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Study on new rural domestic sewage treatment technology based on CASS and VBF

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The paper took the typical rural domestic sewage in the surrounding districts and counties of Chengdu as the research object, and it chose the combined process of cyclic activated sludge system (CASS) and vermibiofilter (VBF). It used computer to simulate the process and systematically analyze the process of related influencing factors, control conditions, operation mechanism of rural domestic sewage and so on. Controlled the inlet water flow Q, the concentration of the inlet water BOD So (equal to 175 mg/L) and sludge age SRT (14.29 d) unchanged, respectively changed the reflux ratio R and dissolved oxygen concentration, and made the concentration of effluent BOD to reach the town sewage treatment plant pollutant discharge standard of GB18918-2002 grade B.

Key words: New rural sewage treatment, CASS, VBF, Computer dynamic simulation.

INTRODUCTION

Took into account the Chengdu belongs to the plain area, and combined with the new rural water supply and drainage system in the process of construction. It made the new rural domestic sewage in Chengdu area was easy to collect [1]. Therefore, it was obvious that developing the process of high hydraulic load, strong ability to remove nitrogen and phosphorus, simple system, convenient operation maintenance, and make the maximum use of local resources was the best choice [2]. The article selected the combination of cyclic activated sludge system (CASS) and vermibiofilter (VBF) treatment process. The wastewater was degraded by CASS technology, and then the VBF process reduced the sludge. At the same time, the paper systematically analyzed the process of related influencing factors, control conditions, operation mechanism of rural domestic sewage and so on, which provided the theoretical guidance for the practical project commissioning.

DETERMINATION OF PROCESS SCHEME

According to the specific characteristics of the new rural domestic sewage in Chengdu plain, this paper put forward the following requirements for the treatment of domestic sewage in new rural areas, 1)Low input and high efficiency. Due to the low income of rural residents, the priority should be given to the technology with low cost, low operating cost, low energy consumption or no energy consumption, stable operation, easy maintenance and high efficiency [3]. 2) Low secondary pollution. it is easy to cause indirect pollution in the process of sewage treatment, so it is necessary to choose the treatment process without secondary pollution or low secondary pollution. 3) Strong resistance to impact load. In order to avoid the waste or paralysis of the system resources caused by the change of the sewage discharge in the domestic sewage treatment system, it is necessary to select the wastewater treatment process with strong impact load capacity [4]. 4) Easy to manage and maintain.

In conclusion, considering CASS and VBF process have the characteristics of 'three low and two little and one high', namely, low construction cost, low operation cost, low management requirements, little area, little secondary pollution, high degree of resources, and they are in line with the direction of sustainable development. Moreover, they have distinctive 'ecological balance' and 'environmental friendly' technical features. Therefore, these processes was the best choice for the treatment of rural domestic sewage [5].

RESEARCH PROGRAM

Selection of control index of sewage treatment

Collected and analyzed the main controlling parameters BOD, COD, SS, NH_3-N and TP from Chengdu six urban area and Jintang, Qingbaijiang, Longquanyi, Pengzhou, Xindu, Pixian, Shuangliu, Wenjiang, Dujiangyan, Chongzhou , Dayi, Qionglai, Xinjin, Pujiang, 20 districts and counties

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(city), the concentration range of BOD, COD, SS, NH_3-N, TP and so on in sewage were shown in Table 1.

Combination of CASS and VBF process

Figure 1 presented that the process mainly included CASS and VBF two important processes. CASS pool was mainly used for the remove of BOD, COD, SS, NH_3-N, TP and so on in the sewage [6-7]. Partial supernatant fluid treated by CASS pool directly to the ultraviolet disinfection canal, and part to the adjusting tank which had the Oxygen filling function. The remaining sludge from the bottom of the CASS pool was deposited into the reservoir, and partial sludge returned to the CASS pool, and part to the adjusting tank. Entered to the adjusting tank and through water quantity and water quality regulation, the supernatant fluid and mud went into VBF pool for sludge reduction. The final drainage of VBF pool returned to CASS pool for processing, and the little sludge into the mud storage pool [8].

