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Research and application of anaerobic baffled reactor (ABR) in China

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Abstract: The principles and characteristics of anaerobic baffled reactor (ABR) are reviewed and the research progress on application of ABR for wastewater treatment in China was summarized. ABR, a kind of the third generation of reactors based on the theory of staged multi-phase anaerobic reactor (SMPA), can be described as a series of UASBs, but tend to be plug flow as a whole. It has notable advantages such as simple design, reduced sludge bed expansion, low sludge generation, extremely stable to hydraulic shock loads, protection from toxic materials in influent, long operation times without sludge wasting, high stability to organic shocks and so on. Focusing on treating wastewater with low strength and high strength as well as combining ABR with other wastewater treatment processes, the treatment efficiency and applications of ABR are analyzed. It turns out that ABR has a high removal rate for treating low strength wastewater at middle or low temperature and especially is superior to UASB in the respect of HRT and temperature requirements. Treating high strength wastewater, the COD removal rate of ABR may even reach above 95%. Besides, ABR may be applied to treat domestic wastewater and complicated industry wastewater combined with other treatment progresses. Based on this, the research orientation and prospect are discussed.

Keywords: Anaerobic baffled reactor, Treatment efficiency, Operational performance.

1. INTRODUCTION

Anaerobic biological treatment technology artificially control and strengthen microbial processes commonly existed in nature, transforming organic matter into inorganic matter and a spot of cellular materials without providing oxygen [Lettinga et al. 1997]. The main reactor of anaerobic biological treatment technology was developed in three stages: the first generation of reactors represented by anaerobic digester; the second generation of reactors represented by upflow anaerobic sludge blanket (UASB); the third generation of reactors represented by expanded granular sludge bed (EGSB) [Sun et al. 2003].

ABR, a kind of the third generation of reactors based on the theory of SMPA, was initially developed from anaerobic rotating biological contactor by McCarty and coworkers at Stanford. Around the same time as Lettinga developed the UASB, McCarty and co-workers at Stanford noticed that most of the biomass present within an anaerobic rotating biological contactor was actually suspended, and when they removed the rotating discs they developed the ABR. However, baffled reactor units had previously been used to generate a methane rich biogas as an energy source. ABR has advantages over other systems as the researches and applications show [Bachmann et al. 1985]. In the early 90s, ABR was introduced into China and draw lots of attention.

2. PRINCIPLE AND STRUCTURE OF ABR

Figure 1 shows the structure of ABR. In structural terms, several vertical baffles divide the reactor into tandem compartments, each of which is a relatively independent UASB [Barber et al. 1999]. A series of bafflers force the wastewater containing organic pollutants to flow under and over the baffles as it passes from the inlet to the outlet. Bacteria within the reactor gently rise and settle due to flow characteristics and gas production in each compartment, but move horizontally down the reactor at a relatively slow rate giving rise to cell retention time (CRT) of 100 d at 20h hydraulic retention time (HRT). Therefore, the wastewater can come into intimate contact with a large amount of active biomass as it passes through the ABR with short HRTs (6~20 h), while the effluent remains relatively free of biological solids [Wang et al. 2004]. As a result, ABR can be described as a series of UASBs, but tend to be plug flow as a whole [Liu et al. 2010].

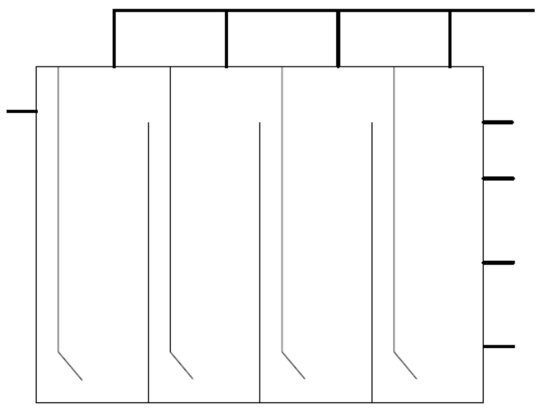

Fig.1 Structural representation of ABR

The two outstanding features of ABR are: (1) Due to baffles and gas production, the flow is completely mixed-flow in each compartment, but is plug-flow as a whole reactor. (2) The separation of acidification phase and methanation phase supplies corresponding suitable environment for the advanced microbial community in each compartment. Therefore, ABR has advantages over other systems as Table 1 shows [Barber et al. 1999].

