Effect of Salinity on Anaerobic Sequencing Batch Biofilm Reactor Treating Industrial Wastewater

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Mustard tuber wastewater posses high salinity ([Cl^{-1}] = 18~23 g L^{-1}), high organic content (COD = 4000 ± 100 L^{-1}) and biodegradability (BOD_5/COD ≈ 0.5). The anaerobic sequencing batch biofilm reactor (ASBBR) pretreatment was employed to reduce much of the organics. The experiment studied the effect of salinity on ASBBR treating mustard tuber wastewater. The ASBBR was conducted at 50 % biomass density, 30 °C and pH value of 7.0 ± 0.2, the effluent COD increased from 290 mg L^{-1} to 1520 mg L^{-1} when the salinity increased from 10000 mg L^{-1} to 30000 mg L^{-1}. The recommendation salinity was obtained under two different subsequent treatments: one was that the effluent from ASBBR discharged into pipelines then treated in wastewater treatment plant, the other was that effluent from ASBBR discharged into natural waters after aerobic treatment.

Key words: Hypersaline Wastewater; Anaerobic Sequencing Batch Biofilm (ASBBR); Salinity; Industrial Wastewater.

Anaerobic treatment is often employed to treat high-concentration organic wastewater, for its obvious advantages, such as tolerance to high content of organic loads[1] and high efficiency at low cost. Those advantages are produced by its high biomass concentration[2]. For this reason, anaerobic sequencing batch biofilm reactor (ASBBR), deriving from sequencing batch reactor (SBR) by adding inert supports to immobilize biomass, is considered to be an attractive way to improve the biomass attachment, then prolong the cellular retention time and reduce even eliminate the time of granules formation and settling[3]. However, the performance of anaerobic reactor could be remarkably impaired when treat hypersaline wastewater due to the adverse impact brought about by high content of sodium and other cations.

Researches about salinity inhibition on anaerobic treatment mainly include: 1) high concentration of sodium cause cell dehydration and the loss of microbial activity, as a result, the biological system would remove less pollutants at more biological oxygen demands[4-6]; 2) low nutrient removal efficiency and high sludge volume index (SVI) would occur when biomass concentration decreased in hypersaline wastewater[7]; 3) high salt content exerted an adverse effect on organic removal rate, nitrification and denitrification efficiency as well as biological phosphorus removal efficiency[5, 8, 9].

To improve the efficacy of biological system treating saline wastewater, the utilization of salt-tolerant microorganisms seems to be a more considerable approach[10, 11]. Ramon Mendez[12] treated high-salinity wastewater with thermophilic anaerobic filter, after a nine-month start-up period, a stable operation was achieved, even when sodium concentration was 8 g L^{-1}; the COD removal reached 73 %. Khannous et al inoculated activated sludge reactor with NaCl-acclimated culture when treated marine-products wastewater, and attained 98 % and 88 % COD removal efficiency at organic load rates of 250 and 1000 mg COD $L^{-1}D^{-1}$, respectively[13].

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Peyton *et al*.,[14] studied phenol degradation kinetics in saline industrial wastewater and concluded that halophilic bacterial could reduce phenol even at 100 g L^{-1} NaCl concentration.

The mustard tuber wastewater was high in organic matters (COD = 4000 ± 100 L^{-1}) and capable of being decomposed by microorganisms (BOD_5/COD ≈ 0.5), thus acclimated anaerobic microorganisms and anaerobic sequencing batch biofilm reactor (ASBBR) were applied as its pretreatment methods. Therefore, the objective of this paper is to investigate the effect of salt concentration on ASBBR performance and provide a guideline for ASBBR design and operation.

