Influence of Al^{3+} Addition on the Flocculation and Sedimentation of Thermophilic Activated Sludge

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Abstract. In this study, the flocculation and sedimentation performance of thermophilic activated sludge with single and multiple dosing of trivalent aluminum (Al^{3+}) were studied. The thermophilic activated sludge samples were cultivated in sequencing batch reactors at 55 °C. The dosages of Al^{3+} were 0.125, 0.5, 1.0, 1.5, and 2.0 meq/L for single dosing, and 0.1 meq/L for multiple dosing. The experimental results indicated that single Al^{3+} dosing could enhance sludge flocculation, but deteriorate sedimentation. While multiple dosing, which allows sufficient time for sludge restructuring and floc aggregation, could optimize flocculation and maintain sedimentation simultaneously. LB-EPS played a more important role than interaction energy in the improvement. Although the responding of zeta potential was insignificant, better flocculability and settleability were achieved through Al^{3+} dosing.

Introduction

Thermophilic activated sludge systems represent a unique and relatively new process for high strength or high temperature wastewater. The advantages of this technology include rapid biodegradation rates, low sludge yields, and excellent process stability. As such, thermophilic activated sludge aerobic process has been widely used to treat wastewaters from the pulp and paper industry, food production, and many other miscellaneous waste streams [1,2]. However, in thermophilic activated sludge, the sludge volume index (SVI) strongly increased with an increased temperature and it is harder to control filamentous bulking [3]. Besides, poor floc formation and sludge settleability is encountered in thermophilic activated sludge. Thermophilic activated sludge treatment is often hampered by unsatisfactory effluent quality.

Dosing of flocculants is one of the most efficient solutions to poor flocculation performance, and Al^{3+} is the most common additive in wastewater treatment, due to the formation of larger flocs compared with other multivalent cations. The flocculation enhancement mechanism can be explained by ion bridging theory and Derjaguin-Landau-Verwey-Overbeek (DLVO) theory [4]. When added to wastewater, cations serve as flocculants and facilitate flocculation by causing compression of double electrical layers and ion-bridging through extracellular polymeric substances (EPS).

In the present study, Al^{3+} was added to thermophilic activated sludge systems according to single and multiple dosing patterns, and a concentration gradient was set under single dosing conditions,to determine the more efficient dosing pattern in thermophilic activated sludge.

Materials and Methods

The reactors were seeded with thermophilic activated sludge (approximately 2500 mg/L) from Qu Yang WWTP in Shanghai, China. Temperature was gradually increased from 20° C to 55° C. All the reactors were operated for a minimum of 3 sludge ages (30 days) and parameters such as the COD, turbidity and SVI in the effluent were monitored on a daily basis for 10 days. The thermophilic activated sludge was collected for the experiments on the condition that the fluctuation

of these parameters was less than 20%. All the thermophilic activated sludge samples were wasted during the last 10 min of the aeration phase.

The thermophilic activated sludge in reactor R-S was cultivated without adding Al^{3+} in the influent. After the reactor operation stabilized, 500 mL of thermophilic activated sludge sample were decanted into 5 identical 250 mL beakers, each receiving 100 mL, to which a different Al^{3+} dosage was added. The Al^{3+} dosages were 0.125, 0.5, 1, 1.5 and 2.0 meq/L, respectively, in beakers designated as S-0.125, S-0.5, S-1.0, S-1.5, S-2.0, respectively. No Al^{3+} was added into beaker C-0, which was the blank control of the experiment. All of the Al^{3+} in the single dosing test was added once. The samples were then mixed at 117 rad/min for 5 min and subsequently at 50 rad/min for 5 min. All the processes were carried out at 55 $\pm$ 1 C. In the multiple dosing test, Al^{3+} at a concentration 0.1 meq/L was added to the influent of reactor R-M and introduced to the reactor in each operation cycle. The mixing pattern was in accordance with single dosing test.

