Experimental Study on Minimization of Sludge Production by Ozonation Process

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Based on the hypothesis of reducing sludge production under cryptic growth conditions, ozone was used as cell lysis agent to treat excess sludge, and then the ozonated supernatant was returned to the aeration tank. The results show that COD and NH_4^+-N removal efficiencies in ozonation process were 87.96% and 84.42%, respectively. Meanwhile, a low excess sludge yield coefficient of 0.113 (g SS/g COD removed) was obtained. Compared with that of the control test, the process configuration decreased the excess sludge production by 51.3%.

Keywords: *ozonation, sludge minimization, cryptic growth, excess sludge yield*

Introduction

A large quantity of biosolids can be produced in a conventional wastewater treatment plant, the handling, treatment, and ultimate disposal of waste biosolids accounts for from 40% to 65% of the operating costs of the plant[1]. Since the use of sludge in agriculture is debatable and sludge incineration cannot be a systematic solution, minimization of sludge production should be preferred.

Every technology used for minimization of sludge production should not impact the efficiency of the wastewater treatment. Lee and Welander minimized sludge production by predating protozoa and metazoa, the apparent sludge yields in the process varied between 0.01 and 0.23 kg TSS/kg COD removed[2]. Hamer and Mason demonstrated that the net biomass growth could be reduced under cryptic conditions[3,4]. Which is to say, when the organic carbon in microorganism is used as substrate of metabolism process, sludge production will be reduced. Based on these hypotheses, it was assumed that ozone could be used as a cell lysis agent, because ozone is a strong oxidation agent, it can promote the biodegradation of the cell, then the treated supernatant was returned to the aeration tank, which will minimize the net excess sludge production.

Materials and Methods

Two vertical flow submerged biofilm systems were run in parallel: one as a control system with discharging the excess sludge directly, the other as a test system with recycling of supernatant that was achieved by ozonating the excess sludge. Each of the reactors had an aeration tank volume of 16.3 L and an inclined tube sedimentation tank volume of 8.5 L. The volume of biomass carrier was 30% of that of the aeration tank. Ozonation was achieved in a column reactor with a diameter of 4 cm and a height of 100 cm. A schematic of the process is presented in Fig. 1.

