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Low Temperature Start-up of Coating Wastewater Treatment Works

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The purpose of this paper was to realize rapid start-up of coating wastewater treatment works under low temperature. Thermal insulation treatment was carried out to the pool wall and pool top of the reactor, heating equipment was arranged to ensure that the reactor can provide appropriate temperature conditions for the inoculated sludge, the amount of influent water was reasonably controlled to ensure that microorganisms have appropriate proportion of nutrient elements, and the effluent water of the reactor was continuously detected and the biophase of the sludge was continuously observed. The practice results showed that the reactor ran stably, and the effluent water met the requirements on quality of washing water and boiler make-up water in Urban Wastewater Reclamation and Reuse Industrial Water Quality (GB/T 19923-2005). The coating wastewater has a complex composition, a high COD content and poor biodegradability(Sun et al., 2009; Zhang and Li, 2009; Dong et al., 2013) as it contains a large amount of residual acrylic resin, amino resin, nitrocellulose film-forming agent, water-soluble dye colorants, brighteners, surfactants and other additives. The present works processed the coating wastewater by adopting a process of "coagulation-hydrolytic acidification-contact oxidation-sand filtration-activated carbon adsorption". When the project started, the local maximum temperature was about 0 ˚C and the average temperature was -5 ˚C, which was not suitable for the growth of microorganisms. The present works adopted rock wool covered insulation, electric heating system configuration and other measures to ensure successful start-up of the hydrolytic acidification pond and contact oxidation pond.

1. Introduction

The present works mainly dealt with the waste water produced by certain leather company in the processing and finishing processes. The wastewater treatment plant of the company had a designed water volume of 100 m^3/d, which was an average water input of 24h every day. The specific treatment process was shown in Figure 1.

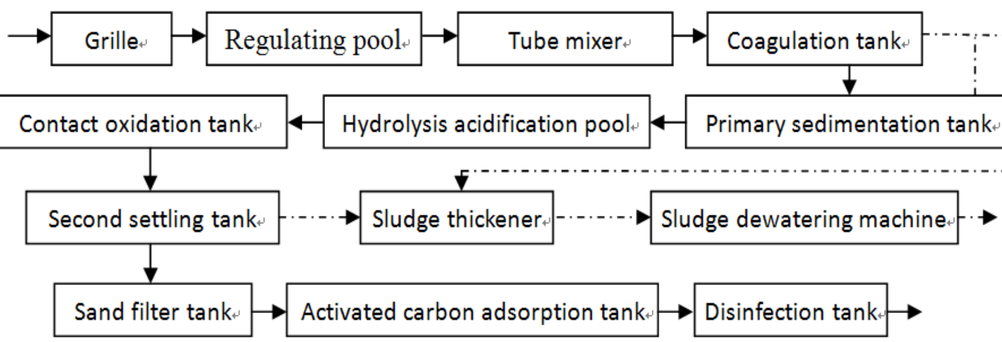

Figure 1: Coating Wastewater treatment process flow chart

The waste water after treatment was mainly used for workshop equipment, floor cleaning and boiler water, therefore the designed effluent water had to meet the requirements on quality of washing water and boiler make-up water in Urban Wastewater Reclamation and Reuse Industrial Water Quality (GB/T 19923-2005). Refer to Table 1 for water quality standards that the designed influent water and the effluent water had to meet.

Table 1: Standards of influent water quality and effluent water quality

Project	pH	SS /(mg·L^{-1})	Chroma /times	COD /(mg·L^{-1})	BOD /(mg·L^{-1})	Ammonia nitrogen /(mg·L^{-1})	Total phosphorus /(mg·L^{-1})	Coliform /L^{-1}
Influent water quality	6~8	1000~ 2000	300~500	2500~ 3000	450~500	50~65	1.5~3.0	>12 000
Effluent water quality standard	6.5 ~ 8.5	≤30	≤30	≤60	≤10	≤10	≤1	≤2 000

