Application of High Efficacy Clarification Tank and Rotary Filter in Advanced Treatment Process of Northern WWTP

Shufang Chen and Xiukui Zhang

ABSTRACT

In order to improve the effluent quality, the advanced treatment process mainly including the combination technology of highly efficient clarification tank and rotary filter was used for Chuanhu Wastewater Treatment Plant in Changchun city. This paper introduces the advanced wastewater treatment process, design parameters of main structures and corresponding equipment. The actual operation results show that advanced treatment process can achieve good effluent quality in spite of high contaminant concentration and big fluctuation of water quality of raw water. Effluent quality can steadily meet the requirement of grade A of pollutant discharge standard of urban sewage treatment plant (GB 18918-2002).1

INTRODUCTION

Changchun Chuanhu Wastewater Treatment Plant was located in Xiaochengzi Village, Kuancheng District, Changchun City. The catchment area of which included Tiexi District, Songjiawazi District and District north of Xiaonan Minggou. It was completed in July 2015 and has been test run. Daily treatment capacity of 200,000 tons, it was responsible for the treatment of more than 500,000 residents living in the area of nearly 81 square kilometers of the Green Park District. In order to meet the requirements of urban development and environmental requirements, the advanced treatment of the Wastewater Treatment Plant used a highly efficient clarification tank and fiber rotary filter combination process to

1 Shufang Chen, The City College of Jilin Jianzhu University, Xuejian Big Street, Changchun City, Jilin Province, China,130114
Xiukui Zhang, China Northeast Municipal Engineering Design & Research Institute Co., Ltd., Gongnong Big Road, Changchun City, Jilin Province, China,130021
ensure that the effluent quality can meet the requirement of grade A of discharge standard of pollutants for municipal wastewater treatment plant (GB 18918-2002).

DESIGN INFUENT AND EFFLUENT QUALITY

Design Influent Quality of Wastewater Treatment Process

According to the Code for Design of Outdoor Wastewater Engineering (GB50014-2006) and the Wastewater Quality Standards for Discharge to Municipal Sewers (CJ 343-2010), the water quality and quantity of domestic and industrial wastewater were weighted. Combined with the results of Changchun Environmental Protection Bureau's monitoring of the sewage quality of Changchun City for many years[1], and with reference to the water quality of Tianjia Wastewater Treatment Plant that had been built in the Chuanhu water system, the main pollutants of the influent quality of Chuanhu Wastewater treatment plant were determined, Table I showed.

TABLE I. DESIGN INFUENT QUALITY OF WASTEWATER TREATMENT PROCESS.

<table>
<thead>
<tr>
<th>Project</th>
<th>COD (mg/L)</th>
<th>BOD (mg/L)</th>
<th>SS (mg/L)</th>
<th>NH\textsubscript{3}-N (mg/L)</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design influent quality</td>
<td>350</td>
<td>180</td>
<td>250</td>
<td>30</td>
<td>40</td>
<td>&lt;6</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>

Design Effluent Quality of Wastewater Treatment Process

Design effluent quality of wastewater treatment process meet the requirement of grade A of discharge standard of pollutants for municipal wastewater treatment plant (GB 18918-2002). The targets of grade A Standard were as shown in Table II.

TABLE II. DESIGN EFFLUENT QUALITY OF WASTEWATER TREATMENT PROCESS.

<table>
<thead>
<tr>
<th>Project</th>
<th>COD (mg/L)</th>
<th>BOD\textsubscript{5} (mg/L)</th>
<th>SS (mg/L)</th>
<th>NH\textsubscript{3}-N (mg/L)</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Effluent</td>
<td>60</td>
<td>20</td>
<td>20</td>
<td>8 (15)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>Advanced Treatment Effluent</td>
<td>50</td>
<td>10</td>
<td>10</td>
<td>5 (8)</td>
<td>15</td>
<td>0.5</td>
</tr>
</tbody>
</table>

ADVANCED TREATMENT COMBINATION PROCESS

Based on the experience of operation and management of domestic and foreign sewage treatment plants, combined with the local environmental protection requirements, the effluent quality requirements of the sewage treatment plant were integrated, and the high efficacy clarification tank and fiber rotary filter and
disinfection treatment method were used for advanced treatment. In the high efficacy clarification tank, COD, SS, and TP pollutants were further removed through the process of coagulation and sedimentation, and the pollutants were further removed through mechanical sieve filtration, adsorption, and biodegradation in the fiber turntable filter[3][4], and then killed bacterial virus in sewage by the disinfection process. The advanced treatment combination process was shown in Figure1.

![Flow chart of advanced wastewater treatment process.](image)

**High Efficacy Clarification Tank**

The high efficacy clarification tank was divided into 4 areas: mixed area, flocculation area, sedimentation area and concentration area. The two advantages of oblique tube sedimentation and sludge recycling reflux were combined, the sedimentation performance was improved, and the water content of sludge discharged from the sedimentation area was reduced. Which were conducive to improving the dehydration efficiency of sludge. The sewage treatment plant was designed on a scale of 200,000 m$^3$/d treatment, with a total water volume change coefficient of 1.3, a high efficacy clarification tank, and a steel mixing structure with a size of 92.25m×31.85m×5.7m and a design flow of 6 grids. The main design parameters and supporting equipment in each reaction area of the high efficacy clarification tank were as follows.