Tab.1. Advantages associated with the ABR

	Advantages
Construction	1. Simple design 2. No moving parts 3. No mechanical mixing 4. Inexpensive to construct 5. High void volume 6. Reduced clogging 7. Reduced sludge bed expansion 8. Low capital and operating costs
Biomass	1. No requirement for biomass with unusual settling properties 2. Low sludge generation 3. High solids retention times 4. Retention of biomass without fixed media or a solid-settling chamber 5. No special gas or sludge separation required
Operation	1. Low HRT 2. Intermittent operation possible 3. Extremely stable to hydraulic shock loads 4. Protection from toxic materials in influent 5. Long operation times without sludge wasting 6. High stability to organic shocks

3. APPLICATION OF ABR

3.1 TREATING LOW STRENGTH WASTEWATER BY ABR

Recently, there are more and more researches on treating low strength wastewater using ABR in China. These researches show that ABR has a high removal rate for treating low strength wastewater at middle or low temperature and especially is superior to UASB in respect of HRT and temperature requirements [Gopala Krishna et al. 2009].

Xin, X. *et al.* did researches on the performance of ABR treating domestic wastewater at 35 ℃. The initial starting-up process of ABR was only 39 d and the COD removal rate was kept about 60%. When HRT was 4~10 h and volume rate loading (VRL) was 1.17~2.9 kgCOD/m^3 ·d, the average COD removal rate was 70.49%~80.2%. When HRT was 7 h and VRL was 1. 612 kgCOD /m^3 ·d, the average COD removal rate was 80.2% [Xin etc al. 2005].

Shen, Y. *et al.* also got high treatment efficiency treating low strength wastewater by ABR. The results showed that 50%, 80%~87%, 86%~92% and 90%~95% of COD removal rate could be obtained with effluent COD concentration of 70~90 mg/L under the condition of 35±0.5 ℃, organic loading rate (OLR) of 0.5~7.0 kgCOD/m^3·d and HRT of 3~12 h [Shen et al. 2004].

Liu, D. *et al.* did research on treating domestic wastewater by ABR. The effluent COD concentration conformed to the national standard under the condition of 8~20 ℃ and HRT of 8 h. The results showed that good treatment efficiency was obtained under the condition of

18 ℃ and HRT of 6~10 h, being superior to UASB requiring the condition of 20 ℃ and HRT of 13-15 h [Liu et al. 2003].

Treating domestic wastewater, ABR should be combined with other process unit to ensure that the effluent COD, nitrogen and phosphorus concentration may meet wastewater-discharging standard. Besides, in practical applications, higher biomass than that in lab or adding carriers may be adopted at the starting-up progress, for guaranteeing the intimate contact between microbes and substrate and shrinking dead space [Peng et al. 2013].

3.2 TREATING HIGH STRENGTH WASTEWATER BY ABR

As having the characteristics of strong ability to resist impact load and biphase separation, ABR performs effectively in treating high strength complicated wastewater. It turns out that the COD removal rate of ABR may reach above 95% when treating high strength wastewater.

Shen, Y. *et al.* studied on the operational performance of ABR treating starch wastewater. The results showed that the average COD removal rate were above 90%, even reaching the top of 98.5%, under the conditions of 35±0.5 ℃, OLR of 10~20 $kg/m^3 \cdot d$ and HRT of 12~24 h [Shen et al. 2002].

Li, Q. *et al.* investigated the performance of ABR for treating synthetic high strength sulfate wastewater. The results showed that under the conditions of 33. 2±0.1 ℃, HRT of 20~24 h, COD of 5000 mg/L and SO_4^{2-} of 300-1500 mg/L, the COD removal rate was above 90% and SO_4^{2-} reduction rate was about 96%. The limiting concentration of SO_4^{2-} for ABR is 2000 mg/L [Li et al. 2007; Wang et al. 2012].

Ye, B. *et al.* established a pilot scale anaerobic baffled regulation pool for leachate per-treatment at a transfer station. Under the conditions of the influent COD concentration of 50000~80000 mg/L, the effluent COD was about 25000 mg/L stably; the TN removal rate was 30%~40%; the TP removal rate was 70%. It turned out that ABR had good impact resistance and stable operational performance under low pH [Ye et al. 2012].

Besides, Huang, R. *et al.* did researches on the performance of ABR treating printing and dyeing wastewater; Zheng, L. *et al.*, landfill leachate; Hu, C. *et al.*, catering wastewater; Cao, X. *et al.*, pesticide wastewater; Luo, Y., beet sugar wastewater. All of them got high removal efficiency [Hu et al. 2007; Zheng et al. 2009; Huang et al. 2010; Cao et al. 2004; Luo et al. 2007].

3.3 COMBINING ABR WITH OTHER WASTEWATER TREATMENT PROCESSES

In view of practical application, the combinations of ABR and other wastewater treatment processes are drawing more and more attentions.

