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Analysis on the Upgrading and Renovation Project of a Wastewater Treatment Plant in Guangdong Province

Di Zhang[1,a], Zhili Luo[1], Lijuan Tang[2], Ziyun Guo[3]

[1]Shaoguan Water Investment Group Co., Ltd, Shaoguan 512000, China;

[2]China Shanghai Architecture Design and Research Institute Co., Ltd, Shanghai 200333, China;

[3]Shangqiu University, Shangqiu 476000, China.

[a]13783433592@163.com

Abstract

Based on a case study of a Wastewater Treatment Plant (WWTP) in Guangdong Province, this paper analyzes the characteristics of the influent water quality of the WWTP, and determines the process route for adding a high-efficiency sedimentation tank and a denitrification deep-bed filter. Determine the dosage of the agent, the dosage of 30% sodium acetate (carbon source) is 80.8 mg/L, the dosage of PAC (flocculant) is 1 mg/L, and the dosage of PAM (coagulant) is 1.5 mg/L, verified the removal effect of high-efficiency sedimentation tank and denitrification filter on total nitrogen (TN), total phosphorus (TP) and suspended solids (SS). After the renovation, the effluent index stably reached the first-level A discharge standard of the "Urban Wastewater Treatment Plant Pollutant Discharge Standard" (GB18918-2002) and the Guangdong Provincial Local Standard "Water Pollution Discharge Limits" (DB44/ 26-2001) for the second period the stricter value of the emission standard.

Keywords

Upgrading Reconstruction; Nitrogen and Phosphorus Removal; High-efficiency Sedimentation Tank; Denitrification Deep-bed Filter.

1. Introduction

A Wastewater Treatment Plant (WWTP) in Guangdong was built in 2003, with a scale of 15,000 m^3/d for the first phase, which was officially put into operation in August of that year. The main process flow is: inlet → grid room and lifting pump station → grit tank → anaerobic tank + oxidation ditch → secondary settling tank → chlorine disinfection tank → outlet. The treated sewage meets the "Urban Wastewater Treatment Plant Pollutant Discharge Standard" (GB189-2002) the first-level B standard and the local standard of Guangdong Province "Water Pollution Pollutant Discharge Limits" (DB 44/26-2001). During the operation period, due to the large difference between the inlet water quality and the designed water quality, the WWTP could not operate normally and the outlet water quality exceeded the national discharge standard. In 2007, the original oxidation ditch was transformed and the second-stage contact oxidation process of the biofilm method was adopted. Now, in order to improve the quality of the water environment and respond to relevant national policy requirements for upgrading and transformation, it is necessary to raise the pollutant discharge standard of WWTP from the first-level B standard to the first level-A standard and the Guangdong Provincial Local Standard "Water Pollution Discharge Limits" (DB44/26-2001) for the second period the stricter value of the emission standard [1].

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2. Introduction to WWTP

The water quality analysis of the inlet and outlet of the WWTP in the first three years of the upgrading project (2017-2109) is shown in Table 1. It can be seen from Table 1 that the actual average inlet water quality of the WWTP meets the design requirements, and the average outlet water quality also meets the factory water discharge standards implemented by the plant. Due to the low-level B standard of factory water, it is not conducive to protecting and improving the water environment. Through long-term water quality monitoring, it was found that the average value of TP and SS actual outlet seriously exceeded the standard limit of the first level-A, in which the TP exceeded the standard rate of 50.26%, the SS exceeded the standard rate of 44%; the NH_3-N and TN indicators occasionally exceeded the standard.

Table 1. Measured and designed inlet and outlet water quality of the WWTP.