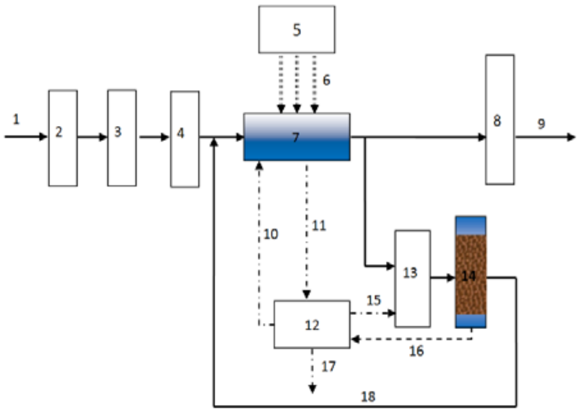

Fig. 1. Flow chart of CASS and VBF process（1.Inlet water; 2.The coarse grid; 3.Fine screen; 4.Grit chamber; 5.Ventilator room; 6.Aeration; 7.CASS pool; 8.Ultraviolet disinfection canal; 9.Effluent; 10.Return sludge; 11.Excess sludge; 12.Mud storage pool; 13.Adjusting tank; 14.VBF pool; 15.Return sludge; 16.Sludge discharging; 17.Efflux sludge; 18.Supernatant reflux.）

Computer dynamic simulate CASS technology

This paper adopted the method of computer dynamic simulation to study the influence factors which are related to organic matter removal of CASS process, controlling parameters and running mechanism. The experiment used continuous completely mixed aeration tank experiment device. The aeration tank was square, and the secondary sedimentation tank and aeration tank were combined and they were separated by reflux baffle. The water of aeration tank entered the secondary sedimentation tank by the hole of reverse-flow baffle, and the return sludge can be realized by adjusting the height of the backflow slit. Different sludge age can be achieved by adjusting the valve of the secondary sedimentation tank. In the process of implementation, the dissolved oxygen concentration and MLSS in the aeration tank were unchanged, and the water quantity or quality was constantly changed to get different sludge load. At the same time, the sludge age was controlled by the mud discharge valve to eliminate the surplus, and the parameters of the four groups under different sludge load were measured [9]. Finally, the work of the calculation, drawing and parameter was completed [10].

VBF treatment of excess sludge

Set the VBF pool [11]: Filter was a cylinder, radius was 0.15m, height was 0.15m, volume was about 39L and the ventilation effect was good. VBF pool was divided into three parts [12-13]: watering zone, filling area and drainage area. There was a layer of elastic filler under the water distributor, and the function of it were secondary water distribution and shading and supplemental oxygen. Filling area was divided into three layers: The upper was earthworms decomposition layer, and it involved fine sawdust, rice husk and peat etc. The middle layer was added layer, and its packing was the same as the upper. Bottom layer was the retainer layer, and it was filled with the ceramic grain filters [14]. The sludge of aeration tank through water distributor and elastic packing was distributed to the filter material surface evenly. After through the packing area of 0.50m high and the hole at the bottom of the device, the sludge was collected into the tank under the vermibiofilter [15]. The experiment selected Eisenia foetida, which showed short sexual maturation period and strong adaptability and high cocoon production rate.

The ceramic filter material particle's diameter was 6.0 ~ 9.0 mm, and its solid density and bulk density respectively was 2.26g/cm^3 and 0.89 ~ 1.00g/cm^3, and its voids and porosity respectively was greater than 41% and 50% . In addition, its specific surface area was about 1.8×10^4 ~$5.0\times10^4 cm^2/g$.

Table 1. The quality of input water.

Performances	BOD	COD	SS	NH_3-N	TP
Water Quality (mg/L)	170-200	240-300	170-200	45-52	4.0-4.5

Adjusted the sludge concentration of suspended solid (SS) to about 300mg/L in running time, the main conditions and design parameters were as follows[16]: the earthworm density was 32g/L, hydraulic load was 3.0m^3/(m^2.d), the earthworm organic load was 35g / (kg.d), pH was about 7, and the DO was 3.5mg/L,SS was 250~350 mg/L.The concentration of volatile suspended solids (VSS) was 160 ~ 200mg/L, and COD was 350 ~ 500mg/L.