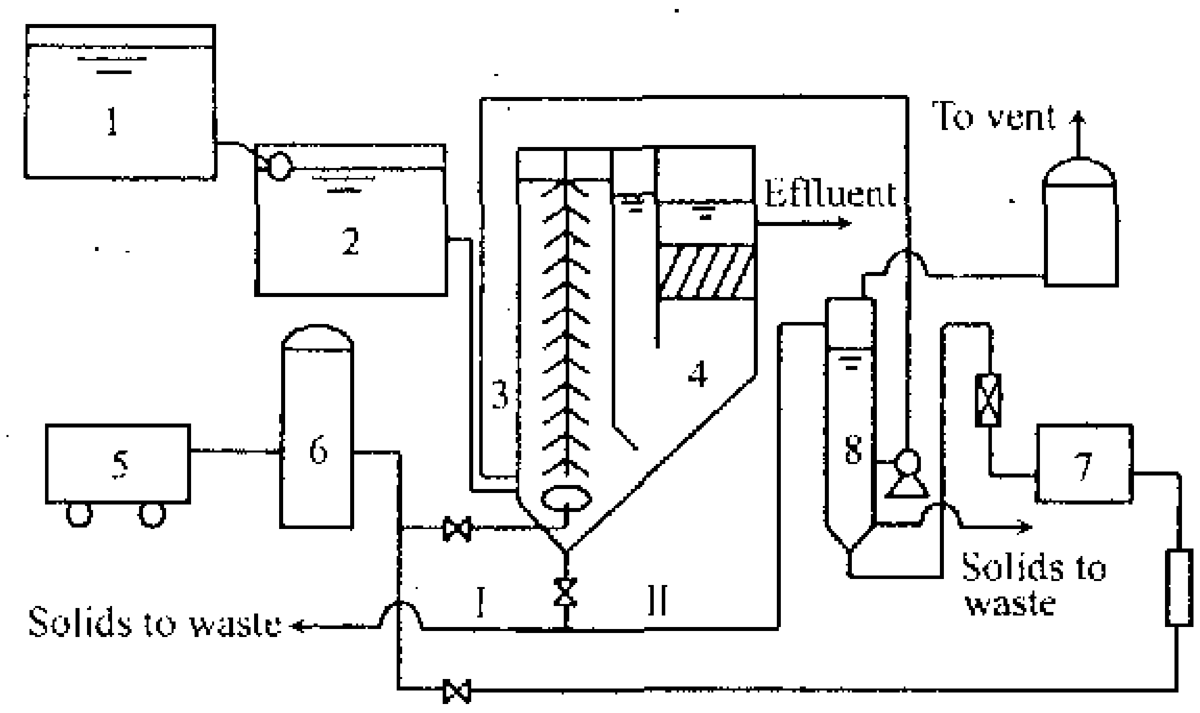

Fig. 1 Schematic arrangement of the experimental system
I —control system process configuration;
II —test system process configuration;
1—storage tank; 2—balance tank; 3—submerged biofilm reactor;
4—inclined tube sedimentation tank; 5—air compressor;
6—air storage tank; 7—ozone generator;
8—contact reactor for ozone and sludge

A mixture of starch, sugar, NH_4Cl, K_2HPO_4 and KH_2PO_4, with an equivalent average COD of 426 mg/L and an average BOD of 244 mg/L was utilized as the food source to represent typical domestic wastewater. The ratio COD: N: P was about 100: 10: 1.

The detention time of wastewater in submerged biofilm aeration tank was 6 hours, and all settled sludge was returned to the aeration tank from settling chamber in both the control

Received Jan. 2, 2002
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and test systems. In aeration tank, DO was about 3 mg/L and the temperature was kept at 26 ℃ with a heater.

Results and Discussion

1 Influence of ozonation on COD, SCOD, VSS/SS and SV% of sludge

Following procedures were done in order to determine the ozone dosage for treating excess sludge: ozone gas was supplied at the bottom of the contact reactor, SS, VSS, COD, SCOD and SV% of the activated sludge were obtained at different reaction time. Then the plots of COD, SCOD, VSS/SS versus ozonation time were drawn. Based on all trends, a suitable ozone dosage might be achieved with which the cells could be solubilized and mineralized to a certain degree as well as the treatment cost for excess sludge should not be too expensive. The result is shown in Figs. 2, 3, 4.

