Advanced Treatment of Printing and Packaging Production Wastewater

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Abstract. Aiming to ensure the quality of final effluent, combined with the existing research reports and similar engineering experience, the process of "Coagulation Sedimentation Contact Oxidation MBR" is selected as the main body to treat the wastewater in this paper. After the wastewater treatment system operates normally for one year, the results show that the removal rates of COD, BOD₅, SS and chroma can reach 97.8%, 97.7%, 97.4% and 96.0% respectively, and the corresponding effluent concentrations are 96 mg/L, 25 mg/L, 18 mg/L and 20 mg/L, respectively, which meets and is better than the secondary discharge standard of the Integrated Discharge Standard of Water Pollutants in Haihe River Basin of Shandong Province (DB37/675-2007). The process has certain engineering advantages as the quality of wastewater treatment is high and the total cost of electricity and medicament for the wastewater treatment is low.

1. Introduction
Packaging and printing industry is closely related to people's life, covering almost all kinds of industries. With the rapid development of the industry, the amount of wastewater in the production process is increasing rapidly, and the impact on the environment is also increasing [1]. The growth wastewater of the carton packaging industry is mainly composed of ink wastewater and starch wastewater, among which ink wastewater is mainly produced in the processes of color matching, printing, cleaning printing equipment, etc., and starch wastewater is mainly produced in the process of tile paste [2]. The wastewater has the characteristics of complex composition, high chemical oxygen demand (COD), high chroma, high starch content and poor biochemical properties, which makes it be more difficult to treat the wastewater [3]. Therefore, it is necessary to research the treatment of wastewater of the carton packaging industry.

At present, the treatment methods of the wastewater include electrolysis, biochemistry, coagulation and membrane separation, and the method of coagulation has been widely used owing to its simple operation and high efficiency [4]. However, because of the high cost of single treatment method and cannot guarantee all water quality indexes meet the standard discharge, combined method is often used in practical engineering to deal with it effectively [5], including coagulation flocculation [6] and coagulation biochemical [7].
It is an effective way to study the wastewater treatment by taking the actual engineering example as sample. Aiming to ensure the quality of final effluent, combined with the existing research reports and similar engineering experience, the process of "Coagulation Sedimentation Contact Oxidation MBR" is selected as the main body to treat the wastewater in this paper, and the results are analyzed and discussed.

2. Process and Methods

A corrugated box packaging plant which produces about 100 m³ of production wastewater per day was selected as a sample. The main pollutants are ink, developer, waste oil, starch, cleaning residue produced by daily equipment maintenance, and a small amount of insoluble impurities. Starch is mainly produced in starch wastewater, and the rest pollutants are mainly produced in ink wastewater [8]. The main water quality indexes and discharge standards are shown in Table 1.

| Index/water quality         | pH  | COD (mg/L) | BOD₅ (mg/L) | SS (mg/L) | Chroma (Times) |
|-----------------------------|-----|------------|-------------|-----------|----------------|
| Effluent Quality            | 6~8 | 4350       | 1100        | 700       | 500            |
| Discharging standard        | 6~9 | 100        | 30          | 70        | 50             |

2.1. Technological process

In view of the characteristics of simple composition and high COD of starch wastewater, the wastewater was pretreated separately to remove most of starch and reduce COD, and then mixed with ink wastewater for treatment. The process flow is shown in Figure 1.