2. Low temperature start-up of coating waste water

2.1 Thermal insulation materials

Rock wool with the characteristics of low price, long-lasting insulation and heat insulation is widely used in buildings, external wall external thermal insulation, and roof and curtain wall external thermal insulation. The pond wall of the present works adopted rock wool to preserve heat, the thickness of the insulation layer was 30mm, the size of the plates was 1000×500×30 (length × width × thickness), the thermal insulation area of primary sedimentation pond was 24.12 m^2, the area of the hydrolytic acidification pond and the contact oxidation pond were both 77 m^2, and the total thermal insulation area was 178.12 m^2. Before the implementation of the thermal insulation, waterproof treatment was performed once to the reinforced concrete walls of the primary sedimentation pond, the hydrolytic acidification pond and the contact oxidation pond, and waterproof crystal cement was painted on the surface once. The roof of the primary sedimentation pond, the hydrolytic acidification pond, and the contact oxidation pond was paved with rock wool insulation board for thermal insulation, the thickness of the insulation layer was 100mm, the size of the plates was 1200×600×100 (length×width×thickness), the top area of the primary sedimentation pond was 11.1 m^2, the top area of the hydrolytic acidification pond and the contact oxidation pond was both 30 m^2 and the total area was 71.1 m^2. The roof insulation cover plate had a detachable function. At the same time, the roof had air vents to which thermal insulation treatment was performed.

2.2 Electric heating system

In addition to thermal insulation treatment, the primary sedimentation pond was additionally disposed with a set of electric heating system. The electric heating system had a built-in water sensor which can detect whether the top of the interior of the heater had water before heating, a built-in adjustable temperature controller which can automatically cut off the power source when the water temperature was too high, two built-in contactors, one of which was for over-temperature power control, the other of which was for constant temperature control. The electric heater was in on-state from the beginning to the end to ensure that the water temperature of the primary sedimentation pond was constant.

2.3 Inoculation temperature

Temperature is one of the important factors that affect the growth and survival of microorganisms. It can directly affect the growth rate of microorganisms, enzyme activity, cell composition and nutritional requirements or indirectly affect the solute solubility, ion transport, cell osmotic pressure and so on. In the activated sludge, mainly the mesophilic microorganisms exist, and their optimum growth temperature is 25~37 ˚C and the minimum growth temperature was 10°C; when the ambient temperature is below 10°C, the vast majority of the mesophilic microorganisms have been unable to metabolize exogenous substance, basically lose activity, and no longer have the ability to degrade the organic matter in the water (Kesavan et al., 2016; Tagliafico et al., 2016; et al, 2016; Li et al., 2006; Widjaja et al., 2017; Humaidah et al., 2017). For the present works, at the beginning of the commissioning, the local maximum temperature was 0 ˚C and the average temperature was -5°C. In order to ensure successful inoculation, the water temperature of the primary sedimentation pond was controlled at about 25℃, the water temperature of the hydrolytic acidification pond can be maintained at 13~18°C, and the water temperature of the contact oxidation pod can be maintained at 10~15°C, basically ensuring the temperature condition required for the survival of the microorganisms.

2.4 Inoculation of sludge

Culture of the activated sludge is divided into natural enrichment culture and artificial inoculation. Usually in summer when the water temperature is high, the biodegradable composition in the influent water is higher, the natural enrichment culture method can be used; in this method, all kinds of microorganisms existing in the raw water were used so that they constantly proliferate in the reactor, the supernatant is removed through static deposition, and then new sewage is injected, this process is repeated time and again until the sludge in the reactor reaches an appropriate sludge concentration. Natural enrichment culture method takes a long time, but after successful cultivation, the operating is stable. Artificial inoculation culture method is to add the bacteria enriched with certain type of pollutants (activated sludge, river sediment, topsoil, etc.) to the reactor, so that the bacteria rapidly proliferate. The culture method takes a short time, but the bacteria are easy to decline, and the stability of the mixed liquid reactor is poor. If the water temperature is lower or the biodegradable components in the water source are less, the artificial inoculation method is adopted (Bai et al., 2013; Zhuo and Zhou, 2009; Shi et al., 2006; Cao et al., 2009).

The sludge inoculated in the present works was taken from the sludge thickener of Lugang Sewage Treatment Plant in Baoding City. The sewage treatment plant mainly dealt with urban sewage with an influent COD of about 300 mg/L. The sludge from the sludge thickener of the sewage treatment plant had higher biological activity, and was suitable as inoculated sludge of the present works. The sludge in the sludge thickener was aerobic sludge with dissolved oxygen of 1.5~2.5mg/L and a sludge concentration of 12580mg/L.