Results and Discussion

Basic Characteristics of the Thermophilic Activated Sludge Systems. The basic characteristics of the thermophilic activated sludge are listed in Table 1. In the multiple dosing scenario, the turbidity of M-0.1 (55.6 ± 13 NTU) was approximately equal to that of S-1.5 (52.5 ± 16 NTU), but was much lower than that of S-1.0 (80.5 ± 18 NTU). All of them were remarkably lower compared with C-0 (145.2 ± 23 NTU). Thus, when an equivalent amount of Al^{3+} was added, thermophilic activated sludge flocculation was promoted via both of the dosing patterns, but multiple dosing scenario is more efficient. In addition, there was no notable difference in SVI level among C-0 (178 ± 26 mL/g), M-0.1 (173 ± 15 mL/g) and S-1.0 (184 ± 29 mL/g), but the SVI reached a higher level in S-1.5 (230 ± 72 mL/g). Thus, multiple Al^{3+} dosing can improving thermophilic activated sludge flocculation effectively, and will not aggravate thermophilic activated sludge sedimentation at the same time.

Table 1 – The characteristics of thermophilic activated sludge flocculation and sedimentation

	Test number	Al^{3+} dosage (meq/L)	Supernatant turbidity (NTU)	SVI (mL/g)	Zeta potential (mV)	Bulk solution content (mg TOC/g VSS)	LB-EPS content (mg TOC/g VSS)	TB-EPS content (mg TOC/g VSS)
Control sample	C-0	0.00	145.2±23	178±26	-7.46±1.05	10.9±0.55	38.8±1.4	36.0±0.42
Single dosing	S-0.125	0.125	135.6±24	174±22	-6.14±0.17	10.8±0.52	34.3±2.5	37.2±2.5
	S-0.5	0.5	112.9±23	180±30	-5.95±0.57	9.98±0.67	31.9±2.7	34.6±0.7
	S-1.0	1.0	80.5±18	184±29	-5.85±0.39	10.9±1.73	29.0±2.3	36.3±3.9
	S-1.5	1.5	52.5±16	230±72	-5.67±0.09	10.2±1.12	23.9±3.1	31.3±3.8
	S-2.0	2.0	30.6±14	244±95	-4.85±0.76	9.20±1.19	18.2±1.3	30.9±3.6
Multiple dosing	M-0.1	0.1	55.6±13	173±15	-5.91±1.16	9.4±1.01	8.42±2.2	16.0±3.15

Influence of Al^{3+} on Thermophilic Activated Sludge Interaction Energy. The absolute value of the zeta potential of M-0.1 was lower than that of C-0 (Table 1), indicating that multiple Al^{3+} dosing also compressed the double electrical layers through charge neutralization; besides, the zeta potential reduction was as slight as that observed when an equivalent dosage of Al^{3+} was added in the single dosing test (S-1.0). In particular, when compared with C-0, the zeta potentials of S-1.0 and M-0.1 decreased by 21.6% and 20.8%, respectively, whereas the turbidity of S-1.0 and M-0.1 decreased by 44.6% and 61.7%, respectively. Although the reductions in the zeta potential were quite similar, the decrease in turbidity achieved by single Al^{3+} dosing was much lower than that observed following multiple Al^{3+} dosing. This also implied that, in addition to zeta potential, other factors also had a more important effect on thermophilic activated sludge flocculation, and the zeta potential wasn't the key parameter contributing to the effluent turbidities.

Influence of Al^{3+} on the EPS Content. The bridging function of bivalent cations could well explain the long-term effect of ions on the transformation of aggregates [5]. However, our previous

research indicated that the influence of trivalent cations on the LB-EPS content and sludge flocculation is more significant than that of bivalent cations [6]. In the present study, following the addition of an equivalent Al^{3+} dosage, both the LB-EPS and TB-EPS contents extracted in the multiple dosing test were significantly lower than those extracted in the single dosing test (Table 1). Therefore, in the multiple dosing test, Al^{3+} effectively enhanced sludge densification through the ion bridging effect.

Al^{3+} Distribution Characteristics in the Thermophilic Activated Sludge. With the increasing single dosage, the Al^{3+} concentration detected in the sludge gradually increased (Fig. 1). When an equivalent amount of Al^{3+} was added through single and multiple dosing, similar Al^{3+} accumulations were noted in the sludge, but the distributions of Al^{3+} among the various sludge components were significantly different (Fig. 1). Al^{3+} could be detected in the bulk solution in the multiple dosing test, but not in the single dosing test. Furthermore, Al^{3+} accumulation in the pellet was dramatically higher in the multiple dosing test, when compared with that in the single dosing test. Accordingly, the accumulation of Al^{3+} in TB-EPS and LB-EPS were much lower in the single dosing test. These findings indicated that the bonding capacity between Al^{3+} and the sludge varied with the dosing pattern, which contributed to the remarkably lower extraction of LB-EPS and TB-EPS in the multiple dosing test.