As shown in Figure 1, the starch wastewater from the workshop flows into the regulating tank I after removing the suspended solids with large particle size by the artificial grille interception. After homogenizing the water quality and quantity, it is sent to the coagulation sedimentation tank I through the lifting pump I. Most of the starch in the wastewater is removed by sedimentation, and the supernatant flows into the regulating tank II to mix with the ink wastewater. The printing ink wastewater intercepts the large-size suspended solids by the mechanical grille, and then flows into the regulating tank II, and joins with the pretreated starch wastewater. The mixed wastewater is lifted to coagulation sedimentation tank II by the lift pump II, PAC and PAM are added successively to make the suspended solids in the wastewater form floc sedimentation, and the supernatant flows to the contact oxidation tank. Under the condition of reasonable aeration and oxygen supply, the organic matter is effectively degraded by the microbial action attached to the biofilm filler. The effluent flows to the MBR tank by itself, and the organic matter is further decomposed and transformed under the action of high concentration activated sludge. The filtration function of MBR can intercept most of the pollutants in the wastewater and reduce the color of the effluent. The effluent is sent to the clear water tank through the production pump, and can be reused for greening water in the plant or directly discharged after disinfection. Or the occasionally substandard wastewater, it is transported to the regulating tank II by the standby pump for further treatment.

The sludge produced by coagulation sedimentation tank I (mainly composed of starch), the sludge produced by coagulation sedimentation tank II and the surplus sludge from MBR tank are all transported to the sludge tank, which is dewatered by a spiral screw dehydrator and then transported out for disposal.

2.2. Design of process unit

2.2.1. Regulating tank I. There is one set of regulating tank, with a design capacity of 15 m³/d, which regulates the water quality and quantity of starch wastewater. Its size is 3.0 m×2.0 m×2.5 m, and the effective volume is 12 m³. Its material is carbon steel and its inner wall is treated with anti-corrosion.
Supporting equipment: one set of artificial grille (the grid gap is 5 mm, the material is SS304); two starch wastewater lifting pumps (one for use and one for standby, the is flow 3 m³/h, the power is 1.1 kW); one set of floating ball level meter; 1 set of mixer (the power is 1.5 kW).

2.2.2. Coagulation sedimentation tank I. There is one set of coagulation sedimentation tank with a design capacity of 15 m³/d, which is divided into reaction area and sedimentation area. Starch wastewater contains some suspended solids which are not suitable for precipitation, and the concentration of organic matter is high and it is difficult to treat. In order to reduce the load of subsequent biochemical treatment unit, PAC and PAM are added in the reaction zone to coagulate starch to form flocs that are easier to precipitate [9, 10]. The concentrations of PAC and PAM are 8% and 0.1% respectively. The starch in the water is precipitated and separated by gravity in the sedimentation area, and then transported to the sludge tank by sludge pump. The total size of coagulation sedimentation tank is 2.0 m×3.0 m×2.5 m (the size of reaction area is 2.0 m×1.5 m×2.5 m, and the size of precipitation area is 2.0 m×1.5 m×2.5 m), and the material is carbon steel, and the inner wall is anticorrosive.

Supporting equipment: one mixer (the power is 1.5 kW); one set of PAC automatic dosing system (one PE dosing barrel the volume of 1.5 m³; two sets of metering pump with power of 0-160 L/h, one for use and one standby; one set of mixer with power of 0.55 kW); one set of PAM automatic dosing system (one PE dosing barrel the volume of 1.5 m³; two sets of metering pump with power of 0-160 L/h, one for use and one standby; one set of mixer with power of 0.55 kW); one set of sludge pump (the flow is 2.0 m³/h, the power is 1.1 kW).
2.2.3. **Regulating tank II.** There is one set of regulating tank, with a design capacity of 100 m³/d, which can absorb the effluent of coagulation sedimentation tank I and ink wastewater, buffer the water quality and water quantity, and ensure the reasonable pH value required by the subsequent coagulation, so as to ensure the normal operation of the follow-up treatment facilities. Its size is 5.0 m × 4.0 m × 3.5 m, and its effective volume is 60 m³. Its material is carbon steel and its inner wall is treated with anti-corrosion.

Supporting equipment: one set of rotating machinery fine grille (the grid gap is 2 mm, the design flow rate is 5 m³/h, the motor power is 1.1 kW); two sets of sewage lifting pumps (one for use and one for standby, the flow rate is 5 m³/h, the power is 1.1 kW); one set of floating ball liquid level meter.