MATERIALS AND METHODS

Reactor description

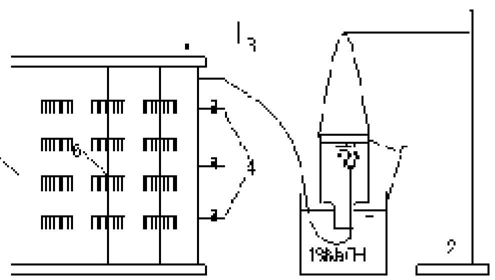
As shown in Fig. 1, the working volume of the plastic reactor was 2.4 L (length, 30.0 cm; breadth, 16.0 cm; height 50.0 cm). Filler material of the reactor was semi-soft fiber. The production of CH_4 was measured by displacing 1 % NaOH in a 2 L serum bottle.

Operation condition

A 2 d batch cycle was used in this ASBBR. The cycle began with feeding for 0.5 h, after a reaction period of 47 h, and ended with 0.5 h discharging step. Its excess sludge was discharge regularly by a pump at the bottom.

Analytical methods

The wastewater obtained from Fuling Mustard Tuber Group Co., Ltd, Chongqing, China. In the past years, the second and third pickle liquid was of high salinity ([Cl^{-1}] = 70-80g L^{-1}, 140-160 g L^{-1}, respectively) and they were used to utilized to make mustard tuber sauce, but with the prohibition on the manufacturing of mustard tuber sauce, both of them needed treatment before their discharge.



1 ASBBR Reactor 2 Bracket 3 Influent
4 Sampling and effluent 5 Biogas collection device
6 Biological packing

Fig. 1. A schematic diagram of ASBBR

To evaluate the performance of the ASBBR, parameters, including effluent COD, dehydrogenase, gas production rate were tested. The methods employed according to Standard Methods for the Examination of Water and Wastewater[15].

The following salinity was tested: 10000 mg L^{-1}, 15000 mg L^{-1}, 20000 mg L^{-1}, 25000 mg L^{-1} and 30000 mg L^{-1}. According to our preliminary experiment result that pH value would significantly affect the performance of ASBBR on treating hypersaline wastewater[16], influent pH value was adjusted to 7.0 ± 0.2 at before the experiment. These reactors were operated at 30 ! with 50 % biofilm density, and the influent COD was controlled at 4000 ± 100 mg L^{-1}. The water influent characterization was presented in Table 1.

RESULTS AND DISCUSSIONS

The effect of salinity

Fig.2 shows the variation in effluent COD and COD removal efficiency at different salinity (10000 mg L^{-1}, 15000 mg L^{-1}, 20000 mg L^{-1}, 25000 mg L^{-1} and 30000 mg L^{-1}).

More salt content could exert more negative impact on microbial activity [17]; however, for anaerobic system treating mustard tuber wastewater, more salinity would bring about more organic content which may lead to higher removal efficiency. The comprehensive influence of salinity and organic load could be obtained from Fig. 2, which is obvious that the influence of salinity is more significant.

When salinity increased from 10000 mg L^{-1} to 30000 mg L^{-1}, at first the removal efficiency

Table 1. The influent characterization.

COD (mg L^{-1})	4000 ± 100
Total nitrogen (mg L^{-1})	500
Total phosphours (mg L^{-1})	8~19
Total dissolved solids (g L^{-1})	38~47
Total suspended solids (g L^{-1})	2.2~4.6
Volatile suspended solids (g L^{-1})	0.8~1.4
pH	6.8-7.2

