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Removal effect of phosphorus in Orbal oxidation ditch

The effect of DO on phosphorus removal was investigated by using Orbal oxidation ditch process. The results show that the anaerobic environment was formed in the area below the longitudinal 1.5m of the outer ditch, which was beneficial to the full release of phosphorus from the polyphosphate bacteria. In the middle ditch and the inner ditch adopt the traditional design and operation mode,when the DO concentration was kept at 1 mg.L^{-1} and 2 mg.L^{-1}, the phosphorus accumulating bacteria had good phosphorus accumulation effect, and the average total phosphorus of the oxidation ditch effluence was stable at 0.14 mg.L^{-1}.

Keywords: Orbal oxidation ditch, DO concentration, longitudinal distribution

1. Introduction

The Orbal oxidation ditch process was invented by Huisman in South Africa in the 1960s. In the 70's, Envirex Corporation continued to develop and promote the anaerobic condition (Zhang 2015, Zhang 2010). This process has the advantages of simple process, convenient management, strong shock resistant capacity and save energy, so it is widely used in the field of wastewater treatment. In the conventional design, the Orbal oxidation ditch is used to maintain the anaerobic condition in the outer ditch, but in actual operation, due to the use of aeration turntable in the outer ditch. Aerobic-anoxic-aerobic-anoxic alternation is often formed in the horizontal direction, so that there is no macroscopic anaerobic environment in space, and the phosphorus removal effect is not very ideal (Zhou 2010, Zhang 2009). In order to achieve good phosphorus removal effect; anaerobic reactor is often added in front of Orbal oxidation ditch in order to increase the anaerobic hydraulic retention time (HRT), but this approach has led to increased construction and operation cost. The Orbal oxidation ditch process of the third sewage treatment plant in Xi'an (China) has been operated for a long time and being reformed continuously without adding the anaerobic reactor. The effect of phosphorus removal is very good. The annual average of total phosphorus in the influence is 6.23 mg.L^{-1}, while the annual average of total phosphorus in the effluence from oxidation ditch is 0.14 mg.L^{-1}. It is necessary to study the practical application and performance of the Orbal oxidation ditch process to this plant to provide reference and technical guidance for engineering design and operation management.

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2. Test equipment and test method

2.1 Test equipment

The test equipment is an Orbal oxidation ditch in the third sewage plant in Xi'an City (China). The municipal wastewater of the plant flows through the grille, the sand settling tank and the selection tank in turn, then enter into four parallel running three-channel Orbal oxidation ditches of the same volume.This experiment takes one of them as the research object.The size of Orbal oxidation ditch is 108m × 50 m × 5.0 m, the effective water depth is 4.5m, the effective volume is 24,300 m^3, the daily treatment of municipal wastewater is about 25,000 tonnes. Eight aeration turntables were set up in the outer ditch and the middle ditch. In the outer ditch (Non-mounted guide plate), the diameter of each aeration turntables is 7400mm, the length is 9.2m, the power of motor is 37kW and the number of discs is 44 pieces. In the middle ditch (mounted guide plate), the diameter of each aeration turntables is 7500mm, the length is 7.5m, the power of motor is 30kW and the number of discs is 17 pieces. In the inner ditch (mounted guide plate), the diameter of each aeration turntables is 5800mm, the length is 5.8m, the power of motor is 22kW and the number of discs is 13 pieces. The oxygen filling capacity of the disc is 1.15 kgO_2/h , the sludge loading is 0.075 kgBOD5/(kgMLSS.D), the mixture concentration is 4 g/L, sludge reflux ratio is 50% -100 % and sludge age is 17 days.

2.2 Test water quality

Orbal oxidation ditch process each ditch has different effect on the removal of phosphorus, so the test water is taken from the water inlet of the outer ditch, the outer ditch, the middle ditch and the inner ditch respectively. After standing for 15 minutes, the supernatant is taken, and the detection analysis is carried out.

