Enhanced Treatment Strategies on Refractory Organics of An Urban Wastewater Treatment Plant

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Abstract: A 15×10^4 m^3/d scale urban wastewater treatment plant used the process of hydrolysis acidification+conventional treatment+advanced treatment. Take it as an example, enhanced treatment on refractory organics were introduced and analyzed. Almost 50% influent wastewater come from industry drainage (papermaking, pharmacy), which contained a lot of refractory organics, and its quality fluctuated seriously. During the early operation period, the average influent and effluent COD were around 310 mg/L and 100 mg/L, respectively. Through increasing the MLSS of hydrolysis acidification pool, altering the sludge external reflow to system entire reflow, decreasing the air blower supply quantity, extending anaerobic pool hydraulic retention time, and so on, the refractory organics removal was enhanced effectively without any reagents addition. Its design and operation experiences provide technical reference for similar urban wastewater treatment plant.
Keywords: hydrolysis acidification pool; refractory organics; reflow; COD.

1. Introduction

A 15×10^4 m^3/d scale urban wastewater treatment plant (WWTP) is located in the central region of China. It covers an area of 219 mu and its construction investment is nearly 30 million yuan. This WWTP is used to treat urban sewage and industrial wastewater from the local high-tech development area, industrial parks and county town. The treatment process is "hydrolysis acidification+conventional treatment+advanced treatment". The designed influent quality is "COD 250~450 mg/L, BOD_5 100~180 mg/L, SS 150~350 mg/L, TN 25~45 mg/L, NH_4^+-N 20~35 mg/L and TP 3~6 mg/L". Discharge standard execute one-class A of "Discharge standard of pollutants for municipal wastewater treatment plant"(GB18918-2002). In the autumn of 2015, this WWTP began trial operation, and was planned to get through environmental protection acceptance within half a year.

2. Process overview

2.1. Treatment process

Wastewater came from industrial parks was in the range of 6×10^4 m^3/d - 8×10^4 m^3/d, most of which was produced by papermaking and pharmaceutical industry[1]. The core part of treatment process was modified oxidation ditch. In order to degrade refractory substances and improve biodegradability, hydrolysis acidification pool was added before the conventional treatment unit[2,3]. The treatment process was shown in Fig 1.

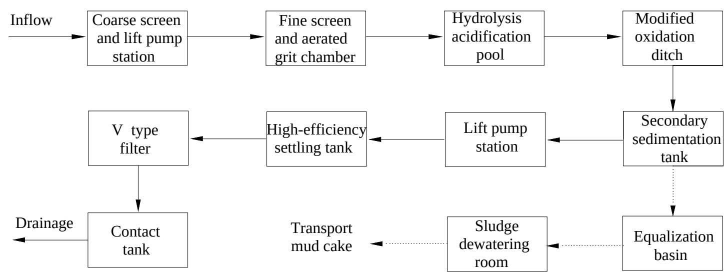

Fig1 Treatment process chart of wastewater and surplus sludge

2.2 Designed parameters

Pretreatment unit is composed of aerated grit chamber and hydrolysis acidification pool. In this unit not only inorganic grit could be removed, but also influent biodegradability is improved. The aerated grit chamber contains two groups, each hydraulic retention time is 150s. Hydrolysis acidification pool also contains two groups, its ascending velocity and hydraulic retention time are 1.1m/h and 6.0h, respectively. The average sludge concentration is 8000 mg/L. Sludge discharge pipeline is installed at the bottom of the pool.

Conventional treatment unit is the modified oxidation ditch. The oxidation ditch contain two groups. In order to enhance nitrogen and phosphorus removal, each group is divided into anaerobic tank, anoxic tank and aerobic tank. Each hydraulic retention time are 1.0 h, 2.7 h and 12.0 h respectively. Each tank has water up to 6.5 m deep, stirring paddles and propellers are installed at the bottom of the tanks. Aerobic tanks adopt the combined aeration pattern of brush aeration and rubber film aeration.