ANALYSIS OF EXPERIMENTAL RESULT

The biochemical reaction kinetic coefficient K, Ks, Vmax, Y, Kd, a, b and so on

Without oxygen consumption rate measurement

Se as the abscissa, *(So-Se)/Xt* (sludge load) as the ordinate, the curve of substrate degradation and substrate concentration without oxygen consumption rate measurement was shown as Figure 2. According to the formula *(So-Se)/Xt =K·Se* got the slope *K≈0.023*.

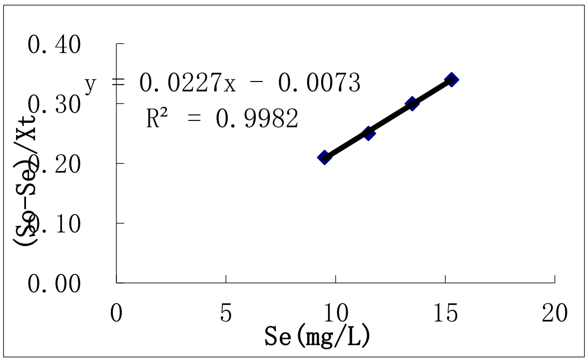

Fig. 2. Curve of substrate degradation and substrate concentration without oxygen consumption rate measurement.

Q·(So-Se)/Xt·V (sludge removal load) as the abscissa, *ΔX/Xv·V* as the ordinate, the curve of activated sludge growth without oxygen consumption rate measurement was shown as Figure 3. According to the formula *ΔX/Xv·V=Y·Q·(So-Se)/Xv·V-Kd*, the yield coefficient of activated sludge microorganisms *Y≈-0.300*, The self-oxidation rate of activated sludge microorganisms *Kd ≈-0.240*.

1/Se as the abscissa, *(So-Se)/Xt* (sludge load) as the ordinate, the curve of substrate degradation curve without oxygen consumption rate measurement was shown as Figure 4. According to the formula *Xt/(So-Se)=Ks/Vmax·1/Se+1/Vmax*, *Ks/Vmax=40.683, 1/Vmax=0.3095*. The maximum specific degradation rate of organic substrate can be obtained *Vmax=3.231*, Saturation constant *Ks=12.59*.

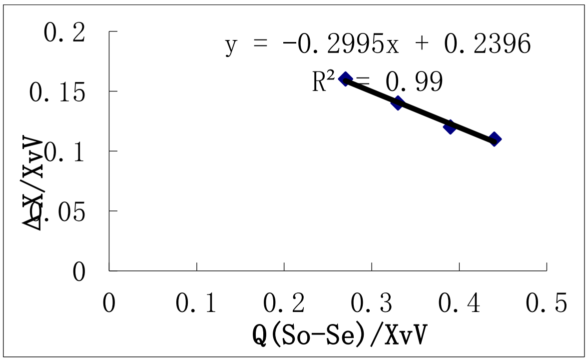

Fig. 3. Curve of activated sludge growth without oxygen consumption rate measurement.

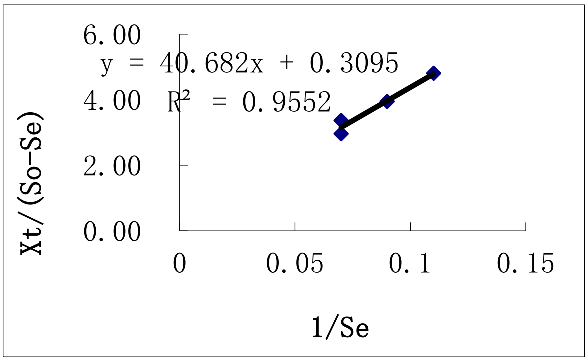

Fig. 4. Curve of substrate degradation curve without oxygen consumption rate measurement.

Therefore, without oxygen consumption rate measurement, the biochemical reaction kinetic coefficient *K=0.023*, *Y=-0.300*, *Kd=-0.240, Vmax=3.231, and Ks=12.59*.

Within oxygen consumption rate

Se as the abscissa, *(So-Se)/Xt* (sludge load) as the ordinate, the curve of substrate degradation and substrate concentration within oxygen consumption rate measurement was shown as Figure 5. According to the formula *(So-Se)/Xt =K·Se* got the slope *K ≈0.022*.