**MIXED AREA**

In the mixed area, a polymerized ferric chloride solution was added, a mechanical mixture was used, and a two-stage mixture was established. The single size was 2.8m×2.4m×8m, and the mixing time is 40 seconds. Each lattice was equipped with a mixed mixer, and the single power is 7.5 kW.
FLOCCULATION AREA

In the flocculation area, polyacrylamide (PAM) was added, and 2 cells per lattice were efficiently clarified, each cell size was 8.1m×7.2m×5.7m, and the flocculation time was 8 min; Each cell was equipped with a set of blender, which consists of a guide tube and a stirring power of 4.5 kW.

TRANSITION ZONE

A 1.6m-wide transition zone was arranged between the flocculation area and the precipitation area.

THE SEDIMENT AREA

The sediment area had the effect of sludge sedimentation and sludge concentration. The sedimentation uses an oblique tube sedimentation tank with a surface load of 14.4m³/(m²・h), a single lattice size of 14.4m×12.5m×5.7m, and a residence time of 30 min; The oblique tube was 1m long and the tilt angle was 60 °.

The high efficacy clarification tank removed 5tDS/d of dry sludge every day. The sludge moisture content was 98.5% and the sludge content was 333m³/d. Two sludge screw pumps were installed in each tank pipe gallery, of which one was a reflux pump, the other was a residual sludge pump. The tank had A total of 8 sets, a single pump flow was 20m³/h, lift was 20m, power was 4kW.

Fiber Rotary Filter

Fiber rotary filter mainly depended on mechanical sieve filtration, which had a certain effect of adsorption and biodegradation. There was set up a fiber rotary filter tank, steel mix structure, design scale of 200,000m³/d, design average filter speed 7.9m/s, maximum filter speed 10.2m/s. The filtration room had a plane size of 28.5m×9.0m, a total of 6 fiber turntable filters, a single cell size was 4.5m×4.0m×4.9m, and a set of turntable filtration equipment per cell filter. The number of Turntable was 14 discs per set. The turntable diameter was 3.0m, The single disk filtration area was 12.6m², the filtration hole diameter was 10μm, and the motor power was 0.75kW; The tank set up two reverse flushing pumps, flush water flow was 50m³/h, H=70kPa, N=2.2kW, and water supply for gap. This section must be in two columns.

Disinfection Contact Tank

There had set up a contact disinfection tank, divided into 2 cells, each size was 38m×24m×4m, contact time was 30min. Liquid chlorine was used for disinfection and the chlorine content was 10mg/L.
**Strong Pump Room**

There was a strong row pump room with a size of 30m×11.4m×4m was equipped with 4 diving sewage pumps(3 with 1 reserve, flow rate was 3650m³/h, lift was 63kPa, motor power was 80kW), each pump was controlled by the PLC system. And according to the accumulated running time automatically alternate running, and set up manual control.

**Chlorinated Room**

There was one injection room with a plane size of 30m×12m. The flocculant was polymerized ferric chloride with an average addition of 30mg/L and a concentration of 10%. There were 3 solution pools(a single pool with an effective capacity of 53m³) and a total of 5 diaphragm metering pumps(4 with 1 preparation, a single flow of 1650m³/h, a pressure of 0.4MPa, and a motor power of 1.5kW). The coagulant used polyacrylamide(PAM) and there was equipped with a PAM solution preparation unit(4000L/h for addition and 1.5kW for motor power). There were 3 diaphragm metering pumps(2 with 1 preparation, single flow was 2000L/h, and the pressure was 0.6MPa. The motor power was 1.5kW), the amount of addition was 1.0mg/L, and the concentration of addition was 0.4%.

**OPERATION RESULTS ANALYSIS**

**Analysis of Influent and Effluent Quality**

The raw water of the sewage treatment plant was mainly derived from wastewater discharged by industries and enterprises in the catchment area and all integrated domestic sewage in the city. After more than a year, the real-time monitoring of the influent and effluent quality was shown in table III. From the table, it can be seen that the water quality index value of the water entering the factory was significantly reduced after the depth treatment of the sewage after the higher concentration of pollutants and the greater fluctuation of the water quality. Which meet the requirement of grade A of pollutant discharge standard of urban sewage treatment plant (GB 18918-2002). Among them, the average removal rate of BOD5, SS, NH3-N was more than 94%, and the average removal rate of COD and TP was also more than 87%.
TABLE III. INFLUENT AND EFFLUENT QUALITY OF WASTEWATER TREATMENT PROCESS.