Advanced treatment unit is composed of high-efficiency settling tank and V type filter. The high-efficiency settling tank contains two groups, liquid polymeric aluminum chloride (PAC) is added in the front for chemical phosphorus removal. The hydraulic retention time of the mixing tank, flocculation tank and setting tank are 120 s, 10 mins and 30 mins, respectively. The setting tanks adopt the opposite flow inclined pipe. V type filter contains two groups, filtration rate and cycle time are 10 m/h and 12h, respectively. Effluent is discharged after contact disinfection.

3. Analysis of operation effect

3.1. Operation effect

3.1.1 Pretreatment unit

Aerated grit chamber operated continuously, and the grit-water separator run well. Gas flowmeter was not installed in the aeration pipeline, this led to higher aeration rate. As a result, effluent oxidation reduction potential (ORP) was above 0 mv. Hydrolysis acidification pool had no sludge adding equipment, its average sludge concentration was under 5000 mg/L. The actual average influent BOD_5/COD was around 0.30, after the treatment of hydrolysis acidification pool, BOD_5/COD would rise to around 0.45.

3.1.2 Conventional treatment unit

Inoculated sludge was from the surplus sludge of a nearby WWTP (5×10^4 t/d, oxidation ditch process). During trial operation period, external and internal reflow ratios of modified oxidation ditch were controlled at 10% and 200%, respectively. The anaerobic tank ORP was above 0 mv. Air blower model was too large, DO at the terminal of aerobic tank was above 5 mg/L. MLSS was around 6000 mg/L, and MLVSS/MLSS was 0.50 - 0.60. The sludge activity was low.

3.1.3 Advanced treatment unit

Through adding liquid PAC, the phosphate wound be transformed from dissolved compound to inorganic particle, and was removed by sedimentation and filtration. Effluent TP would be lower than 0.5 mg/L. During trial operation period, influent TP was under 2.0 mg/L, after the conventional treatment unit, TP was already lower than 0.5 mg/L, so the chemical phosphorus removal apparatus was not run.

3.2 Pollutants removal

Influent COD fluctuated obviously during trial operation period, and its removal efficiency was terrible. Effluent COD was around 100 mg/L in a long time as shown in Fig.2. The influent NH_4^+-N and TP were low, nitrification effect was well, the effluent NH_4^+-N was around 1 mg/L as shown in Fig.3. Without reagent addition, effluent TP can met the discharge standards.

3.3 Problems analysis

From the trial operation experience, effluent COD concentration was so high that it was difficult to meet discharge standard. The main problems existed were as follows.

3.3.1 Fluctuation of influent quantity

During trial operation period, the average daily influent quantity was 12×10^4 - 16×10^4 t/d, which was close to full load (15×10^4 t/d). Among the influent almost 50% was industry wastewater produced by papermaking and pharmacy, which brought large amount of refractory organics. Wastewater quality fluctuated obviously (shown in Fig.2). These all presented great trouble for COD treatment.