Li, J. *et al.* studied on the COD removal characteristics of combined anaerobic baffled reactor-corridor constructed wetland (CABR-CCW) for domestic wastewater treatment. The results showed that the total COD removal rate was 78.9% in summer and autumn and 56.6%

in winter under the condition that HRT of CABR was 20 h and HRT of CCW was 30 h. Besides, the data revealed that about 60% of the removal of COD depended on CABR, while the contribution of CCW was just about 30%, even lower in winter. But the removal of nitrogen and phosphorus mainly depended on CCW [Li et al. 2007]. Zhao, D. *et al.* optimized the process conditions of the combined process of ABR and constructed wetland treating domestic sewage. The optimized result showed that, with the HRT for ABR was 12 h, the average COD removal rate was 76%. While with the HRT for constructed wetland was 4 d, the total COD removal rate of the combined process showed excellent removal rate with COD 89%, SS above 95% and ammonia nitrogen 66. 8%. These results may provide useful information to the potential applications of the combined process of ABR and constructed wetland for sewage treatment at rural areas [Zhao et al. 2011].

Zhang, B. *et al.* studied on the performance of the process of ABR combined with bio-contact oxidation treating domestic wastewater at low temperature of 14 ℃. The Optimum condition of process was the HRT of 20 h (15 h for ABR, 5 h for bio-contact oxidation), under which the average COD removal rate was 81.0%, SS 95.8% and TN only 64.7% [Zhang et al 2012]. The study on the performance of the process of ABR combined with bio-contact oxidation treating domestic wastewater at (35±1) ℃ by Yuan, H. *et al.* showed that the total COD removal rate reached 98% with the HRT of 4 h. ABR contributed about 92%, removing major COD [Yuan et al. 2012]. Besides, the process of anaerobic baffled tank-biological contact oxidation-coagulating precipitation-sand filter was selected to treat towel printing and dyeing wastewater of Qiaosheng textile printing and dyeing co., LTD in the city of Changle, Fujian Province. All the indexes of effluent meet Class One wastewater-discharging standard.

Wu, P. *et al.* applied the combined progress of ABR and membrane bioreactor reactor (MBR) to treat municipal wastewater got the COD removal rate of 91% [Wu et al 2012]. Su, D. *et al.* applied the combined pilot-test progress of ABR and biological aerated filter (BAF) to treat oil-field wastewater, the effluent could meet Class Two of wastewater-discharging standard (GB 18918-2002) [Su et al. 2006].

In practical application, Wu, Y. *et al.* used the combined progress of ABR, integrated aerobic reactor and vertical flow constructed wetland to treat tie-dyeing wastewater in National handicraft factory Weishan Dali. The indexes of effluent meet Class One-B of wastewater-discharging standard (GB 18918-2002). The system operated stably [Wu et al. 2009].

The researches show good treatment performance of the combined progresses, to which ABR contributes mainly. It turns out that ABR may be applied to treat domestic wastewater and complicated industry wastewater combined with other treatment progresses.

4. CONCLUSIONS

At present, there are lots of researches on ABR in fields of starting-up, sludge characteristics, HRT and so on. ABR has showed its superiors, including stronger ability resisting impact load, better butter effect on toxic substance and inhibitory substance and higher economic efficiency especially at normal or low temperature [Wu et al. 2012].

The research orientation of ABR in the future may be concluded as: (1) Optimize operating parameters (HRT, OLR, SRT, F/M and so on) to improve sludge characteristic and treatment performance; (2) Study on the economical efficiency (especially operation cost) and the feasibility of intermittent operation; (3) Remove nitrogen and phosphorus further by combing with aerobic processes.

REFERENCES

Barber, W. P. & Stuckey, D. C. 1999 The use of the anaerobic baffled reactor (ABR) for wastewater treatment: a review. Water Research, 33(7):1559-1578.

Cao, X. & Shen, Y. 2004 Glyphosate-paroducing wastewater and its treament technology. Pollution Control Technology, 16(04):38-40.

Gopala Krishna, G.V.T., Kumar, P. & Kumar, P. 2009 Treatment of low-strength soluble wastewater using an anaerobic baffled reactor (ABR). Journal of Environmental Management, 90(1):166-176.

Huang, R., Liu, X., Huang, C. & Zhou, H. 2010 Experiment study on the treatment of printing and dyeing wastewater by hybrid anaerobic baffled reactor. Environmental Engineering, 28(06):11-15.

Hu, C. & Yin, D. 2007 Treatment for restaurant wastewater with anaerobic baffled reactor(ABR). Industriai Safety and Environmentai Protection, 33(09):28-31.