2.3 Test items and instruments

In this experiment, DO and TP in the oxidation ditch are mainly determined. Because of the complexity of the hydraulic flow state at the corner of the oxidation ditch, the proportion of the total volume of the oxidation ditch is small, so when the DO is determined, the turning point is not used as the analysis object. The measurement section of DO is selected to influence the linear section with stronger regularity, such as 1-9 sections (1.5m in front and back and middle position of the two aeration turntables) as shown in Fig. 1. A portable dissolved oxygen meter of type 120 of Hamilton Visiferm is used for the field determination. The determination method of TP is according to the standard method, (Beijing 2002) and the test points are 3, 6, and 9. Each test item takes 3 parallel water samples for testing, and then the average value is taken.

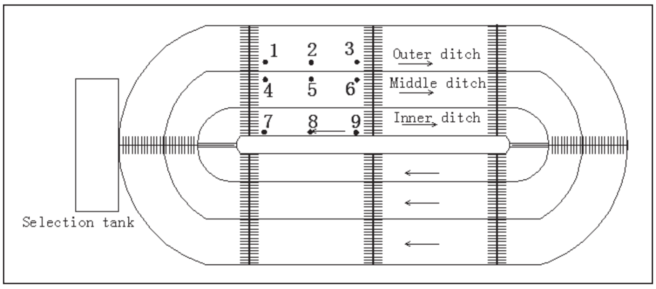

Fig. 1 : The distribution map of Orbal oxidation ditch

3. Results and analysis

3.1 Change of DO in outer ditch of Orbal oxidation ditch

As shown in Fig. 2, because there was no guide plate in the outer ditch, the DO gradient in the horizontal direction of the outer ditch was very small. There was no alternate anoxic zone and aerobic zone in operation. Instead, there was a larger concentration gradient along the tank depth at the same cross section.The average concentration of DO was more than 1 $mg.L^{-1}$ at 0m - 0.5 m; The average DO concentration at 1.5 m was 0.15 $mg.L^{-1}$. The concentration of DO was almost 0 $mg.L^{-1}$ in the region of 2.5 m and below. Therefore, a macroscopic anaerobic zone is formed at the height of 1.5m to the bottom of the outer ditch, which created an anaerobic environment for the full phosphorus release of the phosphorus accumulating bacteria. The width of the outer ditch is 9.2 m, the length is 2 × 10 8 m, and the anaerobic height is about 2 m, which is equivalent to the existence of 3974 m^3 anaerobic space in the outer ditch. Through the calculation, the anaerobic HRT was about 3.8h, this value was greater than the anaerobic HRT in anaerobic/aerobic biological phosphorus removal, which was required in GB50014-2006 (design code for outdoor drainage) at 1 -2h, and the condition of anaerobic phosphorus release was satisfied. As the fresh sewage flowed into the outer ditch from the selection pool, the electron donor of the small molecule was provided for the phosphorus-accumulating bacteria, so that the activity of the phosphorus-accumulating bacteria was enhanced, and the phosphorus-releasing effect was improved. From the change of TP concentration in the outer ditch inlet and each ditch as indicated in Table 1, it could be seen that the TP value in the outer ditch was larger than that in the inlet, which showed that phosphorus release exists in the outer ditch.

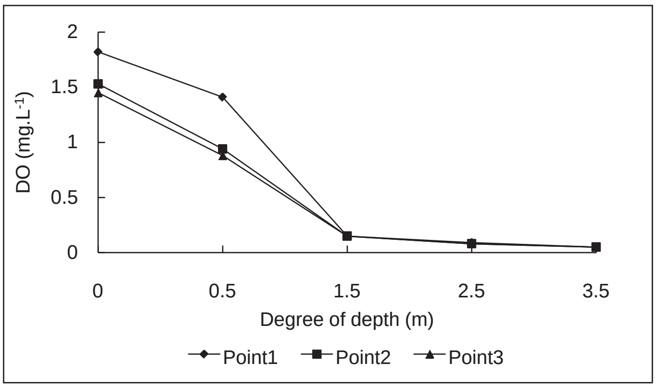

Fig. 2: Variation of DO concentration in the outer ditch of Orbal oxidation ditch

