Application and Evaluation of Removing Nutrients in Wastewater via AAO Process in Tianjin, China

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Abstract. Anaerobic/Anoxic/Oxic (AAO) process is one of the effective measures to remove nutrients from the influents for most wastewater treatment plants in China, and thus, assessing the efficiency of AAO process is of great significance. This study used wastewater samples from Tianjin province in China to make evaluations of this technology. Componental analysis shows that total nitrogen (TN), ammonia nitrogen (NH3-N), and total phosphorous (TP) are crucial in determining the concentrations of nitrogen and phosphorous in Tianjin wastewater. The wastewater in Tianjin is mainly derived from domestic wastewater, and followed by industrial one. Decontamination efficiency analyses show that AAO process can remove 79% of TN and 96% TP in the wastewater, which are high because it is manipulated to its maximum extent by the plant. Moreover, the concentrations of TN and TP in the effluents are 8mg/L and 0.12mg/L, conforming to the national standards in China. AAO process can also degrade BOD (Biochemical Oxygen Demand) from the wastewater, which is also a major pollutant in wastewater. The determining factor of the extensive application of AAO process in Tianjin is that it requires less money compared to its counterparts. Therefore, if similar wastewater sources are happening in other cities in China, AAO technology could be widely used there since it is effective both environmentally and economically.

Keywords: wastewater treatment, nutrients, AAO process, Tianjin, China.

1. Introduction
Wastewater treatment plays an indispensable role in our daily life. On one hand, water scarcity is one of the most serious problems faced all over the world [1-5]. In this case, restoring water supply through the employment of wastewater treatment is crucial to mitigating water scarcity [6-8]. On the other hand, contaminants from both residential and industrial use will pollute waterways and threaten the life of humans, animals, and plants living near water [6]. With the help of wastewater treatment, they can be safely disposed and discharged into rivers. The important contaminants in the wastewater treatment include suspended solids, biodegradable organics, pathogens, nutrients (N&P), heavy metals, and dissolved inorganics [9, 10].

Nutrients, mainly nitrates and phosphates, can lead to eutrophication and algal bloom in the waterways if wastewater is discharged without careful treatment. Moreover, an increase in algae and other plants will lead to a decline in dissolved oxygen (DO) in the water, thereby suffocating many organisms and polluting their natural habitats [11-14]. Therefore, there are many processes and
technologies employed in wastewater treatment plants (WWTP) to remove nutrients from wastewater: AAO (Anaerobic/Anoxic/Oxic) process, Bardenpho process [15], UCT (University of Cape Town) process [16], and Phoredox process [17]. Among them, AAO process is used widely and frequently to treat nitrogen and phosphorous in WWTP [18-20]. Although AAO process is widely used in all provinces in China, there are few evaluations of the effectiveness of this technology in treating nitrogen and phosphorous. As a result, this study chooses Tianjin, a place where a large number of factories are located, as an example to assess AAO process in WWTP. It could provide evidence for the removal of nutrients in wastewater in other cities that share the same characteristics with Tianjin.

2. Method & Data

2.1. Sample source
Water samples were collected from Beitang WWTP in Binhai New Area, Tianjin, which included water before and after the treatment of AAO process from Nov. 26th, 2019 to Dec. 24th, 2019. After that, we measured several pollutants in water samples to evaluate the efficiency of AAO process.

2.2. Wastewater components
Several contaminants in wastewater are crucial in determining the concentrations of nitrogen and phosphorous in the wastewater: Total Nitrogen (TN), Ammonia Nitrogen (NH3-N), and Total Phosphorous (TP) [21, 22]. Our study focuses on the utilization of AAO technology to treat nutrients by measuring the concentrations of TN, NH3-N, and TP before and after the treatment for a month. The methods we used to determine those concentrations are commonly used: Alkaline potassium persulfate digestion UV spectrophotometric method to measure TN, Nessler’s reagent spectrophotometry to measure NH3-N, Ammonium molybdate spectrophotometric method to measure TP.

2.3. AAO process
AAO process is a biological method to remove both nitrogen and phosphorous and developed through a combination of activated sludge process, biological nitrification and denitrification process, and biological phosphorous removal process. Fig.1 shows the AAO process flow chart. The bacteria colony is mainly composed of nitrifying bacteria, denitrifying bacteria, and phosphate accumulating organisms. In the anaerobic reactor, as a result of the release of phosphorous by phosphate accumulating organisms, TP level increases until it reaches maximum in the next stage. Besides, ammonification occurs during this stage, which means nitrogen is converted to ammonia. In the anoxic reactor, it is generally agreed that phosphate accumulating organisms neither release nor absorb phosphorous. When it comes to nitrogen removal, NH3-N level increases significantly because the internal circulation from oxic reactor contains high concentration, and then declines due to denitrification process. In the oxic reactor, the concentration of TP decreases dramatically as a result of the absorption of phosphorous by phosphate accumulating organisms. As for the degradation of nitrogen, ammonia is nitrified into nitrates and nitrites (nitrification) and then transferred to the anoxic process, which means there is a decline in NH3-N level.