2.2.4. **Coagulation sedimentation tank II.** There is one set of coagulation sedimentation tank which is divided into reaction area and sedimentation area. PAC and PAM are successively injected into the reaction area for coagulation reaction, so that the suspended particles in the wastewater become larger flocs, which is conducive to solid-liquid separation [11]; among them, PAC and PAM concentrations are 10 % and 0.2 % respectively. The floc sludge in the water is precipitated and separated by gravity in the sedimentation area, and then transported to the sludge tank by the sludge pump, and the effluent flows out from the triangular overflow weir plate of the sedimentation area to the contact oxidation tank. Its total size is 3.0 m × 3.0 m × 2.5 m (the size of reaction area is 3.0 m × 1.0 m × 2.5 m, and the size of precipitation area is 3.0 × 2.0 m × 2.5 m), the material is carbon steel, and the inner wall is treated with anti-corrosion.

Supporting equipment: one mixer (the power is 1.1 kW) in reaction area; one sludge pump (the flow rate is 2.0 m³/h, the power is 0.55 kW); one set of PAC automatic dosing system (one PE dosing barrel the volume of 1.5 m³; two 2 sets of metering pump with power of 0-160 L/h, one for use and one standby; one set of mixer with power of 0.55 kW); one set of PAC automatic dosing system (one PE dosing barrel the volume of 1.5 m³; two 2 sets of metering pump with power of 0-160 L/h, one for use and one standby; one set of mixer with power of 0.55 kW).

2.2.5. **Contact oxidation tank.** There is one set of contact oxidation tank with a design capacity of 100 m³/d, converts organics such as BOD in starch and ink wastewater into energy substances and inorganic substances such as CO₂ and H₂O under the physiological action of aerobic microorganisms, so as to realize the reduction of pollutants [12, 13]. The design size is 5.0 m × 4.0 m × 3.5 m, and the capacity is 60 m³. The material is carbon steel and the inner wall is anticorrosive.

Supporting equipment: biological packing 60 m³ (braided belt packing, the specification is φ 25mm); aeration pipe (perforated pipe DN25 PVC); two aeration fans (one for use and one for standby, the power is 7.5 kW).

2.2.6. **MBR tank.** There is one set of MBR tank with a design capacity of 100 m³/d, which is used to further remove organic matters and most suspended substances in the effluent of contact oxidation tank by using high concentration activated sludge in MBR tank and membrane filtration function, so as to realize the advanced purification treatment effect of mixed wastewater [14,15]. Its design size is 4.5 m × 3 m × 3.5 m, the material is carbon steel, and the inner wall is anticorrosive.

Supporting equipment: one membrane module (the frame material is SS304; 80 hollow fiber microfiltration membrane, the specification is 6 m²/piece, the material is PVDF), two water production pumps with frequency converter (one for use and one for standby, with flow rate of 10 m³/h, power of 1.5 kW, suction distance of 4.5 m); two sludge return pumps (one for use and one for standby, with flow rate of 10 m³/h, power of 1.1 kW). There are two sets of membrane cleaning system (one set of NaClO cleaning and dosing system, one set of citric acid cleaning and dosing system), one set of backwashing water pump (with flow rate of 15 m³/h, power of 2.2 kW), one pipe mixer (DN50, the material is PE), aeration fan (shared with matching fan of contact oxidation tank), and one sludge pump (with flow rate of 5.0 m³/h, power of 1.1 kW).
2.2.7. Clear water tank. There is one set of clear water tank which is used for temporary storage of MBR effluent for plant greening, road watering or direct discharge. The design size is 3.0 m×2.0 m×3.5 m, and the material is carbon steel, and the inner wall is anticorrosive.

