BIO-ORGANIC CATALYST
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미생물 촉매제를 이용한 슬러지 감량화에 관한 연구

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A Study on Sludge Reduction in Sewage using Microbial Catalysts

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Abstract
In this study, evaluation of sludge reduction and advanced treatment were performed using the batch test. Sludge reduction rate was checked by batch experiment on excess sludge and aerobic sludge. The maximum sludge reduction rate was 37% for excess sludge and 34% for aerobic sludge. As a result of the batch process, the SCODCr 26%, S-N 62% and S-P 82% were removed. Therefore, it is possible to reduce the amount of sludge during the microbial catalyst injection and to remove the organic matter and nutrients simultaneously. In particular, the removal efficiency of S-P is higher than that of the conventional treatment. Especially, the removal efficiency of S-P was higher than that of conventional A2O treatment. In order to evaluate sludge reduction ability after microbial catalytic agent injection, the yield of heterotrophic biomass (YH), decay coefficient of heterotrophic biomass (bH) and observed or net biomass yield (Yobs) were estimated. The yield of YH was 0.32 and 0.25, which was less than 50% of the YH (BOD based) value of general heterotrophic microorganisms. On the other hand, bH was 0.232 day-1, which is a general value. Therefore, it is considered that the main factor of sludge reduction using microbial agent is due to the decrease of biomass build-up rather than the death of sludge microorganisms.

Key words: *Microbial Catalyst, Microbial Activity, Sludge Reduction, Advanced Treatment*

1. Introduction

As the water usage increases, the amount of sewage and wastewater generated is increased, and thus the quality of discharged water is strengthened and the amount of sewage sludge generated is continuously increasing [3]. However, the regulations on disposal and disposal of sludge have been continuously strengthened and the cost has increased. Since the London Convention, which came into force in 1996, was enacted in 2011, all dumping of sludge has been banned and land disposal is underway. Land treatment has problems such as complaints about odor, high treatment cost, securing landfill space. Due to these problems, sludge reduction has been increasing.

Sludge reduction is largely divided into a reduction method from the production stage such as OSA (Oxic Settling Anaerobic) process, a reduction method by pretreatment with ultrasonic wave, ozone, electrolysis, etc., and a reduction method using microbial metabolism process in the digestion tank [4-7]. However, there are limitations in applying the method using the process configuration to the operating sewage treatment facilities, and the method using the pretreatment has a disadvantage that the initial investment cost and the maintenance cost are excessively consumed. In addition, since digester is difficult to install except for large-scale sewage treatment plant, it is inexpensive and requires no secondary contamination. Microbial catalysts are known to reduce the sludge by promoting the activity of microorganisms present in the water.

In this study, the microbial catalyst is injected to increase the microbial activity used in the biological wastewater treatment, and the advanced treatment of the wastewater through the microbial catalyst and the reduction of the sludge are carried out. In order to analyze the characteristics of the microbial catalysts, the treatment efficiency of the microbial catalysts and the removal efficiency of the microbial catalysts were analyzed through the calculation of the amount of the microbial catalysts and the injection conditions and the sludge reduction according to the presence or absence of the microbial catalysts. To evaluate the possibility of sludge reduction, the heterotrophic microorganism production factor (YH), heterotrophic microorganism mortality coefficient (bH) and microbial production factor (Yobs) were estimated.

2. Research Method

To evaluate the sludge reduction capacity and microbial activity using microbial catalyst, the dynamic coefficient was evaluated. To determine the yield factor (YH) of heterotrophic microorganisms to determine the yield of microorganisms and the effect of microbial death on the life cycle of microorganisms, the mortality coefficient (bH) of heterotrophic microorganisms was measured. Sewage and sludge were prepared by considering the F / M ratio of the reaction tank.

2.1. Estimation of microbial catalyst dosage

The microbial catalyst is a biocatalyst, which is a non-toxic, biodegradable material that can act as a liquid in the form of a yellow-based liquid and is stable, Is not added. Microbial catalysts contain organic stabilizers and minerals to enhance the ability of microorganisms to decompose organic matter in the wastewater treatment process and to accelerate the rate of bacterial degradation. The process of microbial catalysis is shown in Fig. 1.