Project	BOD_5		COD		SS		TP		TN		NH_3-N	
	In-	Out-	In-	Out-	In-	Out-	In-	Out-	In-	Out-	In-	Out-
Min	4.5	0.5	16.5	8	5	6	0.3	0.1	6	0.8	1.5	0.2
Max	166	5.4	402	36.7	710	19	10.7	1.5	24	15.1	24.2	8
Avg	32	0.8	88.9	15.9	95.7	10	1.5	0.6	10.9	8.7	7.9	1.9
Asgn	150	10	250	50	200	10	3.5	0.5	-	15	25	5

Based on the above data analysis, the actual inlet pollutant concentration of the WWTP is currently low, and some indicators are unstable. The reason may be that the service scope of the WWTP is mainly the old city, and part of the drainage is combined with rain and sewage, which is affected by rain in the rainy season. Influence, resulting in low and unstable inlet water quality. Secondly, the outlet quality of the WWTP does not meet the standard, and some indicators fluctuate greatly. Therefore, the upgrading of the WWTP is imperative.

3. Mentioned standard renovation project design

3.1 Designed water quality and removal rate of inlet and outlet water

According to the relevant local requirements, after the completion of the upgrading and upgrading of the outlet quality of the WWTP, its discharge standard meets the requirements of the first-level A discharge standard in the "Urban Wastewater Treatment Plant Discharge Standard" (GB18918-2002) and the Guangdong Provincial Local Standard "Water Pollution Discharge Limits" (DB44/26-2001) for the second period the stricter value of the emission standard. After upgrading the standard, the designed inlet and outlet water quality and removal rate are shown in Table 2.

Table 2. The main pollutant treatment requirements of this project.

Project	CODcr	BOD_5	NH_3-N	TN	TP	SS
Inlet	250	150	25	30	3.5	200
Outlet	<40	<10	<5	<15	<0.5	<10
Removal rate	84%	93.33%	80%	50%	85.72%	95%

3.2 Design plan

3.2.1. Biological treatment pond renovation

According to the needs of the upgrading project, the main objectives of the enhancement of the secondary treatment of the biological pond are as follows: firstly, strengthen the nitrification effect in the secondary biological treatment stage; secondly, develop and utilize internal carbon sources, strengthen the removal rate of TN, and reduce the amount of subsequent additional carbon sources; thirdly, strengthen the efficiency of biological phosphorus removal and strengthen the removal of TP

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rate, reduce the consumption of subsequent chemical agents [2]. Through a comprehensive comparison of treatment effects, new investment, operating costs, new land use, etc., this project adopts the regular replacement of the oxidation ditch biological filming plan to achieve the enhancement of the secondary treatment.

3.2.2. Depth process design

The main content of this project is to build a new advanced treatment facility with a scale of 1.5×10^4 m^3/d. The advanced treatment process selects the combination process of "high efficiency sedimentation tank + denitrification deep bed filter" [3]. A new intermediate lifting pump station was built in the plant area to upgrade the current effluent from the secondary sedimentation tank to the advanced treatment workshop. The main design parameters of the intermediate lifting pump station are as follows: plane size L×B = 4.1 m×4.1 m. The lift pump is a submersible sewage pump, Q=477 m^3/h, H=8 m, N=18.5 kW, 3 units in total, 2 used and 1 standby, all of which are frequency conversion and auto-coupling installation.

The high-efficiency sedimentation tank flocculates and sediments the tail water of the secondary sedimentation tank to further remove SS, TP and organic matter (Fig 1). The high-efficiency sedimentation tank integrates a mechanical mixing tank, a mechanical flocculation tank and an inclined tube sedimentation tank. The main design parameters of the high-efficiency sedimentation tank are as follows: the number is 1 group, divided into 2 cells, and the size of the single cell is L×B×H=14.25 m×6.5 m×11.5 m. The mixing time was 3.09 min, the flocculation time was 9.15 min, and the surface load on the sedimentation zone of the inclined tube was 12.02 m/h. The main equipment has 2 mixing mixers, N=7.5 kW. Two flocculation mixers, N=7.5 kW. 2 mud scrapers, D=9.0 m, N=0.75 kW. 2 return sludge pumps, Q=15 m^3/h, H=15 m, N=5.5 kW, 2 sets. 2 remaining sludge pumps, Q=15 m^3/h, H=15 m, N=5.5 kW [4].