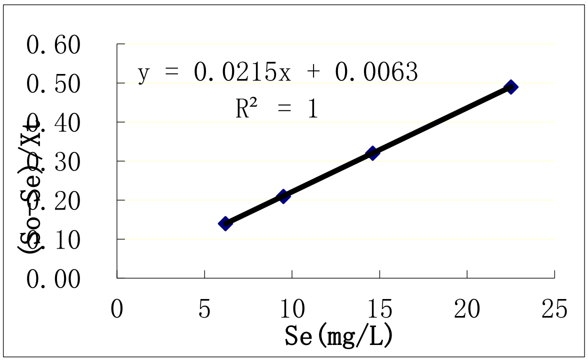

Fig. 5. Curve of substrate degradation and substrate concentration within oxygen consumption rate measurement.

Q·(So-Se)/Xv·V (sludge removal load)as the abscissa, *ΔX/Xv·V* as the ordinate, the curve of activated sludge growth within oxygen consumption rate measurement was shown as Figure 6. According to the formula *ΔX/Xv·V=Y·Q·(So-Se)/Xv·V-Kd*, the microbial yield coefficient of activated sludge was *Y=0.1315*, The self oxidation rate of activated sludge microorganisms was *Kd=-0.075*.

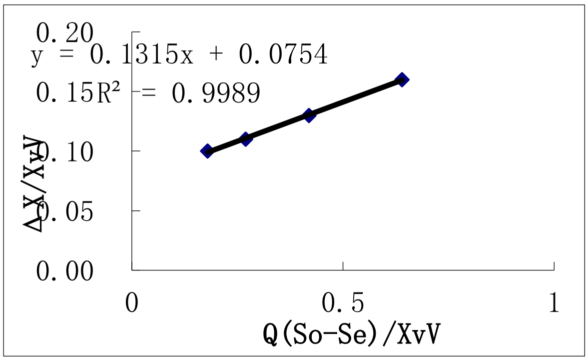

Fig. 6. Curve of activated sludge growth within oxygen consumption rate measurement.

1/Se as the abscissa, *(So-Se)/Xt* (sludge load) as the ordinate, the curve of substrate degradation curve within oxygen consumption rate measurement was shown as Figure 7. According to the formula *Xt/(So-Se)=Ks/Vmax·1/Se+1/Vmax*, *Ks/Vmax=45.210*, *1/Vmax=0.1356*. The maximum specific degradation rate of organic substrate was obtained *Vmax=11.257*, Saturation constant *Ks=3.954*.

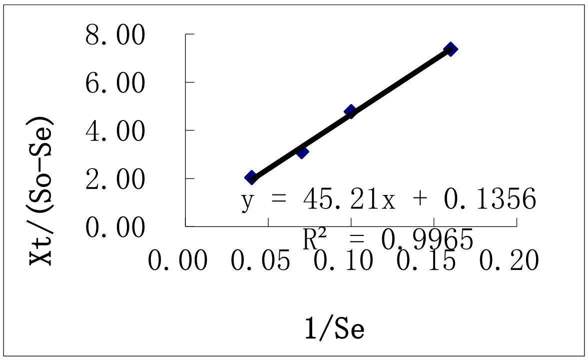

Fig. 7. Curve of substrate degradation curve within oxygen consumption rate measurement.

Q·(So-Se)/Xv·V as the abscissa, *O_2/Xv·V* as the ordinate, the curve of oxygen consumption rate was shown as Figure 8. According to the formula *O_2/Xv·V=a·Q·(So-Se)/Xv·V+b*, *a=0.4956*, *b=0.1029*.

Therefore, within oxygen consumption rate measurement, the biochemical reaction kinetic coefficient *K=0.022*, *Y=0.1315*, *Kd=-0.075*, *Vmax=11.257*, *Ks=3.954*, *a=0.4956*, *b=0.1029*.