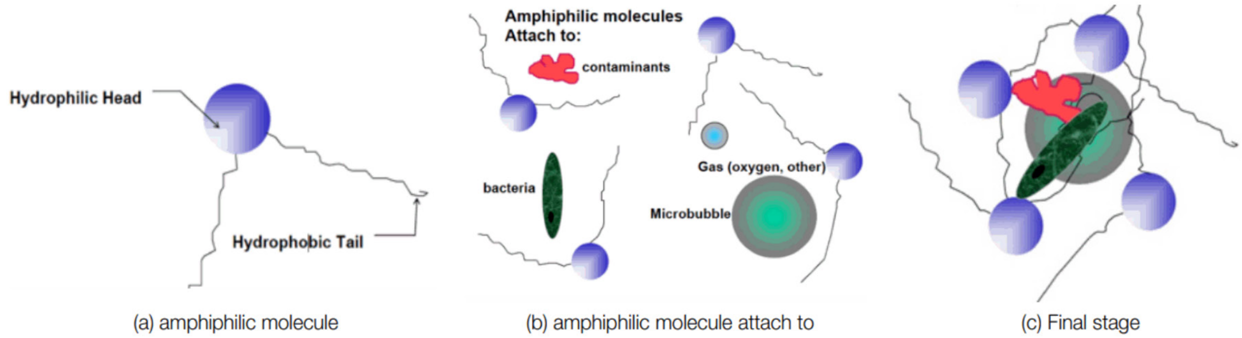


Fig. 1.

Process of microbial catalyst.

The amount of microbial catalyst injected was measured by batch test. The target sludge was sludge of surplus sludge and aerobic sludge of J Water Rehabilitation Center (A2O method) in Seoul city. Experiments were carried out at a flow rate of 1 mL / L of the microbial catalyst per 100 mg / L BOD of raw water. Since the organic matter (BOD) related to microbial growth is present in the raw water and the microbes are calculated as the BOD value, the amount of the microbial catalyst injected is selected based on the BOD standard and the optimization is evaluated based on the SS removal rate.

The sludge reduction efficiency was tested by injecting injection amount (Table 1, Table 2) for each reaction tank based on 2 L of excess sludge and stirring for 4 hours. To further characterize the characteristics of microbial catalysts, we analyzed the organic and nutrient salts before and after microbial catalyst injection to evaluate the advanced treatment efficiency.

Table 1.

Experimental conditions (excess sludge)

Reactor	A1	A2	A3	A4	A5	A6	A7
Injection dosage (mL/L)	Control	20	50	60	78	100	120

Table 2.

Experimental conditions (aerobic sludge)

Reactor	B1	B2	B3	B4	B5
Injection dosage (mL/L)	Control	25	30	35	40

2.2. Estimation of heterotrophic microorganism production factor (YH)

The effluent (Table 3) was filtered through a GF / C filter paper to prepare a filtrate. To prevent nitrification in the reactor, Allythiourea (ATU) was injected at 20 mg / L and mixed for 5 minutes. The SRT was washed with distilled water for 4 ~ 5 times using sludge in operation which was operated for 10 days, and then aerated for more than 2 hours to avoid being affected by residual organic matter. The prepared sewage filtrate and sludge were mixed so that the aerobic tank F / M ratio of the reactor was 0.3. Experiments were conducted at 20 °C and pH neutral range. YH was calculated by calculating concentration of dissolved COD (SCOD) by measuring the concentration of consumed TCOD and produced biomass COD (BCOD) over 20 hours at 3 hour intervals.

Table 3.

wastewater concentration

	COD	BOD	T-N	T-P	SS
Concentration (mg/L)	501.33	150.12	106.90	1.185	130.39

2.3. Estimation of heterotrophic microbial mortality (bH)

In this experiment, the bH value was calculated by OUR (Oxigen Uptake Rate). The measuring device was a Comput-ox respirometer 4R manufactured by N-con. After the appropriate temperature condition was set in the water-bath, the sample was immersed in a 500 mL bottle, and the amount of dissolved oxygen consumed was analyzed over time. Sewage mixed with sludge was filtered with GF / C filter paper and 20 mg / L of Allythiourea was added to prevent nitrification and mixed for 5 minutes. The sludge used in the experiment was rinsed 4 ~ 5 times with distilled water and then aerated for more than 2 hours in order to minimize the influence of organic matter remaining in the sludge. The prepared sewage filtrate and sludge were mixed into OUR laboratory bottle by mixing to the aerobic tank F / M ratio of 0.3.