Lettinga, G., Field, J., Van Lier, J.& Zeeman, G. 1997 Advanced anaerobic wastewater treatment in the near future. Water Science and Technology Advanced wastewater treatment: Nutrient removal and anaerobic processes Selected Proceedings of the IAWQ International Conference on Advanced WastewaterTreatment: Nutrient Removal and Anaerobic Processes (AQUATECH 96), 35(10):5-12.

Li, J., Zhang, K., Zhang, H. & Li, Y. 2007 COD removal characteristics of combined anaerobic baffled reactor-corridor constructed wetland system for domestic wastewater treatment. The second national academic conference on the science of agricultura and environment, 566-569.

Li, Q., Fan, C., Li, L., Song, S. & Teng, H. 2007 Performance of anaerobic baffled reactor for treatment of high strength sulfate wastewater. China Water & Wastewater, 23(15):47-50.

Liu, D., Bi, Y., Li, Q., Guo, L., Zhang, Y. & Liu, X. 2003 Treatment of domestic wastewater by anaerobic baffled reactor (ABR). Journal of Central China Normal University (Nat. Sci.), 37(4):514-517.

Liu, M. & Yang, X. 2010 Research and application of anaerobic baffled reactor for wastewater treatment.Industrial Water & Wastewater, 41(3) :5-8.

Luo, Y. 2007 Treatment of high-strength industrial wastewater with anaerobic baffled reactor (ABR). Beijing Forestry University.

Peng, J., Song, Y., Wang, Y., Yuan, P. & Liu, R. 2013 Spatial succession and metabolic properties of functional microbial communities in an anaerobic baffled reactor. International Biodeterioration & Biodegradation, 80:60-65.

Shen, Y., Sun, L., Guan, W. & Ye, F. 2004 Treatment of low strength wastewater by anaerobic baffled reactor (ABR). Jiangsu Environmental Science and Technology, 17(4):1-2.

Shen, Y., Zhao, D. & Wang, H. 2002 Studies on the performance of an anaerobic baffled reactor for starch wastewater. Water & Wastewater Engineering, 28(09):33-36.

Su, D., Wang, J., Huang, Y. & Zhou D. 2006 ABR and BAF for treating oil-field wastewater: a pilot study. China Water & Wastewater, 22(01):2024-2027.

Sun, L. & Guan, X. 2003 Review and prospect of anaerobic baffled reactor. Journal of Qingdao Institute of Architecture and Engineering, 24(4):82-85.

Wang, X., Zhang, Y. & yang, D. 2012 Studies on the performance of anaerobic baffled reactor for treating high strength sulfate wastewater. Science & Technology Association Forum, 10.

Wu, P., Ji, X. & Shen, Y. 2012 Start-up of combined ABR and MBR system for treating municipal wastewater. China Water & Wastewater, 28(11):18-21.

Wu, P. & Shen, Y. 2012 Application and prospect of anaerobic biological treatment technology. Shanghai Environmental Sciences, 31(01):28-33.

Wu, Y., Lv, X., Zhu, G., Deng, J. & Shi, J. 2009 Research on tie-dyeing wastewater treatment using anaerobic baffled reactor/biofilter/constructed wetland. China Water & Wastewater, 25(22):69-72.

Xin, X., Hu, X. & Cai, H. 2005 Performance of anaerobic baffled reactor treating domestic wa stewater. Techniques and Equipment for Environmental Pollution Control, 6(10):41-44.

Ye, B., Jiang, J., Chen, A. & Wu, J. 2012 Per-treatment of transfer station wastewater by anaerobic baffled regulation pool: A pilot scale research. Chinese Journal of Environmental Engineering, 6(09):2981-2984.

Yuan, H., Peng, C. & Wang, Z. 2012 Treatment of rural sewage using an anaerobic baffled reactor combined with biological contact oxidation process. Technology of Water Treatment, 38(04):91-103.

Zhang, B., Li, Y., Wang, K. & Li, K. 2012 Study on the treatment of domestic wastewater by anerobic baffled reactor/bio-contact oxidation combination process. Enviromental Pollution & Control, 34(08):21-25.

Zhao, D. & Du, J. 2011 Treatment of domestic sewage with integrated ABR and constructed wetland process. Journal of Anhui University (Natural Science Edition), 35(01):97-101.

Zheng, L., Chen, Z., Fang, W., Lin, P., Qiu, F. & Sun, G. 2009 Study on treatment of landfill leachate and its granular sludge with ABR. Journal of Anhui Agri Sci, 37(14):6577-6580.