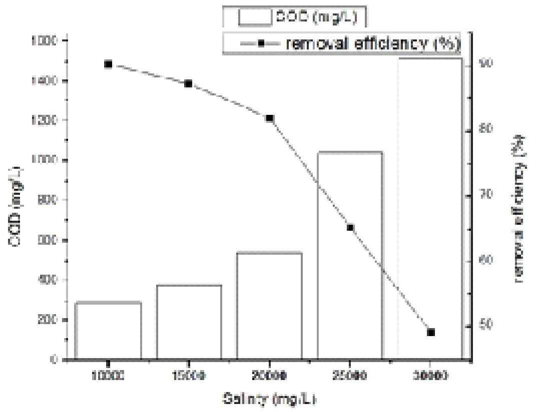


Fig. 2. COD and removal efficiency at different salinity

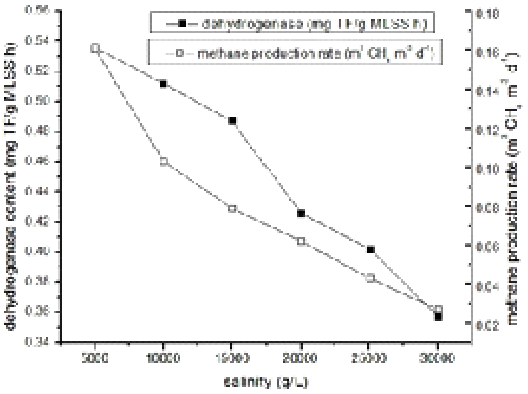


Fig. 3. Dehydrogenase content and CH_4 production rate at different salinity

curve did not drop sharply within the salinity of 10000 mg L^{-1} to 20000 mg L^{-1}. Then with increasing salinity, the removal efficiency decreased significantly. The acclimatization period should be prolonged to achieve satisfactory result in hypersaline environment[18].

Fig.3 shows the variation in dehydrogenase content and CH_4 production rate at different salinity (10000 mg L^{-1}, 15000 mg L^{-1}, 20000 mg L^{-1}, 25000 mg L^{-1} and 30000 mg L^{-1}). The dehydrogenase content dropped about 30 %, from 0.536 µg TF/g to 0.357 µg TF. The methane production rate decreased 0.134 m^3 $CH_4/m^3 \cdot$ d (about 80 %) when increased the salinity from 10000 mg L^{-1} to 30000 mg L^{-1}. In ASBBR, the CH_4 was produced by methanogen after hydrolysis and acidification process. When dehydrogenase content decreased to a low value, a reduction of methane production rate and COD removal efficiency would be observed.

Salinity Design

The optimal salinity could be determined by the discharge methods

Effluent from ASBBR discharged into pipelines then treated in wastewater treatment plant. The ASBBR effluent COD should be below 500 mg L^{-1} to meet the water quality standards for discharge to municipal sewers[19]. This discharge method could be applied to the mustard tuber wastewater factory near the wastewater treatment plant. Based on the experimental result (Fig. 2), being operated at 30°C and salinity under 15000 mg L^{-1}, the effluent could be discharged into pipelines directly.

Effluent from ASBBR discharged into natural waters which characterized by low self-purification capacity and total nitrogen discharge restriction. Thus effluent of ASBBR should contain enough carbon to conduct subsequent denitrification. Based on previous research on aerobic denitrification by SBBR [20], the favorable COD/TN range for denitrification was 2.8 to 3.2 in mustard tuber wastewater treatment. Total nitrogen was 500 mg L^{-1} (Table 1) and assumes the value of COD/TN was 3.0, to guarantee denitrification effect, the effluent COD should be above 1500 mg L^{-1}, thus the adverse effect of high salinity could be alleviated by adding subsequent aerobic treatment.

CONCLUSIONS

The ASBBR operating at 50 % biofilm density, 30 °C, influent COD of 4000 mg L^{-1} and pH value of 7.0 ± 0.2, 1) COD removal efficiency dropped slightly within the salinity of 10000-20000 mg L^{-1}, when salinity exceeded 20000 mg L^{-1}, the removal efficiency decreased significantly; 2) the effluent could discharge into pipelines then treated with municipal wastewater if COD concentration could be reduced below 500 mg L^{-1}, thus the maximum salinity for this ASBBR was 150000 mg L^{-1}; 3) the effluent COD concentration should exceed 1500 mg L^{-1}, if proceeded subsequent aerobic system to further reduce total nitrogen and COD, the adverse effect of high salinity could be alleviated.

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