3. Results and discussion

3.1. Microbial Catalyst Injection amount calculation result

As a result of analyzing the optimal injection amount of the microbial catalyst for the excess sludge, Fig. As shown in Fig. In the first 2 hours, A6 showed the best SS removal rate of 20.3% compared to the control group. However, after 3 hours, A5 (1 mL / L of BOD 100 mg / L) showed the highest SS removal rate of 36.9%. In the control group A1, the SS elimination rate was 3.4% due to endogenous ventilation. Therefore, the maximum SS removal rate could be obtained as 34.7%. In the case of A6 and A7, bubbles are generated after a certain period of time and problems are found when overdosing. Therefore, it is necessary to estimate the appropriate doses when the microbial catalyst is applied.

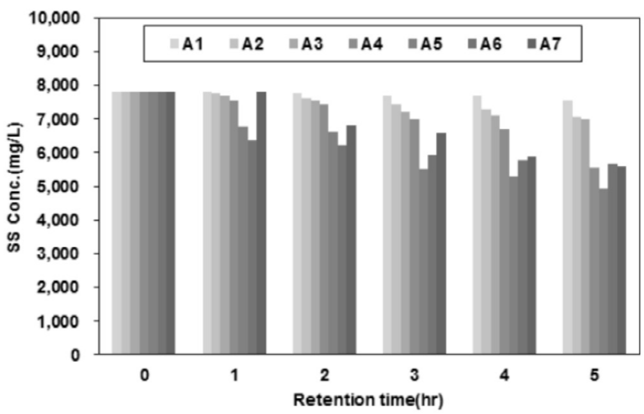


Fig. 2.

SS concentration with excess sludge using catalyst.

Experiments were carried out on a total of five reaction vessels based on the results of surplus sludge experiments. In comparison with the excess sludge, the B1, which is the control group, showed little SS change and the SS removal rate of B3 ~ B5 was similar. The optimal infusion rate of B3 (1 mL / L of BOD 30 mg / L) showed a maximum removal rate of 33.8% after 5 hours at 1.3% removal rate at the initial 1 hour (Fig. 3).

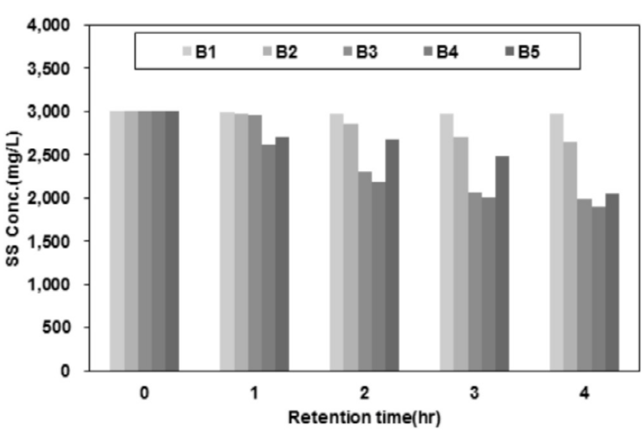


Fig. 3.

SS concentration with aerobic sludge using catalyst.

As a result of analyzing the water quality change in the bioreactor according to the microbial catalyst injection, 4 ~ Fig. 6. In the control group B1, SCODCr decreased by 9.3%, S-N by 8.6% and S-P by 21.1%, but SCODCr increased by 23.9% ~ 25.6%, S-N by 39.3 ~ 61.6% and S-P by 70.4 ~ 82.4% after injection of microbial catalyst. It is believed that this is due to the improvement of the decomposition ability of organic matter and the decomposition ability of bacteria, which is the greatest feature of the microbial catalyst. In the case of B3 (30 mL / L), the concentration of S-P was removed from 5.14 mg / L to 0.961 mg / L after 4 hours and the concentration of S-N was removed from 27.11 mg / L to 10.41 mg / These results are expected to be helpful in reducing the cost of chemicals used in sewage disposal facilities and strengthening T-N standards for future effluent water.

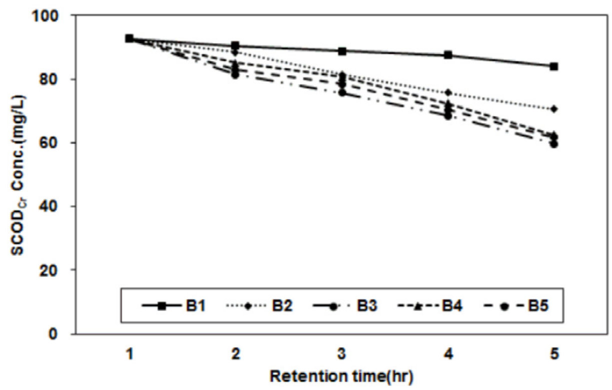


Fig. 4.

