

# Research on System Optimizing of AAO-BAF Wastewater Treatment Process

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**Abstract.** To meet the more strict discharging standard, some combined processes have emerged to realize denitrification and phosphorus removal of wastewater more efficiently. Among them, AAO-BAF combined process was an efficient one. The AAO-BAF system was composed of AAO reactor and BAF. The AAO process was the main unit to complete phosphorus removal and denitrification. The BAF process, external nitrification unit, was mainly used to provide enough electron acceptor for denitrifying bacteria in AAO reactor, which could enhance the efficiency of denitrification of the whole system. So the system optimizing was essential to AAO-BAF combined process. In this paper, the research progress of AAO-BAF wastewater treatment system was summarized and some system optimizing methods were raised too.

## 1 Introduction

The AAO-BAF combination system is a double sludge system. The nitrification reaction mainly occurs in the BAF process. The nitrifying bacteria are solid-film growth, providing electron acceptor nitrate nitrogen for the anoxic phosphorus uptake in AAO. Denitrifying bacteria and denitrifying phosphorus accumulating bacteria are grown in the AAO system by suspending sludge. By maintaining a short sludge age, the nitrifying bacteria can be washed and removed in time, which is beneficial to promote phosphorus removal and denitrification. The separation of the two processes solves the competitive contradiction between the polyphosphate bacteria and the nitrifying bacteria in the traditional process. They can grow in their respective environments, which is more conducive to the stability and high efficiency of the phosphorus removal and denitrification systems. As the country's sewage discharge standards become more stringent, the problems of traditional biological nitrogen and phosphorus removal processes have become increasingly prominent. The combination system of AAO-BAF came into being under such a background. However, as a combined system, the system optimization is especially important for improving the efficiency of nitrogen and phosphorus removal, which is the key to ensuring the effluent compliance. Therefore, this paper studies this.

## 2 Overview of the AAO-BAF system

### 2.1 AAO process

The most widely used nitrogen and phosphorus removal process in the world is the AAO process. The process

can be called the simplest synchronous nitrogen and phosphorus removal process on the system, and the total HRT is less than other similar processes. Under the conditions of anaerobic, anoxic and aerobic alternate operation, the filamentous bacteria cannot proliferate in a large amount. It is not easy to cause sludge expansion, and the SVI is generally less than 100. The concentration of phosphorus in the sludge is high, and it has high fertilizer efficiency. It doesn't need to apply medicine during operation, and the anaerobic tank and the anoxic tank should only be gently stirred to increase the dissolution. For the purpose of oxygen, the operating cost is low. At the same time, the AAO process also has many shortcomings, such as the sludge age's contradiction, sludge backflow problem, contradiction between nitrification and denitrification and organic matter degradation, and insufficient carbon source, etc.[1]

### 2.2 BAF process

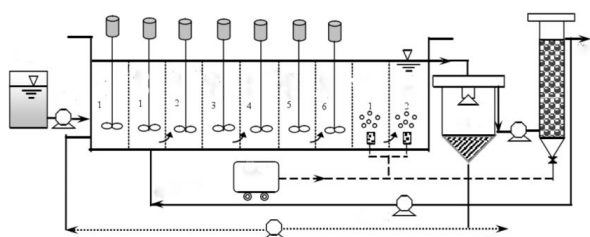
Biological Aerated Filter (BAF) is a new type of biological treatment technology with rapid development. It has the advantages of small footprint, high effluent quality, low investment, flexible operation, easy management, and strong impact load resistance. It can be used not only for secondary and tertiary treatment of sewage, but also for pretreatment of micro-polluted source water. The BAF reactor is mainly composed of a granular bio-filler bed, an aeration system and a backwashing system. The BAF process combines sewage biological treatment with deep filtration, which fully reflects the trend of modern water treatment technology to composite and integrated development. In recent years, the BAF process has developed rapidly, and many experts and scholars have developed various forms of biological aerated filters. At the same time, there are still

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many shortcomings in the BAF process, such as high SS requirements for influent water, frequent backwashing, and poor biological phosphorus removal.