Supporting equipment: disinfection equipment (shared with membrane cleaning system and sodium hypochlorite cleaning and dosing system)

2.2.8. Sludge system. There is one sludge thickening tank to concentrate the excess sludge discharged from the coagulation sedimentation tank and MBR tank to reduce the load of the sludge dehydrator. Its capacity is 5 m³, the material is carbon steel, and the inner wall is anticorrosive.

Supporting equipment: two sludge pumps (one for use and one for standby, pneumatic diaphragm pump, with maximum flow of 8.0 m³/h); One mixer (1.5 kW×98 RPM) and one spiral dehydrator (processing capacity of 3 ~ 6 kg-DS/h, the power is 0.75 kW).

3. Results and discussion

3.1. The effect of wastewater treatment

After commissioning, the wastewater treatment system operates normally for one year. During this period, the effluent quality is stable and the effect is good. The main pollutant indexes such as COD, BOD₅, SS and chromaticity meet the design effluent quality requirements, which are 96 mg/L, 25 mg/L, 5 mg/L and 20 times respectively, which is significantly better than the secondary discharge standard of DB37/675-2007. The water quality of each main treatment unit is shown in Table 2.

Table 2. List of processing efficiency of the main structures

| Main processing unit         | Index | COD (mg/L) | BOD₅ (mg/L) | SS (mg/L) | Chroma (Times) |
|------------------------------|-------|------------|-------------|-----------|----------------|
| Grille                       | Inlet | 4350       | 1100        | 700       | 500            |
|                              | Effluent | 4220         | 1080       | 680       | 470            |
|                              | Removal rate | 3.0%                   | 1.8%       | 2.9%       | 6.0%            |
| Regulating tank I            | Effluent | 4110         | 1070       | 640       | 450            |
|                              | Removal rate | 2.6%                   | 0.9%       | 5.9%       | 4.3%            |
| Coagulation sedimentation    | Effluent | 2260         | 960        | 190       | 90             |
| tank II                      | Removal rate | 45.0%                   | 10.3%      | 70.3%      | 80.0%           |
| Contact oxidation tank       | Effluent | 790          | 280        | 160       | 70             |
|                              | Removal rate | 65.0%                   | 70.8%      | 15.8%      | 22.2%           |
| MBR                          | Effluent | 96           | 25         | 18        | 20             |
|                              | Removal rate | 87.8%                   | 91.1%      | 88.8%      | 71.4%           |

3.2. Technical and economic analysis

The total installed power of electrical equipment in the wastewater treatment system is 45 kW. According to the statistics of stable operation period of the system, the daily power consumption of 100 m³ wastewater treatment is 810 kW·h/d, the electricity charge is 0.8 yuan/kW·h, and the electricity charge for wastewater treatment is 6.48 yuan/m³. Based on 2800 yuan/t and 24000 yuan/t, the cost of PAC and PAM is 0.90 yuan/m³ and 0.35 yuan/m³ respectively. Under the normal operation condition, the chemical cost is 1.25 yuan/m³, and the unit water treatment cost is 7.73 yuan/m³.
4. Conclusion
For printing and packaging wastewater with high content of refractory organic matter, high chroma and poor biodegradability, the main process of "Coagulation Sedimentation Contact Oxidation MBR" is adopted to treat the wastewater in this paper. After the wastewater treatment system operates normally for one year, the results show that the removal rates of COD, BOD5, SS and chroma can reach 97.8%, 97.7%, 97.4% and 96.0% respectively, and the corresponding effluent concentrations are 96 mg/L, 25 mg/L, 18 mg/L and 20 mg/L, respectively, which meets and is better than the secondary discharge standard of the Integrated Discharge Standard of Water Pollutants in Haihe River Basin of Shandong Province (DB37/675-2007), and the total electricity and medicament costs are 7.73 yuan/m³ of wastewater. Therefore, the process has certain engineering advantages as the quality of wastewater treatment is high and the total cost of electricity and medicament for the wastewater treatment is low.

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