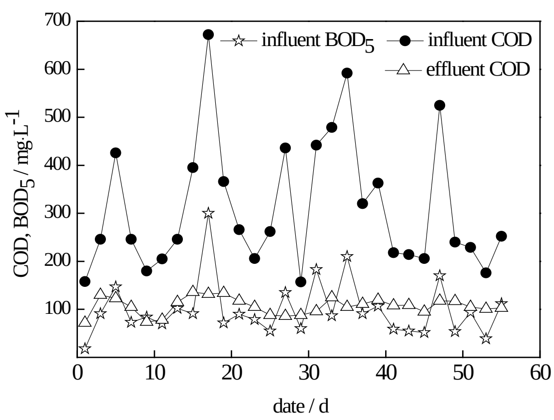

Fig2 COD removal during trial operation period

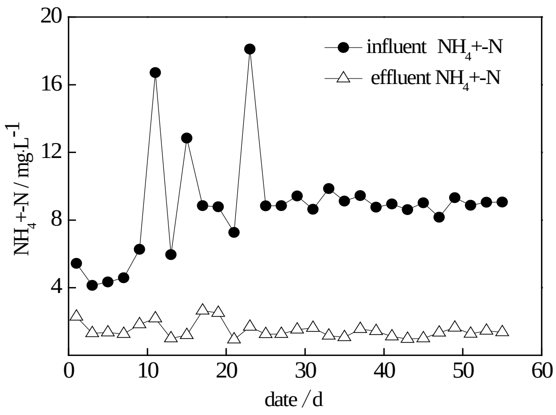

Fig3 NH_4^+-N removal during trial operation period

3.3.2 Sludge shortage in hydrolysis acidification pool

There was no sludge adding pipelines in hydrolysis acidification pool, microbial biomass growth was only depended on influent organics and nutrient substances. MLSS was lower than 5000 mg/L. Sludge shortage limited refractory organics degradation seriously.

3.3.3 Excessive aeration supply in aerobic tank

The actual oxygen supply was far more than the oxygen demand because of the larger air blower. At the terminal of aerobic tank, dissolved oxygen (DO) was above 5 mg/L. High DO concentration not only wasted energy, but also added the DO concentration of external and internal reflow, which was adverse to maintain limited DO environment in anaerobic and anoxic tanks. In addition, excessive aeration would lead the activated sludge step into decline phase, a quantity of activated sludge died and disintegrated, so the effluent COD was increased.

3.3.4 Unutilized volume of oxidation ditch

The designed hydraulic retention time of anaerobic, anoxic and aerobic tanks of the oxidation ditch were sufficient. But because of tank structure, tank type and some other reasons, the mixture of wastewater and sludge in partial zone was mixed inadequately. This decreased the effective tank volume, as a result, actual hydraulic retention time was smaller than the designed ones. Pollutant removal performance was influenced. This effect was more obvious in anaerobic and anoxic tanks.

3.3.5 High ORP in aerated grit chamber

There was no airflow regulation device in air supply pipeline. As a result, air supply was high, and effluent ORP was over 0 mv. This destroyed the anaerobic environment of subsequent hydrolysis acidification pool, and refractory organics degradation was influenced.

4. Suggestion and implementation of enchanced treatment strategies on refractory organics

4.1. Enhanced treatment strategies

On the basis of problem analysis, especially the refractory organics treatment. According to the urgency degree of implement, optimization strategies were suggested in several aspects as follows.

4.1.1 Increase MLSS of hydrolysis acidification pool

In order to supply hydrolysis acidification pool sludge, extend external reflow pipeline from anaerobic tank to the hydrolysis acidification pool (switched by valve). The increased MLSS could not only contribute to buffer the fluctuation of influent quality, but also improve the ability to degrade refractory organics.

4.1.2 Increase hydraulic retention time of anaerobic tank

The anaerobic tank had unutilized volume, which caused actual hydraulic retention time lower than the designed one, and seriously inhibited anaerobic biochemical reactions such as phosphorus-release and organics degradation. For this reason, it was decided to change the sludge reflow pattern froml external reflow to entire reflow (sludge reflowed from secondary sedimentation tank to hydrolysis acidification pool directly). Treat the hydrolysis acidification pool and anaerobic tank as a whole, to maximize the degradation ability of refractory organics under anaerobic environment.

4.1.3 Decrease air blower model

After decreasing the blower model, DO at the terminal of aerobic tank could be controlled at 1.5-2.0 mg/L. This could not only avoid delayed aeration, but also reduce DO concentration in reflowed sludge, which provided well anaerobic environment for hydrolysis acidification pool.

4.1.4 Optimize aeration patterns of grit chamber

During trial operation period aeration rate of grit chamber was high, there was no regulation apparatus in air supply pipeline. Based on this, it was decided to alter aeration pattern from continuous to interval, so that effluent ORP of grit chamber would be reduced.

4.1.5 Regulate influent quantity

During trial operation period, influent quantity was high, while biological treatment system was not mature. So it was necessary to increase influent quantity gradually, until it reached full load operation.