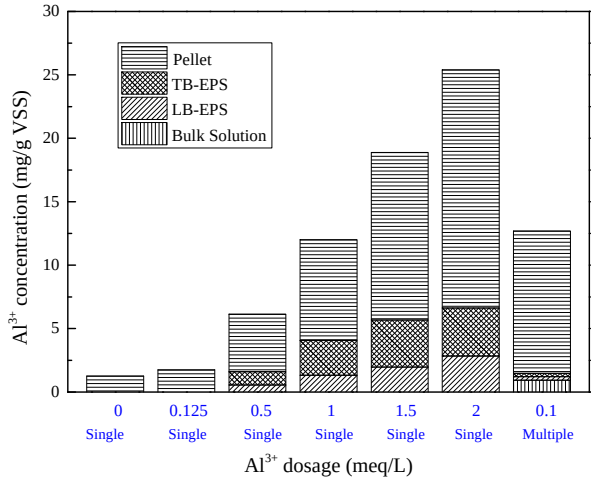

Fig. 1 – The distribution of Al^{3+} in different TS components in single and multiple dosing tests.

Influence of Al^{3+} on Thermophilic Activated Sludge Settleability. The correlation observed in the present study between SVI and LB-EPS under single dosing conditions (R^2 = 0.96) is in good agreement with the findings of previous studies, indicating that EPS content has a significant effect on sludge settleability [7]. However, the results of the multiple dosing test deviated from the tendency exhibited in the single dosing test (Fig. 2). With the equivalent Al^{3+} dosage, the LB-EPS content observed in the multiple dosing test were much lower compared with that observed in the single dosing test, but the values of SVI were similar, suggesting comparable sludge settleability. This also indicated that the correlation between SVI and LB-EPS content worked depending on the structure of thermophilic activated sludge, which changed a lot according to the dosing patterns.

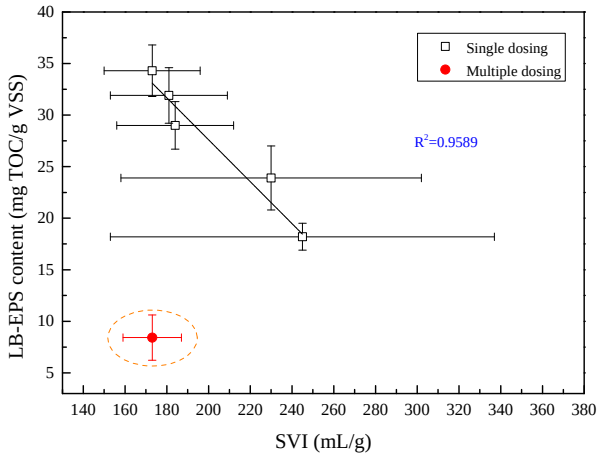

Fig. 2 –The relation between the LB-EPS content and SVI. Error bars represent mean values ± one standard deviation (n=5).

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References

[1] J. Suvilampi, J. Rintala: Environ. Sci. Biotechnol. Vol. 2 (2003), p. 31-35.

[2] T. M. Lapara, J. E. Alleman: Water Res. Vol. 33(1999), p. 895-908.

[3] A. F. Rozich, K. Bordacs: Water Sci. Technol. Vol. 46 (2002), p. 83-89.

[4] G. P. Sheng, H. Q. Yu: Biotechnol. Adv. Vol. 28 (2010), p. 882-894.

[5] D. C. Sobeck, M. J. Higgins: Water Res. Vol. 36 (2002), p. 527-538.

[6] H. S. Li, Y. Wen, A. S. Cao: Bioresour. Technol. Vol. 114 (2012), p. 188-194.

[7] F. X. Ye, G. Peng, , Y. Li: Chemosphere. Vol. 84 (2011), p. 1250-1255.