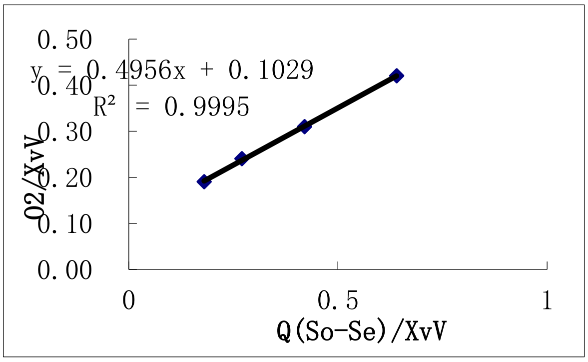

Fig. 8. Curve of oxygen consumption rate.

Discussion the relationship between substrate degradation rate and substrate concentration

In the Figure 9, without oxygen consumption rate measurement or within oxygen consumption rate measurement, the rate of substrate degradation was increased with the increase of substrate concentration. But as for the degradation rate, without oxygen consumption rate measurement was far less than within oxygen consumption rate measurement. In theory, without oxygen consumption rate measurement, the velocity should be larger. Analyzed the cause of this situation was that the MLSS sludge concentration had an influence on the organic matter degradation speed [17].

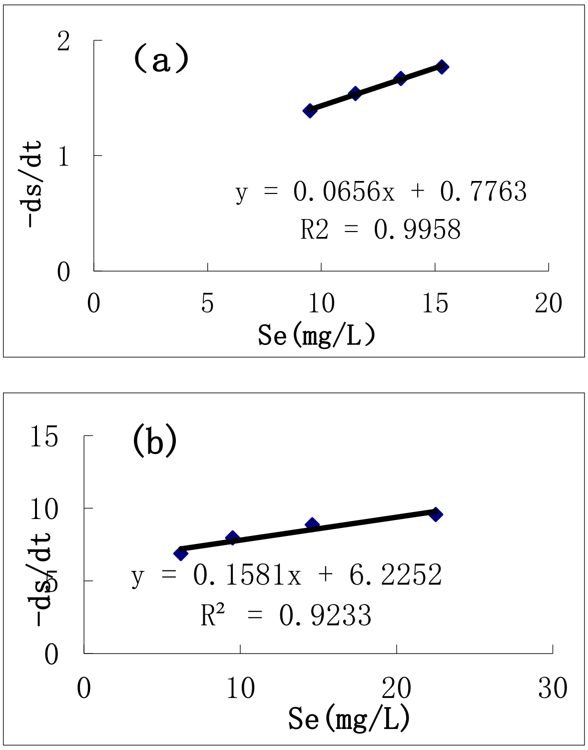

Fig. 9. The relationship between the substrate concentration and the degradation rate of the substrate without(a) and within (b) oxygen consumption rate measurement.

Discussion about the experiment from the relationship between microbial increment rate and substrate concentration

It can be seen from the Figure 10: when the oxygen consumption rate was not measured, the growth rate of activated sludge decreased with the increase of sludge removal load. But when the oxygen consumption rate was measured, the growth rate of activated sludge increased with the increase of sludge removal load. The causes of such differences was analyzed : when the concentration of organic matter in input water respectively was 100 mg/L, 125 mg/L, 150 mg/L, 175 mg/L, and the oxygen consumption rate was not measured, the sludge concentration MLSS respectively was 2481 mg/L, 2555 mg/L, 2629 mg/L, 2704 mg/L. But when the oxygen consumption rate was measured, the sludge concentration MLSS respectively was 3947 mg/L, 3145 mg/L, 2406 mg/L, 1765 mg/L. The sludge concentration was different so that the quantity of microorganism in the sludge also was different. The competition of the microorganism in the sludge to the organic matter and the dissolved oxygen had produced the above result [18].