## 2.3 AAO-BAF system

At present, domestic sewage with low C/N ratio is widespread in China. In view of the shortcomings of the above two processes, many experts, combine the above two processes to form the AAO-BAF system. The AAO-BAF system is shown in Figure 1.



**Fig.1.** Flow chart of AAO-BAF system

The principle of the AAO-BAF system is: the AAO process consists of an anaerobic section, an anoxic section and an aerobic section. The HRT of the AAO segment is very short. In addition to the absorption of the easily degradable organic matter remaining in the sewage, the polyphosphate bacteria mainly rely on the PHB stored in the body to generate energy to grow and reproduce themselves, and actively absorb the dissolved phosphorus in the environment. The form of polyphosphate is stored in the body. By adopting a higher sludge load and a shorter sludge age, the nitrification reaction does not occur in this section, and it is suitable for the growth of polyphosphate bacteria, and the phosphorus removal effect is improved. In the anaerobic and anoxic sections, most of the organic matter is separately phosphorized. The bacteria and denitrifying bacteria are removed by use. An important innovation of the AAO-BAF system is to set up the nitrification of ammonia nitrogen in the BAF system, thus completely separating the denitrification and phosphorus removal processes, and solving the main contradiction between the mutual interference and inhibition of the nitrogen and phosphorus removal processes in the traditional process. Due to the low content of organic matter in the effluent of the AAO system, the concentration of nitrifying bacteria in the BAF system is increased, and the nitrifying bacteria greatly enhances the nitrification effect due to the obligate aerobic state.

The AAO-BAF process integrates the advantages of AAO and BAF. By shortening the sludge age, the nitrification process is separated from the AAO, and the nitrification is achieved by BAF. The AAO is operated under the condition of short sludge age, and the phosphorus removal and denitrification effects are good. The characteristics of BAF under long sludge age conditions are conducive to the stability of nitrification and the complete removal of ammonia nitrogen; the nitrated liquid from BAF provides sufficient electron acceptor for the anoxic section of AAO, which is

denitrifying phosphorus removal. Conditions are provided. Therefore, it is important to explore the optimization of AAO-BAF system for improve the nitrogen and phosphorus removal efficiency of the combined process.

## 3 The research on start-up of AAO-BAF system

### 3.1 The start-up of the BAF

The forming biofilm is the process of culturing and acclimating the membranous microorganisms in the biofilm treatment system, and the metabolic sludge microbial sludge is fixed and grown on the filter material in the water treatment system. Li et al. [2] used a sewage containing certain nutrient solution to start the natural start-up of BAF. It is believed that the change of PH value of the influent and the water can judge whether the film is successful or not, and divide the filming process into adaptation stage, rapid growth stage and stable stage. The filter material is also an important part of the aerated biological filter. The difference of the filter material determines the operation mode of the BAF. Li et al. [3] on the membrane start-up of zeolite aerated biofilters suggested that the nitrification removal rate of ammonia nitrogen can be stabilized as a sign of membrane maturation, and nitrifying bacteria have a biological regeneration function on zeolite.

In the AAO-BAF system, the start-up of the BAF is different from the start-up when the BAF is used for water treatment alone. To exert the nitrification of BAF, a stable biofilm must be formed on the filler. The rapid start-up of the AAO-BAF process will involve the domestication and cultivation of two sludge systems. The BAF should be started separately, and then the AAO and BAF can be connected to successfully start the dual sludge system. Chen et al. [4] used the composite start-up combined with the fast mud-laying start-up and the natural start-up to start up the BAF unit in the AAO-BAF process. He found that the proliferation rate of the start-up nitrifying bacteria was faster than that of the general start-up, and the removal rates of  $\text{NH}_4\text{-N}$ , COD, and TP were high. In the AAO-BAF system, the type of influent water is also important for the BAF unit to form biofilm quickly. Wang et al. [5] used the artificial preparation of two different influent waters containing ammonia-containing organic matter-free water and actual domestic sewage for the start-up of the BAF in the AAO-BAF system. He found that BAF, which contains no organic matter in the water, started faster.

