Design and operation effect of corn starch wastewater treatment project

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Abstract. The corn starch wastewater was treated by the combination of “IC anaerobic + two-stage AO biochemical + modified Fenton”. The design parameters and treatment effects of the main construction sections of the project were introduced. The operation results of the project show that the combined process has a good treatment effect on corn starch wastewater. In the case where the average concentration of COD in the influent water is 17640 mg/L, the average concentration of NH$_3$-N is 91.1 mg/L, and the average concentration of TN is 1266 mg/L. The average concentration of the COD, NH$_3$-N and TN in the effluent water after treatment are 36 mg/L, 1.2 mg/L and 11.6 mg/L, respectively, which meets the design standard requirements. The process control method of using some high-concentration organic wastewater beyond the anaerobic section can achieve the standard treatment of total nitrogen without the need of external supplementary carbon source, which has significant economic benefits.

1. Introduction
Starch is an important industrial raw material. It is widely used in addition to edible and processed foods, especially in textile, paper, medicine, fermentation, casting, gluing, chemical, machinery and drilling industries. It plays an important role in national economic production [1-4]. The starch industry is an industry that produces starch or starch deep-processed products (starch sugar, glucose, starch derivatives, etc.) from agricultural products such as corn, potato, wheat, and rice. The starch industry needs about 1.7 tons of raw materials to get 1t products. In the production process, the water demand is large, as well as the wastewater discharge. Moreover, the wastewater is an organic wastewater containing a large amount of organic matter such as starch, protein, sugar, fat, etc., which is difficult to handle [5-7]. In domestic starch production, 80% of the raw materials are derived from corn, and the main sources of corn starch wastewater are dry corn conveying washing water, corn soaking water, germ separation, yellow pulp wastewater and other processes [8-10].

In this context, this study takes the wastewater treatment project of a corn starch production enterprise in Binzhou, Shandong Province as an example. The process flow of the wastewater treatment project, the design parameters of the main structures and the operation results are introduced in detail, in order to provide reference for the design and operation of the same type of wastewater treatment project.

2. Design scale and design of wastewater treatment engineering
According to the amount of wastewater generated in the production process of the enterprise, the designed wastewater treatment scale of the project is 800m$^3$/d.
According to the measured data of wastewater generated by the enterprise, the influent water quality of the project is shown in Table 1.

| index               | CODcr (mg/L) | SS (mg/L) | pH     | TN (mg/L) | CL\(^-\) (mg/L) | SO\(_4^{2-}\) (mg/L) | Water temperature(℃) |
|---------------------|--------------|-----------|--------|-----------|------------------|-----------------------|-----------------------|
| concentration       | ≤20000       | ≤1000     | 4.0~6.0 | ≤1000     | ≤1200            | ≤500                  | 35~50                 |

According to the wastewater discharge standard of the locality of the enterprise, the water quality of the designed effluent of the project is determined, as shown in Table 2.

| index               | CODcr (mg/L) | SS (mg/L) | pH     | NH\(_3^-\)N (mg/L) | TN (mg/L) |
|---------------------|--------------|-----------|--------|---------------------|-----------|
| concentration       | ≤50          | ≤10       | 6.0~9.0 | ≤5                  | ≤15       |

3. Process flow and description of wastewater treatment project

According to the water quality characteristics of corn starch wastewater, combined with the main characteristics of the pollutants to remove the required process conditions, the use of "IC anaerobic + two-stage AO biochemical + modified Fenton" combination process as the main process through the comprehensive process comparison. The process flow is shown in Figure 1.

Process description: The drainage of the workshop flows into the lifting pool for adjustment, and then lifted to the protein sedimentation tank by the lift pump for solid-liquid separation. The protein deposited at the bottom of the tank is pumped to the workshop for recycling. The sediment clearing liquid is self-flowing into the pre-acidification tank. The pool is hydrolyzed and acidified. The effluent from the pre-acidification tank is pumped into the IC anaerobic reactor. The organic pollutants in the wastewater are converted into methane and other substances in the anaerobic reactor. The anaerobic reactor effluent flows into the anaerobic sediment. The tank intercepts the sludge lost from the anaerobic reactor. The sludge at the bottom of the anaerobic sedimentation tank is periodically returned to the IC anaerobic reactor by the pump or periodically discharged to the sludge concentration tank. The effluent of the anaerobic sedimentation tank sequentially flows into the first-stage anoxic tank, the first-stage aerobic tank, the second-stage anoxic tank, the second-stage aerobic tank and the second settling tank, to achieve efficient removal of COD, NH\(_3^-\)N, TN, TP and other pollutants in wastewater, and protein precipitation from the reaction process. During the reaction, it is necessary to pass some high-concentration wastewater from the protein sedimentation tank to the first-stage anoxic tank and the second-stage anoxic tank. In addition to the nitrification carbon source, the soda ash should be replenished to the primary aerobic tank and the secondary aerobic tank during the reaction to balance the alkalinity consumed during the nitrification reaction. The secondary aerobic tank outlet is provided with an internal reflux pump to return the nitrifying liquid to the first-stage anoxic tank. The secondary settling tank is provided with a sludge return pump to return the sludge to the first-stage anoxic tank to maintain the biomass of the two-stage AO biochemical system. The mud pump of the secondary settling tank periodically discharges the excess sludge to the sludge concentration tank. The secondary sedimentation tank effluent flows into the modified Fenton reaction sedimentation tank for advanced treatment. The biochemical residual pollutants are further removed by sequentially adding sulfuric acid, ferrous sulfate, hydrogen peroxide, caustic soda, and PAM agents to the modified Fenton reaction tank. The solid-liquid separation and water purification are realized through the sedimentation tank, and the COD, color, TP and SS pollutants in the wastewater are efficiently removed, and the effluent reaches the standard discharge. The sludge in the sludge concentration tank is concentrated and then sent to a stacked screw sludge dewatering machine for dewatering, and the dewatered sludge is transported for disposal.
4. The main building design of wastewater treatment project