<table>
<thead>
<tr>
<th>Project</th>
<th>COD (mg/L)</th>
<th>BOD\textsubscript{5} (mg/L)</th>
<th>SS (mg/L)</th>
<th>NH\textsubscript{3}-N (mg/L)</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Influent</td>
<td>45.6~451.</td>
<td>54.9~121.0</td>
<td>51.0~145.0</td>
<td>6.1~39.8</td>
<td>22.8~41.0</td>
<td>0.8~5.9</td>
<td>6.8~9.0</td>
</tr>
<tr>
<td>Actual effluent</td>
<td>11.0~45.1</td>
<td>2.3~6.3</td>
<td>2.0~9.0</td>
<td>0.02~4.8</td>
<td>5.7~11.9</td>
<td>0.06~0.5</td>
<td>6.6~7.7</td>
</tr>
<tr>
<td>Average removal</td>
<td>87.3</td>
<td>94.4</td>
<td>94.1</td>
<td>94.5</td>
<td>74.5</td>
<td>88.4</td>
<td></td>
</tr>
<tr>
<td>rate(%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note, Value in table ( ) is average.

Analysis on the Removal Effect of Organic Substances

In sewage treatment, organic matter is an important indicator of water quality, and its removal effect directly affects whether sewage can be discharged or not. Changes in the intake and outflow of COD and BOD\textsubscript{5} from the plant during the year were shown in figures 2 and 3. From the figure, it could be seen that the intake COD varies greatly within one year. The COD values in May, September, and October were low, while the values in other months were higher, especially in January-March. The maximum could reach 450.98 mg/L. After advanced treatment of sewage, the COD value of the effluent was between 11.03 and 45.07 mg/L, and the removal rate was 76.5 to 92.4 %. The COD value met the requirements for the
design of sewage discharge standards. Compared with COD, the change of BOD$_5$ in raw water was not large. Relatively speaking, the value of BOD$_5$ in February and March was higher. After the advanced treatment of sewage, the value of BOD$_5$ in water was 2.31~6.31mg/L. The limit of 10mg/L for water effluent was greatly reduced, and the removal rate of water outflow was 90.7 to 97.3%. It can be seen that the processing process can achieve good results for the removal of BOD$_5$. This is mainly due to the role of biological turntable filters in the advanced treatment system, so that the biodegradable organic matter has been greatly removed.

Figure 3. Results of BOD$_5$ of tertiary sewage treatment effluent.

Figure 4. Results of SS of tertiary sewage treatment effluent.
Analysis on The Removal Effect of SS

The concentration of intake SS was 51.00~145.00mg/L. There were certain differences between months. Overall, the SS values in September and October were lower. After treatment, the SS value of the effluent reached 2.00~9.00mg/L, which met the discharge requirements of the sewage plant. In the year, the removal rate of SS was 90.1~97.2%, which achieved a good removal effect. In this process, the removal of SS in addition to the contribution to SS in the primary and secondary processes, so that the SS value can be further reduced to less than 10mg/L, which was mainly the role of the efficient clarification.

Effect Analysis of Denitrification

![Figure 5. Results of TN of tertiary sewage treatment effluent.](image)

TN and NH3-N are important parameters of sewage and are also important indicators of control in sewage treatment. Changes in the intake and outflow of TN and NH3-N from sewage plants during the year were shown in Figures 5 and 6. The TN change range in incoming water was 22.79~40.97mg/L, and the TN value in different months of the year did not change much. The variation range of TN in effluent was 5.65 to 11.89 mg/L, which met the requirements of the 15 mg/L limit of the sewage discharge standard. The removal rate of TN is 74.5~94.6%. Compared with TN, the changes in intake NH3-N were larger, ranging from 6.09 to 39.84mg/L, and the value of NH3-N from April to October was lower. During the year, the NH3-N value of the effluent was 0.02 to 4.77 mg/L, which well met the requirements of the sewage discharge standard. The removal rate of NH3-N was 87.2 to 98.6%. In this process, the removal of TN and NH3-N was mainly done in the biological turntable filter.
Figure 6. Results of NH$_3$-N of tertiary sewage treatment effluent.

Analysis on the Effect of Phosphorus Removal

During the year, the changes in TP entering and exiting the water were shown in Figure 7. It could be seen from the figure that the concentration of TP in incoming water varies greatly, with a range of 0.81 to 5.94 mg/L, of which the values of TP in February and March were large. The value of TP in effluent was 0.06 to 0.48 mg/L, which satisfied the requirements of sewage discharge. The removal rate of TP was
74.5 to 94.6%. Similar to the removal of nitrogen, in this advanced treatment, the removal of TP was mainly done in the biological turntable filter.

CONCLUSIONS

The sewage treatment plant adopted a high-efficiency clarification tank and fiber rotary filter combination process, and the water quality index value of the factory water had been significantly reduced, which met the Grade A standard in the "pollutant discharge standard" of the urban sewage treatment plant, in order to design and operate similar sewage plants, which had a certain reference role.

ACKNOWLEDGEMENT

Project information: Jilin province education department "13·5" science and technology project, JJKH 20181346 KJ.

REFERENCES