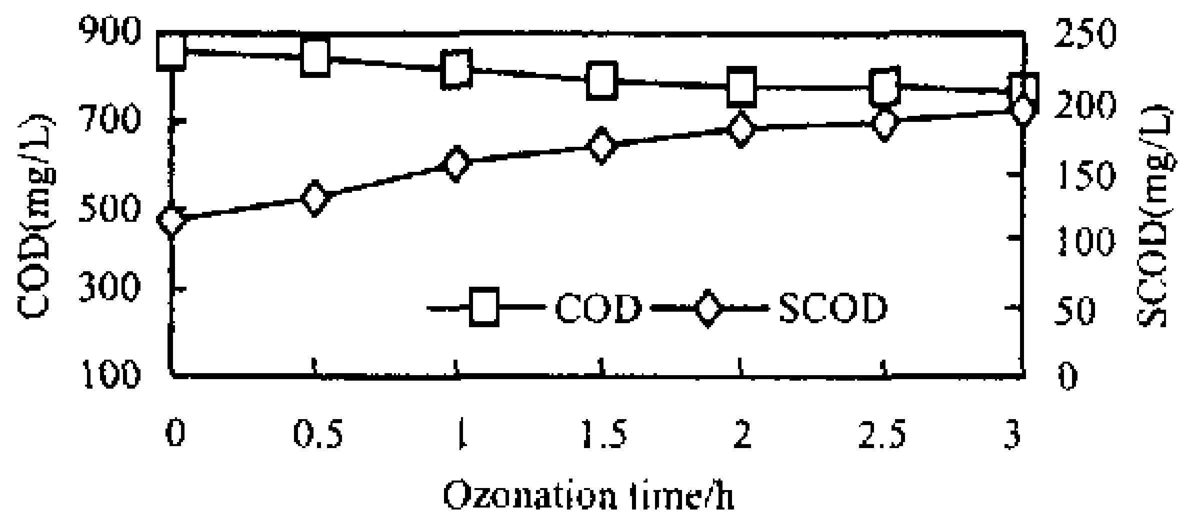

Fig. 2 Relationship between ozone time and COD, SCOD

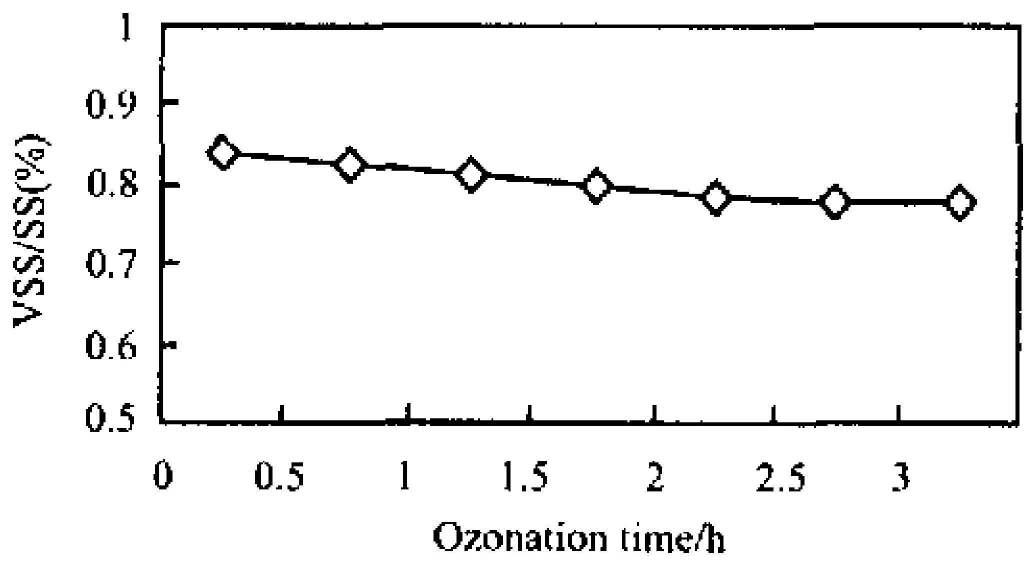

Fig. 3 Effect of ozonation on VSS/SS of sludge

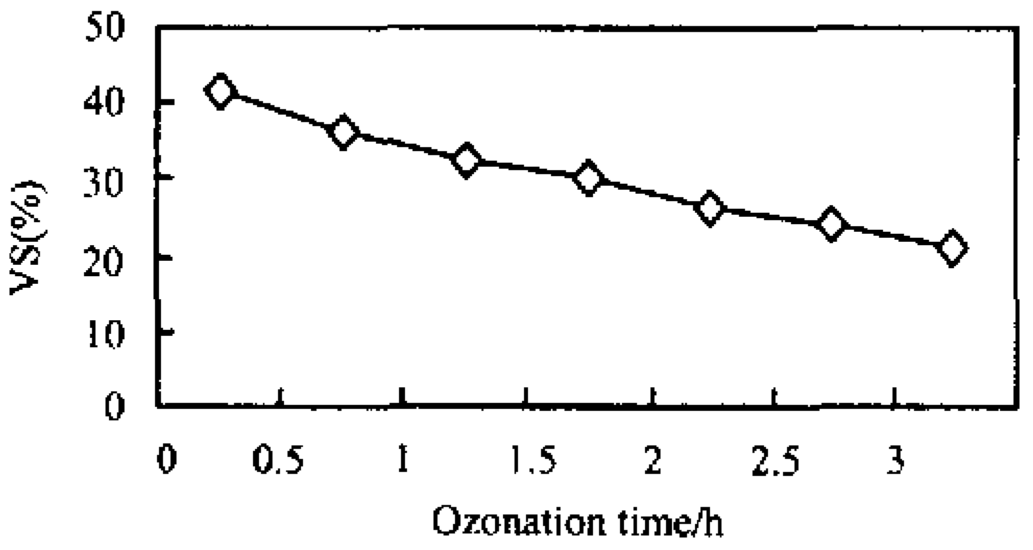

Fig. 4 Effect of ozonation on SV% of sludge

The data were obtained with an ozone gas concentration of 1.2 mg/L. SCOD concentration increased while COD concentration decreased with increasing ozonation time. Especially, more than 10% of COD decreased at an ozone dosage of 25 mg O_3/g MLSS. Furthermore, about 9% of COD of sludge before ozonation became SCOD at the same ozonation time. These results indicated that sludge ozonation led to both solubilization and mineralization of the sludge.