Fig. 1 AAO process flow chart [23].
3. Results

3.1. Concentration variation of TN
The concentration of TN in the influent of the wastewater ranges from approximately 30 mg/L to 50 mg/L during one month, with a mean of 39 mg/L (Fig. 2). After the treatment of AAO process, the average concentration of TN in the effluent is approximately 8 mg/L according to the original data, much lower than the untreated wastewater. Based on calculation, the efficiency of AAO technology ((influent-effluent)/influent×100%) of removing TN from the wastewater is about 79%.

![Fig. 2 Total Nitrogen in wastewater before and after the treatment of AAO process](image)

3.2. Concentration variation of NH3-N
It is schematically shown in Fig. 3 that with a range of approximately 25 mg/L to 35 mg/L, the concentration of NH3-N before the treatment of AAO process is about 30 mg/L on average, while the post-treated wastewater has a concentration of approximately 0.3 mg/L on average. This highlights the high efficiency of removing NH3-N through AAO process, and the efficiency in our experiments is 99%.

![Fig. 3 Ammonia Nitrogen in wastewater before and after the treatment of AAO process](image)

3.3. Concentration variation of TP
The concentration of TP in the influent of the wastewater is fluctuating between 0.1 mg/L to 5.3 mg/L, but the mean is about 3.3 mg/L (Fig. 4). After the treatment of AAO process, the average concentration drops to 0.12 mg/L, and every data is near the mean number of the concentration, emphasizing the effectiveness and viability of this technology. The calculation indicates that the efficiency of degrading TP is about 96%.
4. Discussion

4.1. Sources of wastewater

Domestic wastewater: About 90 percent of wastewater in Beitang Wastewater Treatment Plant comes from domestic wastewater. Sources of domestic water include the following human activities such as human excreta, washing, laundry, cooking, drinking [24]. Among them, cleaning detergents used in laundry and human excreta contain a large proportion of nitrogen and phosphorous, which means that concentrations of nitrogen and phosphorous in the influent and water samples collected in our experiments are rather high [25]. As a result, we will be able to look into the effectiveness of AAO process in removing nitrogen and phosphorous [26].

Industrial wastewater: About 10 percent of wastewater in Beitang Wastewater Treatment Plants comes from industrial wastewater. Though it does not constitute a large part, it contributes to the increase in concentrations of both nitrogen and phosphorous because Tianjin is the second biggest industrial city in China [27-30]. Therefore, some industries that produce fertilizers will release nitrogen and phosphorous in its wastewater so that their concentrations will increase, providing the suitable water samples for our experiments.

4.2. Evaluation of AAO process

AAO process, a technology to remove both nitrogen and phosphorous, can be manipulated artificially to focus on degrading phosphorous. On this circumstance, the efficiency of removing phosphorous is over 90%, while the efficiency of removing nitrogen is very low. However, if operated well, the efficiencies of removing nitrogen and phosphorous can be over 60% [31]. Our calculations based on those data mentioned above show that the efficiencies of removing nitrogen and phosphorous by AAO process are 79% and 96%, respectively. Also, according to the national standards, AAO process has the ability to make the concentration of TN lower than 9 mg/L and that of TP lower than 2 mg/L in effluents [32]; in our experiments, the average concentrations of TN and TP in effluents are approximately 8 mg/L and 0.12 mg/L. All these evidence demonstrate that AAO process has the potential of removing nitrogen and phosphorous effectively in WWTP in Tianjin.

Compared with other processes to treat nitrogen and phosphorous in wastewater, AAO process has several advantages. First, it is easy to operate. The underlying reason is that this process involves only a few pieces of equipment and includes only three phases, which are much less complicated that other equivalent technologies [33]. Second, there are only three phases in this process and it is easy to control the process, so it is cost-effective. Third, it has the additional benefit of removing BOD from the wastewater, another important pollutant that needs to be treated. During the oxic phase, BOD concentration decreases constantly because of the decomposition by aerobic organisms. Thanks to the above three advantages, AAO process is widely applied in most of the WWTP in Tianjin, and broadly speaking, in China.
5. Conclusion

This work focuses on the application of AAO process in removing nitrogen and phosphorous from wastewater in Tianjin, China. Thanks to the bacteria colony and the stipulated three phases, nutrients can be removed substantially from wastewater. The efficiencies of removing TN and TP are 79% and 96%, which is among the most effective applications of AAO process. This study also shows that about 90% of wastewater in Tianjin comes from domestic wastewater sources and about 10% of wastewater comes from industrial wastewater sources that contain relatively high concentrations of nitrogen and phosphorus, furthering highlighting the effectiveness of AAO process. Therefore, it indicated that in areas that have the similar wastewater sources as Tianjin, AAO process should be widely used in WWTP to remove nutrients. Besides, the economic benefits offered by AAO process are important: the process is easy to operate and economical. Moreover, some carbon sources, such as BOD, can also be removed through this biological process. Based on all those evidence, our conclusion is that while the efficiencies of removing nitrogen and phosphorous can rarely be high at the same time, AAO process still remains effective and presents various advantages, so it could be broadly applied in Tianjin and other similar cities in China.

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