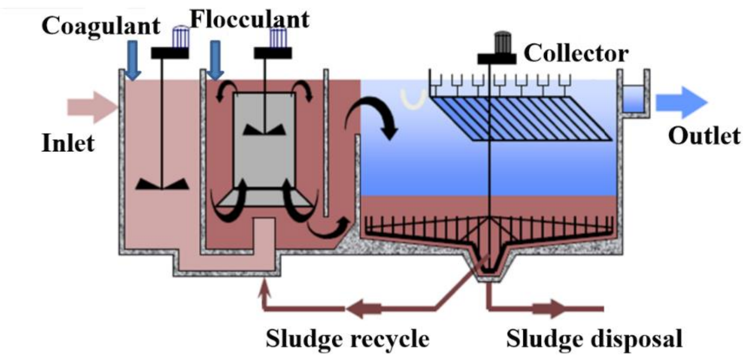

Fig. 1 Working principle diagram of high-efficiency sedimentation tank

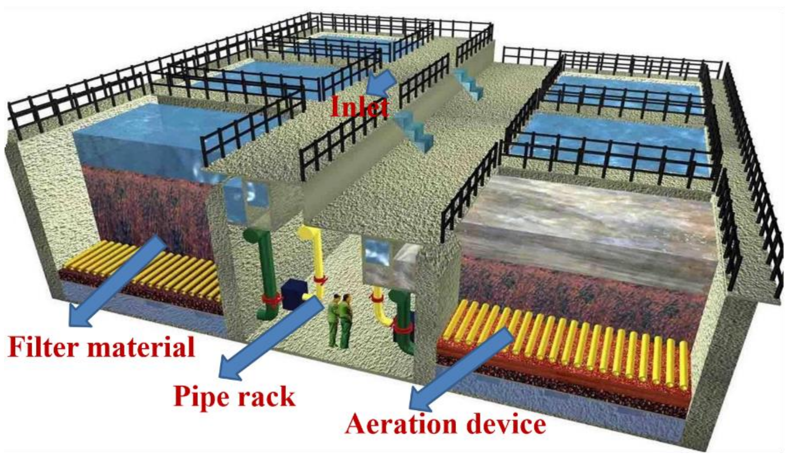

Fig. 2 Schematic diagram of denitrification deep-bed filter

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The filter medium of the denitrification deep-bed filter is quartz sand, which mainly conducts biological denitrification of NO_3-N in the water to reduce the concentration of TN, and at the same time physically filters the SS (Fig 2) [5]. There is one denitrification deep-bed filter with 4 cells in total, and the single cell size is L×B×H=9.0 m×2.9 m×5.15 m. The design average filtration rate is 5.79 m/h, the peak filtration rate is 8.8 m/h, and the average flow forced filtration rate is 8.68 m/h. The design backwash cycle is 24 to 48 hours, and the single backwash time is 17 min. backwash is divided into three stages: air washing-air washing-water washing, in which air washing is 2 min, air washing is 10 min, and water washing is 5 min. The backwash water intensity of the denitrification deep-bed filter is 5 L/(m^2·s), and the backwash gas intensity is 25 L/(m^2·s). The backwash water pump adopts a submersible pump with a flow of 648 m^3/h, a head of 10 m, and a power of 30 kW. There are two in total, one for use and one for backup. The backwash fan adopts roots blower, the air volume is 39.15 m^3/min, the air pressure is 70 kPa, and the power is 75 kW. There are 2 units in total, one for use and one for backup. The filter material adopts high-strength quartz sand, the particle size of the filter material is 2 ~ 3 mm, and the uniformity coefficient is 1.35. The supporting layer adopts 5 layers of natural pebbles of different specifications, with a particle size of 3.2 ~ 19.1 mm and a depth of 0.4 m. The gradation is alternately arranged, and the secondary air distribution and secondary water distribution are effectively realized during backwashing, so that the entire filter is air-watered. The distribution is very uniform, preventing air blow-by, hydraulic short circuit and mud ball generation in the filter bed [4].

