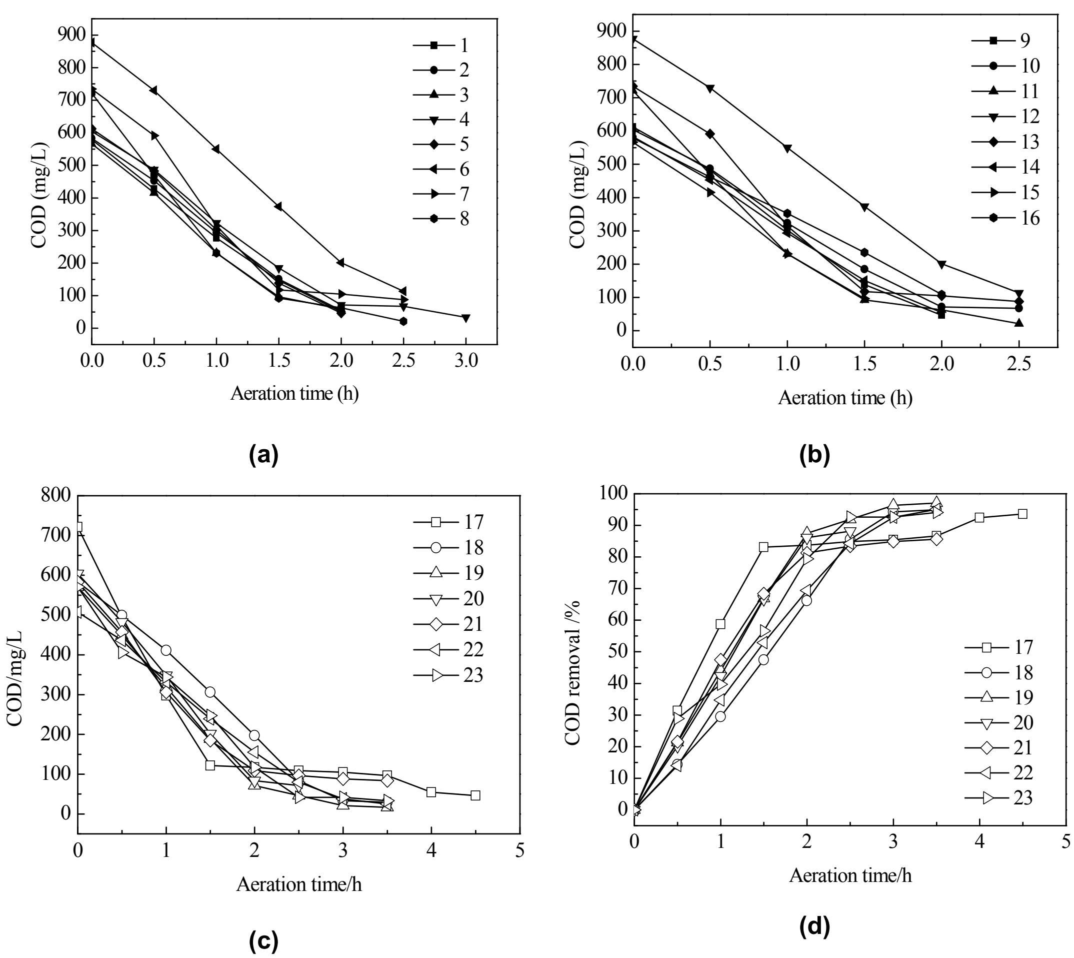


Fig. 5. Effects of aeration time on COD

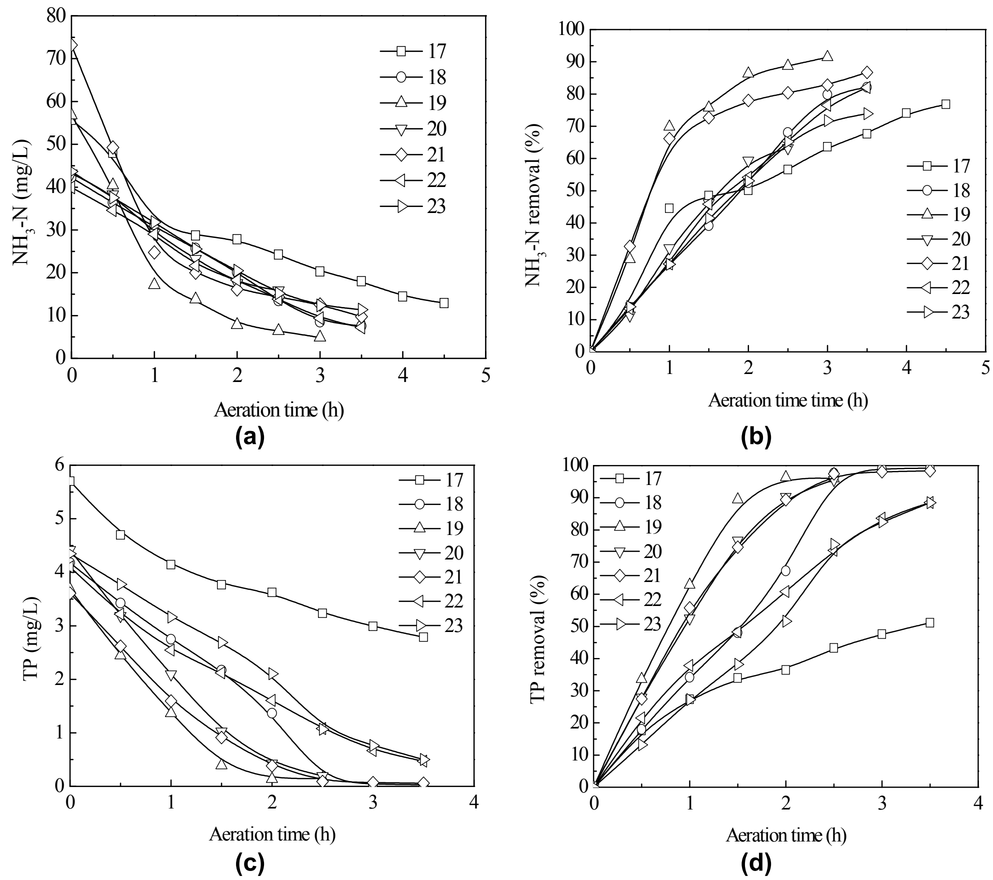
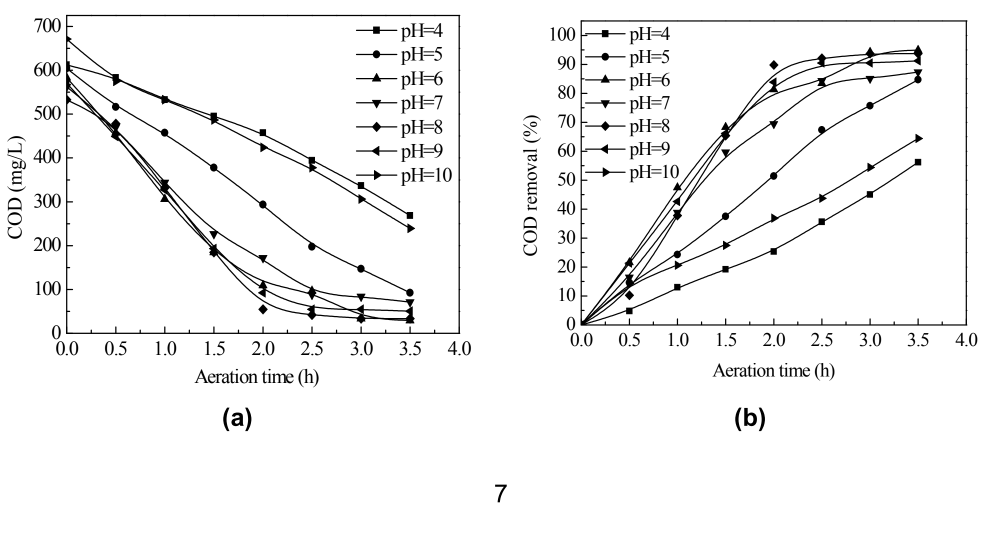


Fig. 6. Effects of aeration time on NH_3-N and total phosphorus

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)

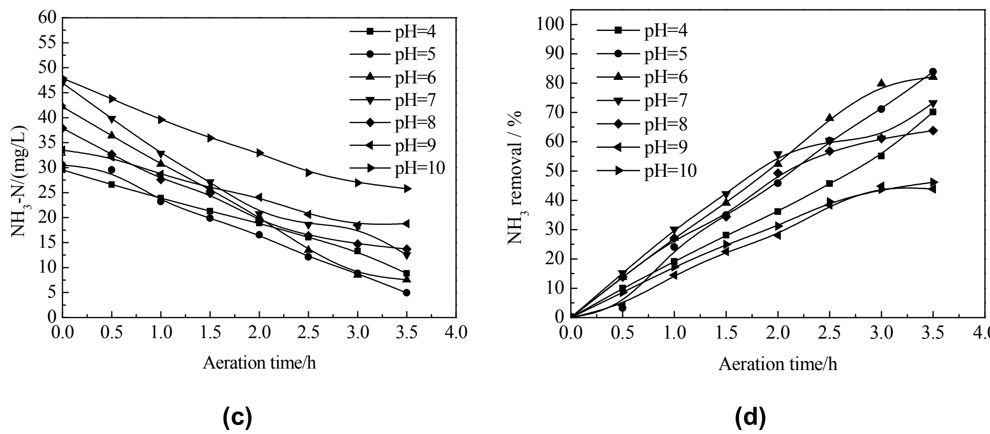


Fig. 7. Effects of pH on COD and NH_3-N

5. 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. Bagasse, as carriers in the sequencing batch reactor, had better characteristics of the bio-film attachment and performance of wastewater treatment. Using bagasse as carriers could achieve the purposes of reducing treat-cost of cane sugar wastewater and contamination of environment. This wastewater treatment method had the advantages of simple operation, economy and high efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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