The designed wastewater treatment scale of this project is 800m³/d. The design parameters of each main building are shown in Table 3.

| Number | The name of the structure               | structure type                                | parameter                                                                 |
|--------|----------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------|
| 1      | Lifting pool                           | Rectangular pool of underground steel truss structure | Effective volume: 300m³                                           |
| 2      | Protein precipitation tank             | Integrated steel equipment                   | Surface load: 0.7m³/m²·h                                               |
| 2      | Pre-acidification tank                 | Rectangular pool of underground steel truss structure | Effective volume: 400m³                                           |
| 3      | IC anaerobic reactor                   | Integrated steel equipment                   | Equipment size: ø9.0m×20.0m                                          |
| 4      | Anaerobic sedimentation tank           | Integrated steel equipment                   | Surface load: 0.7m³/m²·h                                               |
| 5      | Primary anoxic pool                    | Rectangular pool of steel raft structure on semi-ground | Net size: 20.0mx10.0mx6.5m, Designed sludge concentration: 3000mg/L, Denitrifying sludge load: 0.036kg/( kgMLSS.d), COD load: 0.08kgCOD/( kgMLSS.d), Ammonia nitrogen load:0.05kgNH₃⁻-N |
| 7      | Primary aerobic pool                   | Rectangular pool of steel raft structure on semi-ground | Residence time: 3.6d, Designed sludge concentration: 3000mg/L, COD load: 0.08kgCOD/( kgMLSS.d), Ammonia nitrogen load:0.05kgNH₃⁻-N |

Figure 1. Process flow chart for wastewater treatment
5. Operation effect of wastewater treatment project
Since the commissioning of the project in May 2018, the operation effect has been stable, and the effluent water quality has reached the discharge standard. The workshop laboratory performs daily routine sampling tests on each section. Through the statistical analysis of the routine test data of the workshop laboratory on April 1, 2019 and June 30, 2019 for three consecutive months, the treatment effects of COD, NH$_3$-N and TN in each section of the project were obtained, as shown in Table 4.

Table 4. Treatment effects of COD, NH$_3$-N and TN in various sections of the project

| The name of each work section | COD | NH$_3$-N | TN  |
|-------------------------------|-----|----------|-----|
| Protein precipitation tank    | Influent average (mg/L) 17640 | 91.1 | 1266 |
| Hydrolysis acidification + IC anaerobic reactor + anaerobic sedimentation tank | Influent average (mg/L) 15560 | 96.7 | 710.2 |
| Primary anoxic pool + Primary aerobic pool + Secondary anoxic pool + Secondary aerobic pool + Second settling pool | Influent average (mg/L) 866 | 596.5 | 667.5 |
| Modified Fenton reaction sedimentation tank | Influent average (mg/L) 95 | 1.3 | 12.1 |
| Modified Fenton reaction sedimentation tank | Average effluent (mg/L) 36 | 1.2 | 11.6 |

It can be seen from Table 4 that the corn starch wastewater treatment project using the "IC anaerobic + two-stage AO biochemical + modified Fenton" combination process has good treatment...
for major pollutants such as COD, NH$_3$-N and TN, etc. In the case where the average concentration of COD in the influent water is 17640 mg/L, the average concentration of NH$_3$-N is 91.1 mg/L, and the average concentration of TN is 1266 mg/L. The average concentration of the COD, NH$_3$-N and TN in the effluent water after treatment are 36mg/L, 1.2mg/L and 11.6mg/L, respectively, stable to meet the design standards.

The project supplements the effluent of some protein precipitation tanks beyond the IC anaerobic reactor, and supplements the high-concentration organic wastewater to the primary anoxic tank and the secondary anoxic tank. The proportion of wastewater exceeding the partial wastewater accounts for 5%-10% of the total wastewater, which is realizes the standard treatment of total nitrogen without external carbon source, and greatly saves the cost of supplementation of denitrification carbon source, has significant economic advantages.

The project achieves the high-efficiency denitrification treatment effect of the biochemical treatment process through the combination of two stages of AO, and the total nitrogen removal efficiency reaches over 98%, which greatly improves the operational stability of the denitrification treatment process, and simultaneously exceeds the IC anaerobic reactor. The nitrification and denitrification of organic nitrogen species carried by high-concentration organic wastewater have created favorable conditions.

This project uses the modified Fenton process as an advanced treatment measure for biochemical wastewater, achieving good treatment results, COD removal efficiency of more than 60%, and synergistically efficient removal of TP and SS in wastewater, laying a foundation for stable discharge of wastewater.

6. Conclusion
The corn starch wastewater was treated by the combination of “IC anaerobic + two-stage AO biochemical + modified Fenton”. The design parameters of the main construction sections of the project were introduced, and the treatment effects of the main sections of the project were counted. The actual operation results of the project show that the combined process has good treatment effect on corn starch wastewater. The average concentration of COD, NH$_3$-N and TN in the treated effluent were 36mg/L, 1.2mg/L and 11.6mg/L in the case of the average concentration of COD, NH$_3$-N and TN in the influent of the project were at 17640 mg/L, 91.1 mg/L and 1266 mg/L, respectively, which was stable to meet the design standards. The process of using some high-concentration organic wastewater to surpass the anaerobic section can achieve the standard treatment of total nitrogen without external carbon source, and had significant economic benefits.

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