COD decreased from 866 mg/L to 768 mg/L and SCOD increased from 115 to 193 at an ozonation time of 3 hours. Ozone could disrupt the cell walls and cause the release of the organic substance from the walls. The rate of carbon solubilization was high in the first 2 hours and accounted for 86% of that in total 3 hours of ozonation, and the sludge mineralization rate decreased with the prolongation of ozonation time. This phenomenon might be due to that the low concentration ozone couldn't oxidize sludge cells to a greater extent. The influence of ozone concentration on the mineralization and solubilization of sludge should be further investigated. In addition, the ratio of inorganic substance increased with the ozonation time, which is presented in Fig. 3.

It could be seen that VSS/SS decreased from 0.842 to 0.775 in 3 hours of ozonation time. It was an indication that part organic substance in biosolids was solubilized or mineralized by ozone. During the first 2 hours, organics decreased quickly and decreasing rate became slow with the extended ozonation time.

Fig. 4 shows the relationship between ozone dosage and the SV% of the sludge. SV% was found to decrease with increasing ozone dosage. It can be seen that SV% decreased from 42 to 21.5 in 3 hours of ozonation time, which indicated that the sludge settling characteristic was improved greatly. It was assumed that the filamentous bacteria in activated sludge were damaged and their structure was changed by ozone also. Consequently, these results suggested that the ozonation has a remarkable effect on maintaining and improving the sludge settling characteristics. Previous study has reported similar results of ozonation on the sludge settling characterictics[5].

Based on the above experimental findings, 2 hours was considered to be an appropriate ozonation time. Ozone concentration multiplies by ozonation time and air flow, and divides by MLSS of the sludge, then the parameter of 0.025 kg O_3/kg SS was obtained.

2 Comparison on treatment effect of the two systems

The two reactors were run for 1 month under identical conditions to reach steady state. During this period, both reactors were fed with the same synthetic feed at an average flow rate of 65.2 L/d and the excess sludge was wasted from both of the reactors daily. In the test reactor, the daily excess sludge wastage from the test reactor was ozonated with an ozone dosage of 0.025 kg O_3/kg SS. Upon ozonation, the sludge was settled for 1.5 hours and the supernatant was then recirculated back into the aeration tank of the test reactor. Thus, the test reactor received the solubilized sludge with a COD of about 630 mg/L in addition to the influent synthetic feed.

The ozonation of the test reactor continued for 76 days. The general operating parameters of both of the reactors for the total of 76 days are given in Table 1.

Table 1 Operating parameters of the control and test reactors

Parameter	Control reactor	Test reactor
Influent flow rate (L/day)	65.2	65.2
Recirculated ozonated sludge (L/day)	—	3.16
Detention time (hrs)	6	5.72
SS of the excess sludge (mg/L)	1 340	1 570
DO (mg/L)	2.94	3.12
Wasted sludge (L/day)	3	3
Influent COD (mg/L)	316	316
Effluent COD (mg/L)	34.8	41.7
COD of the ozonated sludge (mg/L)	—	628.4
COD removal efficiency (%)	88.99	87.96
SS of the ozonated sludge (mg/L)	—	746
Influent NH_4^+-N (mg/L)	32.4	32.4
Effluent NH_4^+-N (mg/L)	3.6	5.2
NH_4^+-N of the ozonated sludge (mg/L)	—	53.4
NH_4^+-N removal efficiency (%)	88.89	84.42

As can be seen from Table 1, for the control system the removals of COD and NH_4^+-N were 88.99% and 88.89%, respectively. For the test system, because the recirculation of supernatant of the ozonated sludge increased the influent concentration of COD and NH_4^+-N, so the test system had a higher load of COD and NH_4^+-N. The removals were also higher and reached 87.96% and 84.42%, respectively. This means ozonation of the excess sludge has no inhibition to the carbon removal and nitrification. Effluent quality was excellent and could meet the demands of the National Criteria. During the experimental period, the variation of sludge yield coefficients in two reactors was plotted in Fig. 5.