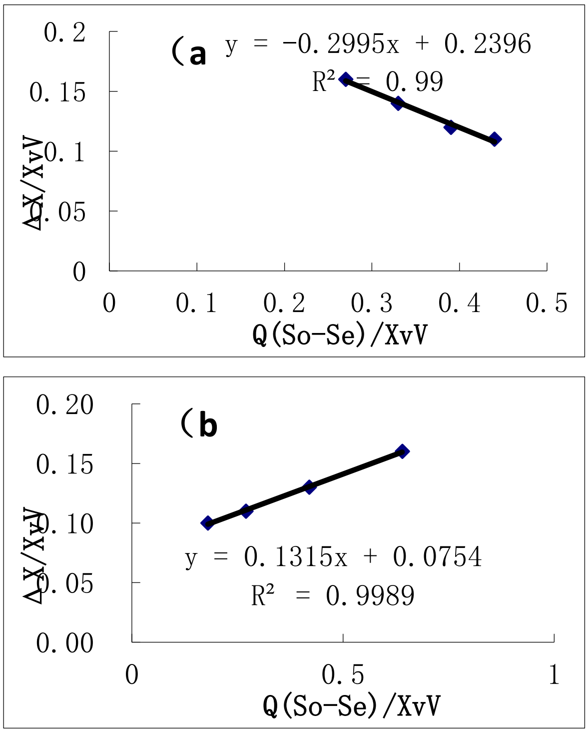

Fig. 10. Growth curves of activated sludge without(a) and within(b) oxygen consumption rate measurement.

Effect of control parameters on the system

Controlled the inlet flow rate Q, the air inflow O_2, dissolved oxygen concentration DO (2.01mg/L), the concentration of the inlet water BOD So(equal to 175mg/L) and sludge age SRT(14.29d) unchanged, and changed reflux ratio R, the relationship between reflux ratio and organic matter in water was shown in Table 2.

Table 2. The relationship between reflux ratio and organic matter in water.

Reflux ratio R(%)	20	30	40	50	60
Se (mg/L)	20.1	15.2	12.6	11.0	9.9

It can be seen from the date that the concentration of effluent BOD Se decreased with the increase of reflux ratio. Therefore, In other conditions remaining unchanged, increasing the reflux ratio can increase the degradation of organic matter [19]. The causes of the result was analyzed: Increasing the reflux ratio was equivalent to increasing the amount of sludge returned to the reactor, which increased the amount of microbes in the reactor. The amount of organic matter in the water was decreased because of the adsorption and ingestion of microorganism [20].

The inlet flow rate Q, the BOD concentration So (equal to 175mg/L) of input water and reflux ratio R (30%) were controlled to be unchanged, and the air flow was changed to change the concentration of dissolved oxygen DO. Then the following data were obtained in Table 3.

From the above data, it was concluded: increased the concentration of dissolved oxygen DO can reduce the concentration of organic matter so that the organic matter concentration can reach a higher standard, and changed the dissolved oxygen concentration DO can also make other parameters change in the treatment process. Increased O_2, the concentration of dissolved oxygen in the reaction pool increased. Increased the dissolved oxygen concentration satisfied the growth and reproduction of microorganisms for oxygen demand, made the microbial growth and reproduction have further consumption to organic matter. At the same time, it made the concentration of organic matter in water decreased gradually. Finally, higher emission standards was achieved [21].

Table 3. The relationship between dissolved oxygen and removal organic matter.

	1	2	3	4	5
Air input O_2	9000	10000	11000	12000	13000
Dissolved oxygen concentration DO (mg/L)	0.89	1.23	1.65	2.11	2.62
Effluent BOD Se (mg/L)	29.5	22.5	17.6	14.2	11.8
MLSS X (mg/L)	1281	1762	2322	2939	3591

Sludge age SRT (d)	10.38	14.29	18.84	23.84	29.13

CONCLUSIONS

The sludge age changed with the change of other parameters, but the single change of sludge age had no effect on the concentration of organic matter in the effluent. Substrate degradation rate increased with the increase of substrate concentration. When the oxygen consumption rate was measured or not measured, the quantity of sludge increased. Not only the concentration of organic matter had an effect on the increment of microbes, sludge concentration and dissolved oxygen and so on also played an important role in the increment of microbes. In addition, the demand for O2 increased with the increase of organic matter removal. Controlled the inlet flow rate Q, inlet water BOD so (equal to 175 mg/L) and sludge age SRT (14.29d) invariable, respectively changed reflux ratio R and the dissolved oxygen concentration DO (2.01mg/L). When the dissolved oxygen concentration DO (2.01 mg/L) was invariable, and the concentration of BOD So decreased with the increase of reflux ratio. When the reflux ratio of R (30%) was unchanged and changed the concentration of dissolved oxygen DO, and it was found that increased dissolved oxygen concentration DO can reduce the concentration of organic compounds. When reflux ratio was greater than 30% or when the concentration of DO was 1.65mg/L, the concentration of effluent BOD can reach the GB18918-2002 level B standard of ‘municipal wastewater treatment plant pollutant emission standard’.