Table 1. Changes of TP

Test position	External ditch inlet	Outer ditch	Middle ditch	Inner ditch
TP/($mg.L^{-1}$)	4.43	4.71	2.54	0.14
Removal rate	–	-6.3%	46%	94.5%

3.2 Change of DO in middle ditch of Orbal oxidation ditch

As shown in Fig. 3, the average DO concentration in the middle ditch was over 1 $mg.L^{-1}$, the horizontal DO concentration gradient was larger, and there was a horizontal aerobic-anoxic-aerobic section. Due to the installation of the guide plate, the size and distribution of DO concentration were the same as that of the conventional operation mode (the conventional Orbal oxidation ditch was also equipped with the guide plate). It was shown in Table 1 that the removal rate of TP in this ditch was 46%, and there was a good effect of phosphorus accumulation.

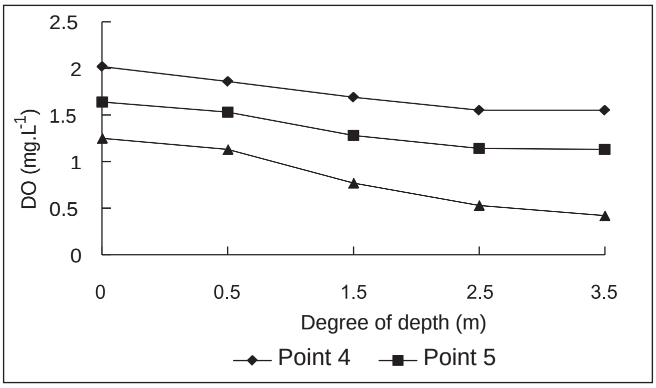

Fig. 3: Variation of DO concentration in the middle ditch of Orbal oxidation ditch

3.3 CHANGE OF DO IN INNER DITCH OF ORBAL OXIDATION DITCH

As shown in Fig. 4, the dissolved oxygen concentration in the inner ditch was high, and the DO concentration was more than 2mg.L^{-1}, showing a aerobic state.There was almost no DO concentration gradient in the horizontal direction, and the DO concentration in the vertical direction was also smaller. Due to the installation of the guide plate, the DO size and distribution rule in the whole ditch were the same as those of the conventional operation mode (the regular Orbal oxidation ditch is equipped with a guide plate). The main function of the ditch was to remove phosphorus and organic matter. The removal rate of TP was 94.5% and the concentration is 0.14 mg.L^{-1}.

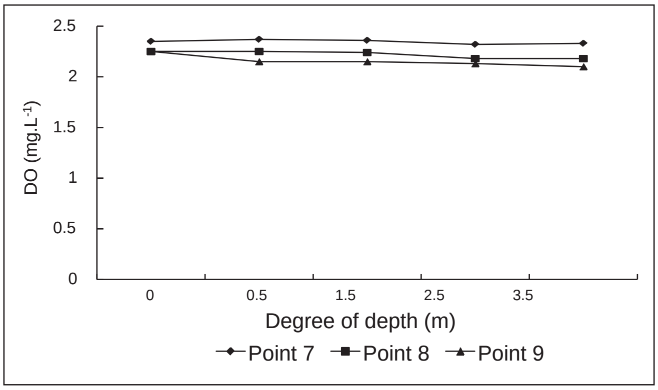

Fig. 4: Variation of DO concentration in the inner ditch of Orbal oxidation ditch

4. Conclusion

No guide plate was installed in the outer ditch of Orbal oxidation ditch, which could transform the horizontal aerobic anoxic environment into longitudinal aerobic anoxic environment. The presence of anaerobic environment provided favourable conditions for phosphorus removal. The total removal rate of TP in Orbal oxidation ditch was 98% when the influent TP concentration was 6.23 mg.L^{-1} and the effluent TP concentration was less than 0.14 mg.L^{-1}.

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