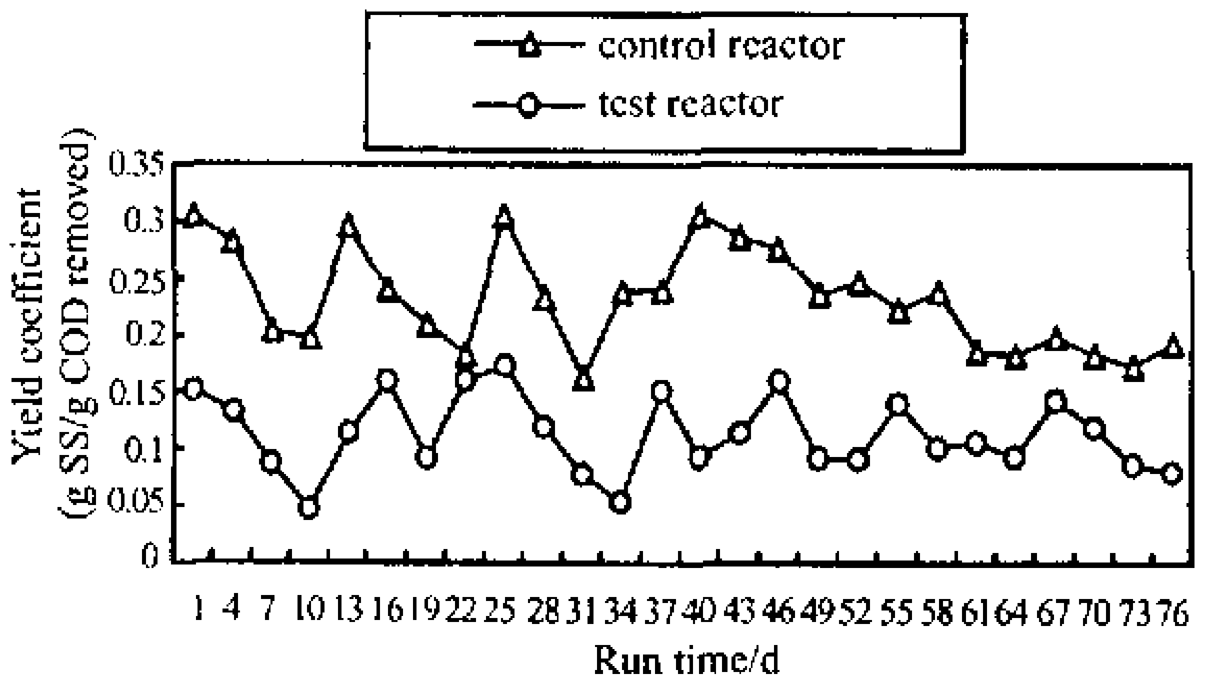

Fig. 5 Daily yield coefficients of the test and control reactors

The sludge yield coefficients of the control reactor varied from 0.163 to 0.306 and averaged 0.232, whereas the ozonated test reactor had an average yield coefficient of 0.113. Compared with the low yield coefficient of the control reactor, ozonation process decreased its value by 51.3%.

3 Economic analysis

An electric fee of about 10 Yuan (RMB) is needed to produce 1 kg of ozone gas. Based on the experimental data, the operation cost of sludge ozonation could be calculated. A quantity of 3.16 L/d sludge at a 1 570 mg MLSS/L of concentration was treated, and ozone dosage was 0.025 kg O_3/kg SS, so sludge ozonation operation cost is equal to (10 Yuan/kg O_3 × 1.57 kg SS/m^3 × 0.025 kg O_3/kg SS) 0.39 Yuan/m^3 sludge. For the treated wastewater flow was 65.2 l, thus the additional cost for wastewater treatment is 0.39 Yuan/m^3 × (3.16 l/65.2 l) = 0.02 Yuan/m^3. This is to say, sludge ozonation process only increased a little operation cost for wastewater treatment.

Conclusions

(1) The optimal ozone dosage for excess sludge was 0.02^5 kg O_3/kg SS in minimization of sludge by ozonation process.

(2) During the experimental period of 76 days, the test system with ozonation process has average removals of 87.96% and 84.42% for COD and NH_4^+-N and the effluent quailty is excellent.

(3) The test system with ozonation process acquired a low sludge yield coefficient of 0.113 g SS/g COD removed. Compared with the control system, the test process could reduce the waste sludge production by 51.3%.

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