### 3.2 The start-up of the AAO-BAF system

The start-up of the AAO-BAF system means that when the BAF is successfully foremed into biofilm, it is connected to the AAO and continuously operated with the domestic sewage. Chen et al. [6] used the organic-free water distribution to start up the BAF, and then connected the two reactors with the domestic sewage as

raw water. The COD removal rate was relatively stable. The removal rate of P is not high at the beginning of the operation but the removal rate is almost 100% at the end. This is because the nitrification in AAO causes the return sludge to contain a large amount of nitrate nitrogen, which destroys the anaerobic environment of the anaerobic section. With the operation of the system, the biofilm in BAF already has good nitrification ability. Therefore, the polyphosphate bacteria have sufficient carbon source, the phosphorus release rate is increasing, and the phosphorus removal rate is continuously increased. Wang et al. [7] started up the AAO-BAF system using a low C/N ratio. It was found that phosphorus was mainly removed by denitrifying phosphorus removal during the process of low C/N ratio initiation. This can save the volume of the aerobic zone and reduce the amount of aeration. Zhang et al. [8] conducted a second start-up test on the AAO-BAF system that was suspended for one month, and studied the operational characteristics of AAO's different volume ratio starting modes. It is considered that the one-month shutdown has little effect on the performance of the AAO-BAF system except for organic matter and ammonia nitrogen. In the AAO reactor, the volume ratio of anaerobic, anoxic and aerobic zone is 2:5:2, which is more conducive to the recovery of phosphorus removal performance and sludge settling performance of AAO-BAF system. The AAO-BAF system has good nitrogen and phosphorus removal efficiency. In the startup phase of the system, the COD removal rate can reach 80%, the  $\text{NH}_4\text{-N}$  and TP removal rate can reach 100%, and the TN removal rate can reach more than 65%.

## 4 The research on AAO-BAF optimal operation condition

### 4.1 Optimum volume ratio of anaerobic section, anoxic section and aerobic section in AAO

In order to achieve the purpose of deep nitrogen and phosphorus removal, it is necessary to realize denitrifying phosphorus removal in the AAO process section. Peng et al. [9] used the domestic sewage with a C/N ratio of 3.21 as the influent of the AAO-BAF system. It was found that the nitrogen and phosphorus removal efficiency of the system was the best when the volume ratio of each area of the AAO process was 3:4:2. Because the larger the volume of anaerobic zone, the more sufficient the phosphorus release effect of polyphosphate bacteria, the larger the volume of anoxic zone, the more obvious the denitrifying phosphorus removal effect. Li et al. [10] studied the difference in sludge settling between AAO-BAF and AAO processes in treating higher C/N ratio domestic sewage. The volume ratio of AAO process section of combined system is 2:5:2, while the volume ratio of AAO process is 2:3:4. The SVI of the AAO-BAF system was changed to about 80, and there was no concern about sludge expansion. Chen et al. [6] studied the removal of nitrogen and phosphorus in the volume ratios of AAO segments: 1:2:6, 2:3:4 and 1:6:2. He believes that the system's

denitrifying phosphorus removal is at its best when the volume ratio is 1:6:2. This is because the volume of the anoxic section increases, the HRT of the anoxic section increases, which is beneficial to increase the proportion of denitrifying phosphorus removal bacteria in the polyphosphate bacteria, thereby increasing the removal rate of organic matter, nitrogen and phosphorus. When the aerobic section volume is reduced, the growth of nitrifying bacteria is inhibited, which is beneficial to the subsequent nitrification reaction in BAF.