$SCOD_{Cr}$ concentration using catalyst.

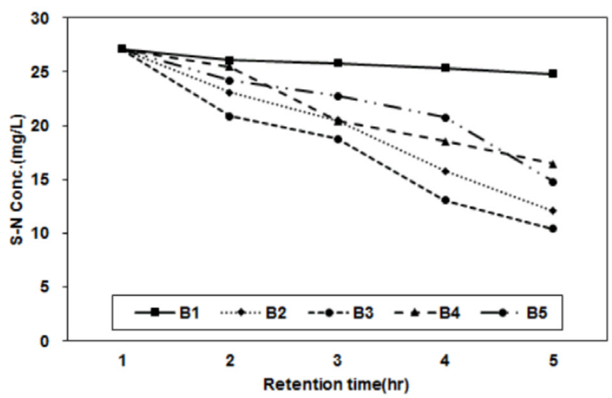


Fig. 5.

S-N concentration using catalyst.

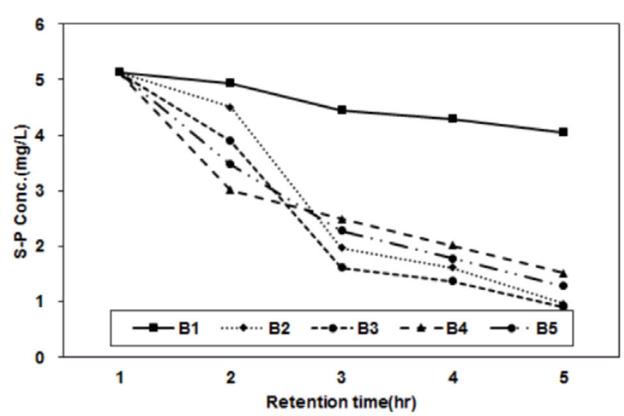
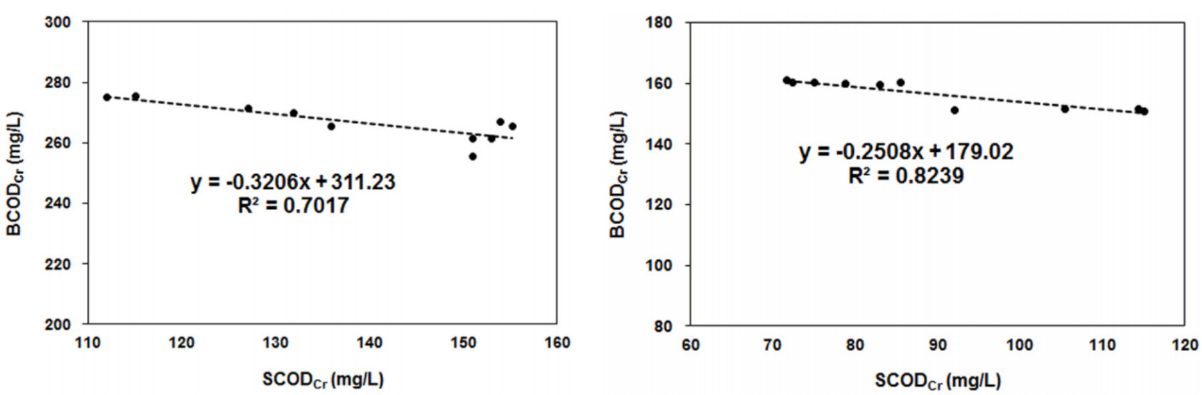


Fig. 6.

S-P concentration using catalyst.