3.2.3. Sludge dewatering plant upgrade

The WWTP currently uses centrifugal dewatering technology, and the moisture content of the sludge after dewatering is below 80%. At present, the equipment can meet the treatment requirements, but in view of the aging of the equipment, only the desilting equipment will be updated and not modified in this issue. The sludge disposal method still follows the existing disposal method and is sent to the landfill for landfill disposal without modification.

3.2.4. Tail water disinfection process

The current situation of this project is to use a contact disinfection tank and add chlorine dioxide for disinfection. Therefore, this upgrade and renovation will maintain the status quo to avoid idle waste of existing facilities and new investment.

Table 3. Running records for 8 consecutive weeks

Week		1	2	3	4	5	6	7	8
TN (mg/L)	**Inlet**	14	16	13.5	10	16.6	12	13.3	14.7
	Outlet	4.41	4.36	4.81	4.5	5.02	3.96	4.4	5.11
	Removal rate	68.5%	72.8%	64.4%	55.0%	69.8%	67.0%	66.9%	65.2%
TP (mg/L)	**Inlet**	1.44	2.36	1.09	3.3	2.71	1.2	1.6	2.44
	Outlet	0.248	0.231	0.218	0.13	0.2	0.04	0.09	0.134
	Removal rate	82.8%	90.2%	80.0%	96.1%	92.6%	96.7%	94.4%	94.5%
NH_3-N (mg/L)	**Inlet**	6.87	7.7	9.42	8.9	10.8	13.4	9.4	8.5
	Outlet	0.23	0.38	0.36	0.13	0.13	0.137	0.09	0.11
	Removal rate	96.7%	95.1%	96.2%	98.5%	98.8%	99.0%	99.0%	98.7%
COD_{Cr} (mg/L)	**Inlet**	54	44.5	51.6	51.8	49.9	63.0	55.4	50.7
	Outlet	11.2	9.99	6.43	7.74	6.95	9.72	5.54	7.47
	Removal rate	79.3%	77.6%	87.5%	85.1%	86.1%	84.6%	90.0%	85.3%
SS (mg/L)	**Inlet**	67	88	63	55	68	53	73	87
	Outlet	4	6	3	3	4	2	2	4
	Removal rate	94.0%	93.2%	95.2%	94.5%	94.1%	96.2%	97.3%	95.4%

4. Engineering operation effect

The project was commissioned and operated in June 2021. At present, the average daily treated water volume of the system is about 14,350 m^3/d, during which the dosage of 30% sodium acetate (carbon

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source) dosage is 80.8mg/L, PAC (flocculation Agent) dosage of 1mg/L, PAM (coagulant) dosage of 1.5mg/L. The quality of inlet and outlet water from the WWTP was tested for 8 consecutive weeks, as shown in Table 3. It can be seen from the operating data that the effluent water quality indicators have a good removal effect after the standard is upgraded. The removal rate of TN is 55% ~ 72.8%, the removal rate of TP is 80% ~ 9.7%, and the removal rate of NH_3-N is 95.1% ~ 99%, COD removal rate is 77.6% ~ 90%, SS removal rate is 93.2% ~ 97.3%. The expected effect of the upgrading project, the effluent meets the first-level A discharge standard in the "Urban Wastewater Treatment Plant Pollutant Discharge Standard" (GB18918-2002) and the Guangdong Provincial Local Standard "Water Pollution Discharge Limits" (DB44/26-2001) for the second period the stricter value of the emission standard.

5. Conclusion

Considering the actual situation and requirements of the project, through the optimization and transformation of the biological tank, and the addition of 'efficient precipitation + denitrification deep bed filter' advanced treatment process, TN, SS and TP are well removed. After the upgrade, the effluent indicators of the WWTP meet the requirements of the first-level A discharge standard in the "Urban Wastewater Treatment Plant Discharge Standard" (GB18918-2002) and the Guangdong Provincial Local Standard "Water Pollution Discharge Limits" (DB44/26-2001) for the second period the stricter value of the emission standard.

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