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REFERENCES

1. J.Q. Li, C.Y. Guo, P.H. Fei, *ESIAT.*, **1**, 70 (2012).
2. S.M. Dong, *Jiangsu Univ*, 1 (2011).
3. S.J. Rui, *Agric. Sci. Technol. Inf.*, **20**, 39 (2015).
4. J.R. Zhang, *Biotechnol. World*., **12**, 19 (2015).
5. J. Wang, Q. Wang, J.Y. Chen, M.H. Luo, *Chin. Water. Waste Water*., **27**(19), 17 (2011).
6. Y.P. He, W.Y. Gao, J.B. Chen, *Res. Econ. Environ. Prot.*, **9**, 79 (2014).
7. Q. Ge, S.C. Zhou, D.H. Huang, *Chin. Water. Waste Water.*, **29**(7), 101 (2013).
8. H. Li. *Chin. Water. Waste Water.*, **26**(20), 154 (2010).
9. S. Siripong, B.E. Rittmann, *Water. Res.*, **5**, 1110 (2007).
10. L. Ying, A.J. Guo, Z. Jing, *CESCE Part B.*, **1**, 334 (2011).
11. X.D. Li, J.P. Qiu, X.J. He, Y.Q. Xiao, *Water. Purif. Technol.*, **27**(4), 36 (2008).
12. Y.Q. Dai, *Shanghai Jiao Tong Univ*, 1 (2010).
13. J.Z. Jiang, M.Y. Xing, J. Yang, *Chin. Water. Waste Water.*, **30**(15), 6 (2014).
14. Y.D. Zheng, Y.F. Lu, A.F. Wu, *Chin. Water. Waste Water*, **32**(3), 1 (2016).
15. J.Z. Li, X.Z. Luo, Z. Zhen, D.H. Su, *Environ. Pollut. Control.*, **12**, 11 (2008).
16. Y.L. Guo, B. Meng, S. Wang, *Chin. J. Environ. Engin.*, **8**(2), 729 (2014).
17. M. Juan, P.C. Yao, W. Li, *Water. Sci. Technol.*, **61**(9), 2325 (2010).
18. Y.Y. Wang, Z.X. Zhang, M. Yan, *CAST, J. Environ. Sci. Health*, **45**(3), 370 (2010).
19. B.P. Mcnicholl, J.W. Mcgrath, J.P. Quinn. *Water. Res.*, **41**(1), 127 (2007).
20. T. Mino, MCMV. Loosdrecht, J.J. Heijnen, *Water. Res.*, **32**(11), 3193 (1998).
21. J. Yang, D.H. Yi, L.M. Zhao, *Chin. Environ. Sci.*, **28**(10), 892 (2008).

ПРОУЧВАНЕ НА НОВА ТЕХНОЛОГИЯ ЗА ОБРАБОТКА НА СЕЛСКИ БИТОВИ ОТПАДНИ ВОДИ НА БАЗАТА НА CASS И VBF

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(Резюме)

Статията има за изследван обект типични селски битовофекални води от околните квартали и райони на Ченду като обект. Беше избран комбиниран процес на циклична система с активна утайка (CASS) и вермибиофилтър (VBF). За да се симулира процеса и да се направи систематичен анализ на свързаните влияещи фактори, условията за контрол, операционния механизъм на селски битови отпадни води и т. н. беше използван компютър, Контролиран входящия на водния поток Q, концентрацията на БПК на входящата вода S_0 (175 мг / л) и възрастта на утайките SRT (14.29 г) са без промяна, съответно се променя съотношението рефлукс R и концентрация на разтворен кислород, и беше постигнато концентрацията на БПК на отпадъчните води да достигне стандарта за заустване на замърсители на GB18918-2002 клас B на градската станция за пречистване на отпадъчни води.