3.2. Estimation of heterotrophic microorganism production factor (YH)

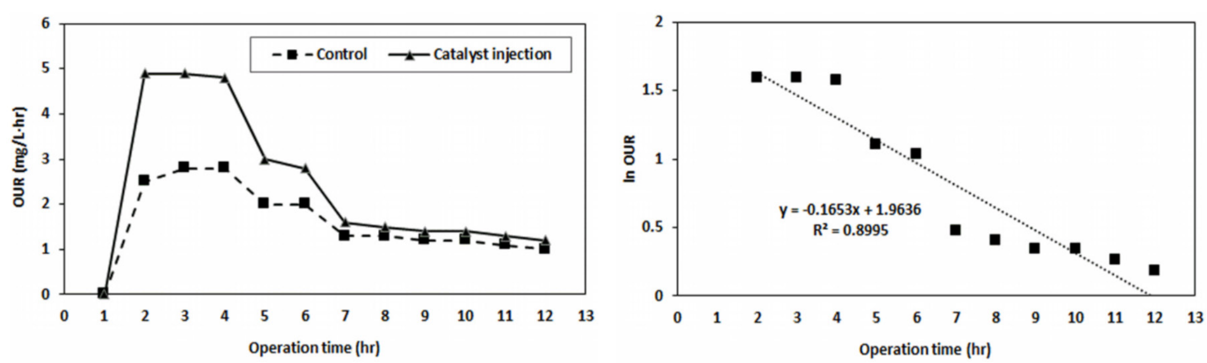
The results of the YH experiment on the aerobic tank injected with the microbial catalyst are shown in Fig. 7 and Fig. 8. As shown in Equation (1), YH is obtained from the relationship between BCOD and SCOD. The total YH is 0.32 and the second YH is 0.25, which is 20% lower than the theoretical YH value 0.40 (COD based) And it was less than 50% of 0.67 which is YH value of BOD standard. In the general YH experiment, BCOD is inversely proportional to SCOD, but SCOD is decreased but BCOD is kept constant in this study. This can indirectly confirm that the endogenous respiration of the microorganism is caused by the injection of the microbial catalyst.



(a) 1st (b) 2nd

Fig. 7.

Estimating of Y_H using ΔBCOD/ΔSCOD.



(a) OUR curve (b) ln OUR curve

Fig. 8.

catalyst with activated sludge for b_H.

(1)

$$Y_H = \frac{\Delta BCOD}{\Delta SCOD}$$

Compared with the 0.13 ~ 0.29 kg SS / kg COD, which is the YH value range of the OSA method, which is related to the conventional sludge reduction, it showed a similar value [1]. In the present study, the amount of sludge was reduced by injecting a microbial catalyst into the aerobic tank of the existing process, while the OSA method reduced the amount of sludge by inducing a luxury uptake of the microorganisms transported by the anaerobic tank at the downstream of the settling basin. It seems to be easily applicable.

3.3. Estimation of heterotrophic microbial mortality (bH)

bH is calculated by measuring the amount of oxygen consumed for a certain period of time. In order to compare before and after the injection of the microbial catalyst, two samples were measured. 7 (a). When the microbial catalyst was injected, the oxygen uptake rate was about twice as much as the initial oxygen uptake time of 6 hours. It can be seen that the microorganism catalytic agent increases the decomposition ability of microorganisms.

Fig. 7 (b) calculates b'H as the slope of the graph obtained by linearly taking the OUR value as the natural logarithm for the interval (decreasing interval) excluding the initial one hour. The calculated b'H is substituted into the equation (2) to calculate bH.

(2)

$$b_H = \frac{b'_H}{1 - Y_H(1 - f'_p)}$$

bH: Decay coefficient for heterotrophic biomass
f'P: Fraction of biomass leading to particulate products
YH: Yield coefficient for heterotrophic biomass
b'H: Heterotrophic decay coefficient in traditional model

At this time, the value of f'P was calculated to be 0.08, which is a general value, assuming 20% of the inactive material of the cell [2]. The mortality coefficient (bH) of the general sludge was 0.24 to 0.43 day-1, which was 0.32 day-1 on average. The mortality coefficients (bH) calculated in this study were 0.21 day-1 and 0.23 day-1, and the values of Ekama [8] and IWAPRC The value was 0.24 day-1 as presented in ASM No.1 [10].

3.3. Estimate the actual microbial production factors (Yobs)

Yobs (Observed heterotrophic yield coefficient) can be defined as the ratio of the maximum increase of microorganisms to the decrease of the substrate, as shown in the following equation (3).

(3)

$$b_{obs} = \frac{\Delta X_{max}}{\Delta S}$$

The production coefficient of the heterotrophic microorganism (YH), bH, and SRT can also be shown by the following equation (6) [9].

