Treatment of coke plant wastewater by A/O fixed biofilm system

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Abstract Coke plant wastewater was treated by an anaerobic–aerobic (A/O) biofilm system. A lab-scale experiment, during which semi-soft media were packed in both the anaerobic and the aerobic reactors, was carried out. The influence parameters, such as HRT, C/N ratio, OLR, and the recycling flow rate on the performance of the system, were studied. The results showed that a sufficient carbon source was important to the performance of bio-degradation system. The COD removal rate increased from 64.15% to 83.28% by raising C/N in wastewater from 2.5 (no external carbon source) to 5. But the effluent COD concentration was still a little higher than the discharge standard. In order to make it meet the discharge standard, a deep treatment, coagulation, was applied, which was proved as an effective method. Then the effluent COD concentration can be brought to lower than 200 mg·L⁻¹. The NH₄-N removal rate in this system was satisfactory, being higher than 99%. In addition, it was almost not affected by both C/N ratio and coagulation treatment. The results show that the system is feasible to treat coke plant wastewater.

Keywords: coke plant wastewater, fixed biofilm, ammonia nitrogen, COD, HRT, OLR.

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The long-term environmental impacts of wastewater from coke plant can be very high, especially due to the discharge of large amounts of wastewater. The composition of coke plant wastewater is complicated and varies from one factory to another, depending on the quality of raw coal, carbonation temperature, and the method used for by-products recovery. The wastewater contains ammonia, thiocyanate, phenolics and other organic compounds, such as mono- and poly-cyclic nitrogen-containing aromatics, oxygen- and sulfur-containing heterocycles and polynuclear aromatic hydrocarbons (PAHs)\(^1\text{–}^4\). These wastewaters are very harmful due to their high ammonia content and the presence of inhibitory or toxic organic compounds. Most of the heterocyclic compounds and PAHs have been reported to be mutagenic and even carcinogenic\(^5\text{,}^6\). There are many coke plants throughout China because coal is the main energy source. It is therefore necessary to remove these substances from coke plant wastewaters to reduce their harmful effect on the environment.

The biological wastewater treatment systems, including the conventional activated sludge system, fluidized bed, and fixed biofilm system, are developed rapidly in recent years. A conventional activated sludge system is inefficient in removing chemical oxygen demand (COD) and high concentration of nitrogen because of the presence of refractory and
biologically inhibitory organic compounds such as PAHs and nitrogenous heterocyclic compounds in coke plant wastewater\cite{7}. In addition, the activated sludge system is characterized by relatively high-energy consumption and biomass production, leading to relatively high operation costs and problems with the disposal of large amounts of sludge (incineration, seasonal variations in demand for it as a fertilizer). The suspended growth system is ineffective to remove nitrogen from coke plant wastewater mainly because it is difficult to retain nitrifying bacteria, which reproduce themselves much slower than heterotrophic bacteria in the aeration basin\cite{8}. So, the major problem to take into account is longer residence time for biodegradation bacteria. At present, the fluidized bed system is suitable only for the lab-scale experiment. That is to say, it is very difficult to be bio-augmented.

In recent years, extensive work has demonstrated that the anaerobic-aerobic (A/O) system is an efficient and cost-effective method for the removal of nitrogen and organics. With the development of new packing media, the fixed growth system has been receiving more attention since the 1980s for biological nitrogen control\cite{4,7,9-11}. The main advantage of it is to maintain a large number of nitrifying bacteria in the system by attaching bacteria onto packing media. Therefore, the nitrification performance can be enhanced. In these previous studies, relative few combined the two methods. Here packing media were used in both reactors.

The objective of this study was to investigate the feasibility of a fixed growth system for the removal of COD and nitrogen from coke plant wastewater. The major parameters affecting the efficiency of biofilm system, which include chemical nature of wastewater, hydraulic retention time (HRT), organic loading rate (OLR) and recycling flow rate ($R$), etc., were investigated. The optimum conditions were selected.

1 Materials and methods

Lab-scale experiments were conducted to study the efficiency of the A/O biofilm systems for the degradation of organics and removal of nitrogen. The experimental set-up is shown in Fig. 1. The dimension of the anaerobic reactor was $\Phi 20 \times 80$ cm, and the effective volume was adjustable, 4.22, 5.63 and 7.03 L respectively. The dimension of the aerobic reactor was $\Phi 20 \times 120$ cm, and the effective volume was also adjustable, 6.75, 9.01 and 11.25 L respectively. Because microorganisms activity was limited by their period, a sedimentation tank was applied in order to recycle sludge and to discharge water with better quality. Otherwise, the dropped inactive microorganisms might bring the effluent COD very high. The volume of sedimentation tank was 4 L. Not only anaerobic but also aerobic reactors were packed with semi-soft media, which were recently studied by Li\cite{7} and Zhang et al. (2011).