2.5 Influent water

In the present works, microorganism acclimation and the culture of bacteria of urban sewage were carried out synchronously. That is, in the process of cultivation, a gradual water intake operation was adopted so that the microbial population in the activated sludge gradually formed an enzyme system capable of metabolizing a specific industrial wastewater, i.e., coating wastewater. During acclimation, the microorganisms that can break down the coating waste water grow and were reproduced, and the inadaptable microorganisms were eliminated, thus the acclimated activated sludge had the ability to treat the coating waste water (He et al., 2002; Yang et al., 2011; Wang et al., 2003). First, waste water, hot water and activated sludge at a volume ratio of 5:3:2 and 6:3:1 were added into the contact oxidation pond and the hydrolysis acidification pond respectively to be stuffied for 12h. At this time, the microorganisms in the activated sludge were in an adaptation period of growth, the microorganisms basically did not proliferate and adapted to the new environment instead to reserve conditions for proliferation. This 12-hour stuffying provided a stable external condition for the microorganisms to adapt to the new environment. After the 12-hour stuffying, according to a designed amount of influent water, water flowed in for 6h per day, and the contact oxidation pond aerated continuously for the rest of time, the dissolved oxygen concentration remained at about 4mg/L, while the hydrolytic acidification pond did not aerate. The water quality of the effluent was detected every day and a microscopic examination was conducted to the sludge, according to the results, the daily amount of influent water was increased, until the designed amount of influent water was reached.

2.6 Water quality detection and microscopic examination

During the start-up of the reactor, COD change in the hydrolytic acidification pond is as shown in Figure 2:

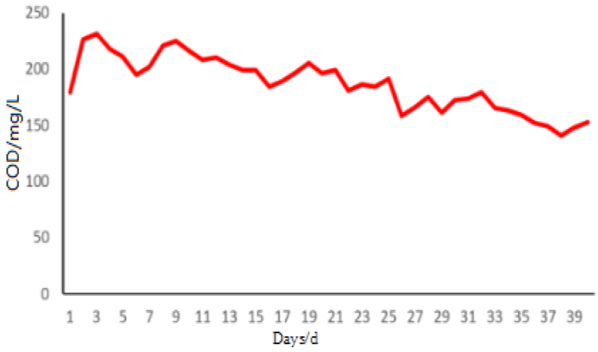

Figure 2: Hydrolytic acidification pond COD change curve

During the start-up of the reactor, the COD change in the contact oxidation pond is shown in Figure 3:

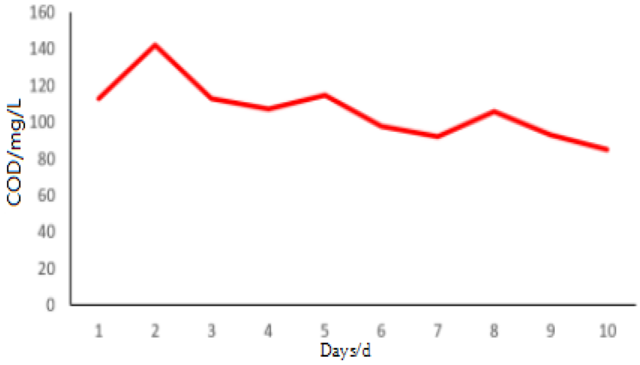

Figure 3: Contact oxidation pond COD change curve

The COD detection results of the hydrolytic acidification pond and the contact oxidation pond in start-up stage showed that the time when the activity of the microorganisms in the contact oxidation pond and the hydrolytic acidification pond was restored and the dominant population was formed were 40d and 10d, respectively. Microscopic examination was constantly conducted to the sludge in the hydrolytic acidification pond and the contact oxidation pond. The microscopic examination result showed that there were a few microorganism species in the hydrolytic acidification pond and the contact oxidation pond at the initial stage of start-up, and a few algae and small protozoa could be observed, and meanwhile some residual bodies of larger protozoa without activity existed. The biophase of the sludge in the hydrolytic acidification pond changed slowly. The number of the microorganisms started to increase obviously after the start-up lasting for half a month. A large number of miniature protozoa and a few ciliates were observed through microscopic examination. The biophase of the sludge in the contact oxidation pond changed faster and more obviously, and a large number of microorganisms could be observed after three to four days of start-up, and protozoa such as vorticellidae and epistylis could be clearly observed. A small amount of paramecium, nematodes, etc. can be observed, indicating good activated sludge (Qi, 2012). After four days of start-up, the biophase of the sludge in the contact oxidation pond started to be stable without bigger changes.