(4)

$$Y_{obs} = Y_H \cdot \frac{1}{1 + SRT \cdot m_s \cdot Y_H}$$

(5)

$$Y_{obs} = Y_H \cdot \frac{1}{1 + SRT \cdot k_e}$$

(6)

$$Y_{obs} = Y_H \cdot \frac{1}{1 + SRT \cdot b_H \cdot (1 - (1 - f) \cdot Y_H)}$$

bH: Decay rate
f: Fraction of inert material formed during decay / lysis (endogenous residue)
SRT: Solid retention time
YH: Yield coefficient
Ke: Endogenous respiration
ms: maintenance coefficient

Yob and YHs were obtained by substituting YH and bH, which are shown in Table 4, and SRT was applied for 10 days. The calculated Yobs values were 0.121 and 0.095, which correspond to 18% and 15% of the theoretical production yield value of 0.67. Therefore, it can be concluded that the production yield YH due to the microbial catalyst injection is about 0.108.

Table 4.
Biokinetic parameters estimation (aerobic sludge)

Experiment	SRT (day)	Y_H (mgCOD/mgCOD)	b_H (day^{-1})	Y_{obs} (day^{-1})	
1^{st}	10	0.32	0.23	0.121	0.108
2^{nd}		0.25	0.21	0.095	

4. Conclusion

This study was conducted to estimate the production and mortality coefficients of heterotrophic microorganisms for sludge reduction by microbial catalyst injection. The results were as follows.

1) Through the batch test, 33.8% of SS, 25.6% of SCODCr, 61.6% of S-N and 82.4% of S-P were removed. It seems that the removal of organics and nutrients is improved by increasing the nutrient source of bacterial in the wastewater during microbial catalyst injection. It is considered to be effective not only for reducing sludge but also for advanced treatment of microbial catalysts.

2) The production coefficient (YH) and the extinction coefficient (bH) of the heterotrophic microorganisms, which generally have a carbon source as a substrate, were analyzed through calculation of the kinetic coefficients after the microbial catalyst injection. YH calculation result was 0.32, 0.25, and the general heterotrophic microorganism YH (BOD based) And less than 50% of the YH (BOD based) value. On the other hand, bH showed a typical value of 0.232 day-1. The main reason for the reduction of sludge using a microbial catalyst is that the microbial catalyst accelerates the activity of microorganisms, consuming most energy in metabolism.

This study confirms that sludge reduction effect is achieved by injecting a microbial catalyst. However, since the present study was conducted as a batch test, it is necessary to carry out further verification through the continuous experiment.

References

1. Nam, D.-H. and Jang, H.-S., "Evalutaion of Excess Sludge Reduction in the OSA Process using Kinetic Parameter and Mass Balance," J. Korean Soc. Water Qual, 25(4)530~538(2009).

2. Park, J.-B., Hur, H.-W. and et al, "Assessment of the Organic and Nitrogen Fractions in the Sewage of the Different Sewer Network Types by Respirometric Method," Korean Soc. Environ. Eng, 31(8)349~654(2009).

3. Fall, C., Silva-Hernandez, B. C. and et al, "Sludge reduction by ozone: Insights and modeling of the doseresponse effects," J. Environ. Manage, 206:103~112(2018).
crossref

4. Brooks, R. B. and Gard, I., "Heat treatment of activated sludge," Wat. Poll. Control, 67:592~601(1968).

5. Frolund, B. T., Grie, P. and Nielsen, H., "Enzymatic activity in the activated-sludge floc matrix," Appl. Micro. Biotechno, 43:755~761(1995).
crossref

6. Chen, G. H. and An, K. J., "Possoble cause of excess sludge reduction in an Oxic-Settling-Anaerobic activated sludge process (OSA proccess)," Water Res, 37(16)3855~3866(2003).
crossref

7. Wang, Z., Yu, H. G. and et al, "Recent advances in membrane bio-technologies for sludge reduction and treatment," Biotechnol. Adv, 31:1187~1199(2013).
crossref

8. Ekama, G. A., Dold, P. L. and Marais, G. V. R., "Procedures for determining influent COD fractions and the maximum specific growth rate of heterotrophs in Activated sludge system," Water Sci. and Technol, 18:91~114(1986).

9. van Loosdrecht and Henze, "Activated sludge model No.2D, ASM2D," Water Sci. and Technol, 39(1)165~182(1999).

10. APHA; AWWA; WEF, "Standard Methods for the Examination of Water and Wastewater,"20th Ed. Washington, DC: (1999).