4.2. Enhanced treatment effects

According to enhanced treatment strategies, reconstructed project was carried out. It took 15 days to extend sludge external reflow pipelines, change air blower model. After reconstructed project, entire reflow pattern was adopted, sludge reflowed from secondary sedimentation tank to hydrolysis acidification pool directly (reflow radio was 10%). Through regulating flowmeter in the main influent pipeline, influent quantity increased from 10×10^4 t/d to 15×10^4 t/d gradually. Meanwhile, DO at the terminal of aerobic tank was controlled at 1.5-2.0 mg/L strictly. Operation effect after reconstructed project was shown in Fig 4 and Fig 5.

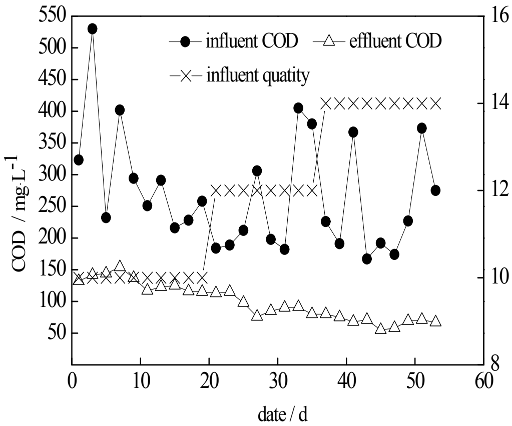

Fig4 COD removal efficiency after reconstruction

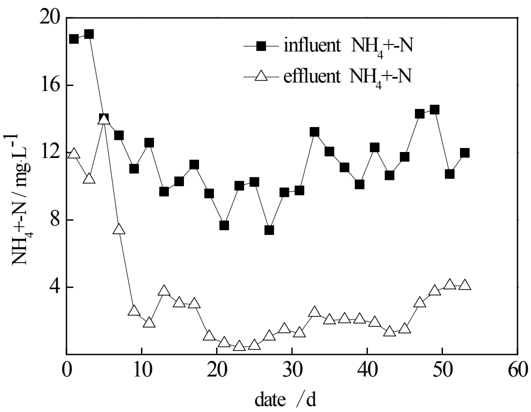

Fig5 NH_4^+-N removal efficiency after reconstruction

It could be seen nitrification was just influenced a little, effluent NH_4^+-N concentration was below 5 mg/L steadily. Controlling DO at the terminal of aerobic tank under 2.0mg/L had no influence on nitrification. In addition, ORP of hydrolysis acidification pool decreased sharply from above 0 mv to below -50 mv, which created an excellent anaerobic environment. MLSS of hydrolysis acidification pool increased to 6000 mg/L gradually, abundant microorganisms was provided to degrade refractory organics.

4.3. Performance of later operation period

After carrying out enhanced treatment strategies, although effluent COD showed a decline tendency, it was still above 50 mg/L, which means organics came from papermaking and pharmaceutical industry could not be degraded adequately in the current process system. In fact, although this WWTP was urban wastewater treatment plant nominally, the influent wastewater was mainly industrial wastewater. During the later operation period, Fenton-type reagent and diatomite were attempted to add in the advanced treatment unit to degrade excessive COD[4,5], and effluent COD decreased below 50 mg/L finally, but the cost was high.

Later, environmental protection administration of the city strictly controlled the industry discharge situation, pollution level of the influent wastewater was decreased, and the final effluent quality could meet discharge standard without reagents addition. This also illustrated that the enhanced strategies to degrade refractory organics established in this paper was effecitve.

5. Conclutions

1) Anaerobic treatment unit was essential to degrade refractory organics. Abundant sludge concentration and well anaerobic environment were the key factors to ensure its operation effect.

2) During trial operation period, regulated influent quantity strictly and increased step by step could make up the effect of influent quality fluctuation to some extent.

3) Aeration grit chamber was not suitable for the urban wastewater treatment plant which had hydrolysis acidification pool.

4) When designing wastewater treatment structures, it was necessary to consider not only supply sufficient mixing intensity, but also flowing characteristics of fluid, to utilize the volume sufficiently and avoid short flow.

6. Acknowledgements

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7. References

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