2.7 Nutritional elements

Like other organisms, microorganisms need to constantly absorb nutrient substances from the external environment for metabolism. The amount of carbon source required in the metabolism of the microorganisms is the maximum, providing energy for the microorganism. The influent COD of the coating wastewater of the project reached 2500~3000 mg/L, which can provide sufficient carbon source for the microorganisms in the activated sludge. Since the influent water of the hydrolytic acidification pond and the contact oxidation pond was the sewage after coagulation and sedimentation, COD removal rate was higher; at the start-up stage, phenomenon of higher ratio of the ammonia nitrogen and total phosphorus appeared, thus there was the need to add proper amount of influent water before coagulation and sedimentation into the reactor to supplement carbon source. The lack of nitrogen sources can cause filamentous bacteria to grow or the activated sludge to grow in a disperse way, and also could inhibit the proliferation of the activated sludge; the lack of phosphorus sources would affect enzyme activity and affect the physiological functions of microorganisms. During the start-up process of the hydrolytic acidification pond and the contact oxidation pond, since the influent has a high content of ammonia nitrogen, and at the hydrolytic acidification stage, ammonia nitrogen and total phosphorus in the sewage were increased due to the decomposition of complex organic compounds, the phenomenon of lack of nitrogen source and phosphorus source did not appear.

3. Project processing effect

Commissioning work began on February 9, 2014 and ended on April 25, 2014, and lasted more than 70 days. The start-up and commissioning of the coating wastewater treatment project at a relatively low temperature was realized and the normal production of the enterprise was effectively guaranteed. During normal operation, The actual effluent quality and effluent standards were shown in Figure 4.

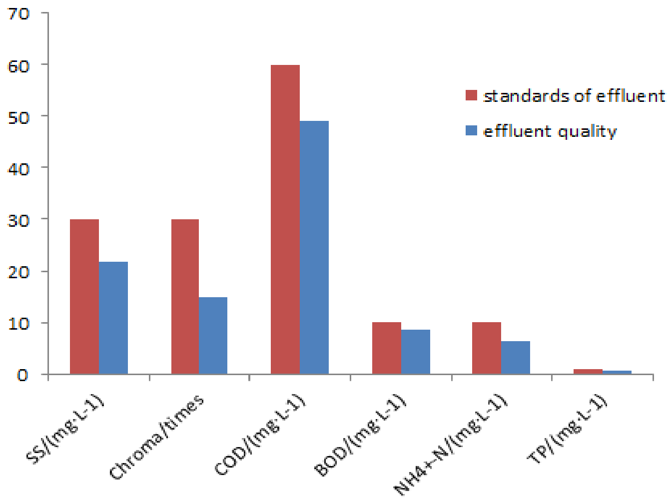

Figure 4: Actual effluent quality and effluent standards comparison chart

Operating results showed that the effluent water quality was stable and design requirements were met. The quality of the effluent water of the main treatment units of the system is shown in Table 2.

Table 2: Effluent water quality of the system main processing units

Project	pH	SS/ $(mg \cdot L^{-1})$	Chroma /times	COD/ $(mg \cdot L^{-1})$	BOD/ $(mg \cdot L^{-1})$	Ammonia nitrogen $/(mg \cdot L^{-1})$	Total phosphorus $/(mg \cdot L^{-1})$	Coliform $/L^{-1}$
Influent water quality	6~8	1000~ 2000	300~500	2500~3000	450~500	50~65	1.5~3.0	>12 000
Primary sedimentation pond	7~9	103.5	100	243.4	50.0	28.31	0.51	>4 000
Hydrolytic acidification pond	6.5~ 8.0	95.8	60	165.5	83.5	42.72	5.62	>4 000
Secondary sedimentation pond	7.5~ 8.5	90.5	40	85.5	27.2	15.64	3.77	>4 000
Sand filtration tank	7.5~ 8.5	54.3	25	59.4	18.1	7.50	1.73	>2 000
Clear water pond	6.5~ 8.0	21.7	15	49.1	8.5	6.20	0.65	≤1 500

4. Conclusions

(1) Under the condition of low temperature, the start-up of the hydrolytic acidification pond and the contact oxidation pond was successfully completed by carrying out thermal insulation to the wall and top of the reactor and adopting the electric heating, the removal rate of COD, ammonia nitrogen, and total phosphorus of the hydrolytic acidification pond and the contact oxidation pond reached a higher level, effluent water was stable, and the effluent water of the entire works reached reuse standard.

(2) Under the condition of external average temperature of -5 ˚C, the water temperature of the hydrolytic acidification pond and contact oxidation pond can be kept above 15 ˚C through rock wool thermal insulation and electric heating measures, which provided suitable and stable environmental conditions for the growth of microorganisms in the sludge.

(3) It was feasible to use the sludge in municipal sewage treatment plant as inoculation sludge to complete the start-up of hydrolytic acidification pond and contact oxidation pond under low temperature condition. During the start-up process, sludge inoculation and acclimation process were monitored by detecting COD of the influent and effluent water and observing biophase.

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