### 4.2 Nitration solution reflux ratio in AAO-BAF system

In the AAO-BAF combination system, the nitrifying liquid is refluxed from the BAF unit to the anoxic tank of the AAO section to provide sufficient electron acceptor for denitrifying phosphorus removal. Wu et al. [11] have shown that under the condition of sludge concentration of 3500mg/L, when  $R=200\%$ , the denitrification effect is the best, the total nitrogen removal rate is  $\geq 80\%$ . When  $R>200\%$ , the  $\text{NO}_3\text{-N}$  concentration of the effluent from the anoxic section increases due to the shortened reaction time of the actual denitrification. Therefore, the enhancement of the nitrogen and phosphorus removal efficiency of the AAO-BAF combination system is inseparable from a suitable nitrification liquid reflux ratio. Chen et al. [6] increased the reflux ratio of nitrifying solution from 100% to 400%. The TN removal rate increased with the increase of the reflux ratio of nitrifying solution. However, the increase is in a decreasing law. When the reflux ratio of nitrifying solution is 200%, the effluent meets the national first-class B emission standard. When the nitrifying liquid reflux ratio is 300% and 400%, the effluent meets the national first-class A emission standard, and the anoxic phosphorus uptake increases. Peng et al. [9] studied the removal rate of total nitrogen and total phosphorus in the reflux ratio of each nitrifying solution while maintaining the volume ratio of each zone of AAO section of 3:4:2. It shows that the nitrogen and phosphorus removal of the system is the best when the reflux ratio of the nitrifying solution is 250%. Most of the phosphorus-concentrating bacteria have the ability to denitrify and remove phosphorus, and ensure that the concentration of nitrate nitrogen and total phosphorus in the anoxic zone is almost zero.

### 4.3 The C/N of Influent

As people's living standards improve and their living habits change, the components of domestic sewage also change, especially the C/N ratio is getting lower and lower. Wang et al. [7] have shown that when the C/N ratio is 5.5, the nitrification liquid reflux ratio is increased, and the TN and P removal rate is increased. When the C/N ratio is 4, the nitrification liquid reflux ratio is increased, and the total nitrogen removal rate is first. After the increase, the phosphorus removal rate has almost no effect. Kern-Jespersen et al. [12] have shown that the denitrifying phosphorus uptake rate of

polyphosphate bacteria under hypoxic conditions is a first-order equation for polyhydroxy fatty acid (PHA) reserves in polyphosphate bacteria. Zhang et al. [13] used the actual sewage as the research object to explore the effect of C/N ratio on the AAO-BAF process. The results showed that the influent organic matter concentration was low or high, which could affect the denitrifying phosphorus removal effect of the process by limiting the amount of anaerobic phosphorus release.

#### 4.4 Other operating conditions

Chen et al. [6] have shown that SRT=10d not only satisfies the system with sufficient sludge volume, but also ensures that a certain amount of excess sludge is discharged every day without affecting the phosphorus removal effect of the system. Wang et al. [7] used AAO-BAF system to treat low-carbon nitrogen than actual domestic sewage under low temperature conditions. The results show that the system can achieve deep nitrogen and phosphorus removal under the conditions of average temperature of 14.2°C and C/N of 4.81. Zhang et al. [14] used COD/TN as the treatment target of 4 or so. By adjusting the influent flow rate and BAF aeration, the effects of HRT and BAF gas-water ratio on the running performance of AAO-BAF denitrifying phosphorus removal system were studied. Studies have shown that when ART has HRT≥6h and BAF gas-water ratio≥4:1, the removal rate of COD, ammonia nitrogen, TN and phosphorus is optimal in AAO-BAF system.

### 5 Conclusions

(1) The AAO-BAF system integrates the advantages of AAO and BAF, and exerts the characteristics of good dephosphorization and denitrification of AAO, which is beneficial to the stability of nitrification effect and the complete removal of ammonia nitrogen, and provides conditions for denitrifying phosphorus removal; The process is relatively simple, and the total water residence time is not long.

(2) The BAF unit in the AAO-BAF system is fast-started with water containing no organic matter. This process solves the contradiction between the sludge age between the nitrifying bacteria and the polyphosphate bacteria in the traditional AAO, so that both can maximize their own advantages, and is a new process capable of deep nitrogen and phosphorus removal and energy saving.

(3) Under the conditions of the optimum volume ratio is adopted in each area of the AAO stage, HRT, sludge age and sludge reflux ratio, it is helpful to find the optimal nitrification liquid reflux ratio to obtain the removal rule of nitrogen and phosphorus.

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