

Research Article

Study on Treatment of Salicylhydroxamic Acid Wastewater from Tungsten Molybdenum Mineral Processing

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Salicylhydroxamic acid is an excellent collector of oxidizing ore, and it has an efficient collection performance for tungsten molybdenum ore. However, the utilization ratio of salicylhydroxamic acid is relatively low in the flotation process, and a large amount of flotation wastewater discharged might cause damage to the water environment. This study mainly compared the effects of natural sunlight degradation, ozonation, and Fenton oxidation processes on the treatment of salicylhydroxamic acid wastewater from W–Mo mineral processing. The results showed after 30 hours degradation by natural sunlight, the COD_{Cr} removal rate of wastewater was only 25.99%. When the initial pH was 8, the dosage of O₃ was 1.3 mg/L and the reaction time was 60 minutes; O₃ oxidation could remove 40.37% COD_{Cr} from wastewater, and the BOD₅/COD_{Cr} value increased to higher than 0.3 after 15 min reaction. Under the Fenton oxidation conditions such as initial pH 3, H₂O₂ dosage 0.96 g/L, and the molar ratio of H₂O₂ to Fe²⁺ 2:1, 90.43% COD_{Cr} could be removed from flotation wastewater after 90 min reaction, and the BOD₅/COD_{Cr} value was obviously improved. Fenton oxidation was a high efficient processing technology for salicylhydroxamic acid wastewater, and the effluent could meet the discharge and reuse emission standard requirements in China.

1. Introduction

W–Mo ore is one of the dominant minerals in China due to abundant reserves, high utilization value, and high economic benefits. According to the data from the China Mineral Resources Report, up to the end of 2016, the national tungsten mineral resource reserves increased by 6% to 101.955 million tons and occupied the first place in the world [1]. A large amount of flotation wastewater was produced during the mineral processing which was the absolutely necessarily tache before utilization of mineral resources Based on statistic data, the water consumption of per ton mineral with flotation is about 4~7 m³, while the gravity separation process is high to 6~15 m³ [2]. Due to the low utilization efficiency of the flotation process, large amount of flotation reagents remained in the flotation wastewater which was certainly toxic to ecological environment.

During the W–Mo ore flotation process, fatty acids, amines, citric acid, and phosphoric acid are the commonly used collectors which have the disadvantage of poor

selectivity, low flotation efficiency, and certain toxicity. Salicylhydroxamic acid is an innovative collector, which has lone pair of electrons of oxygen atom and nitrogen atom with the similar positions in the hydroxyl group structure. It is beneficial to coordinate with metal cations on the surface of tungsten ore to form chelate ring. Meanwhile, the stability of the chelate is enhanced by increasing the density of electron clouds of atomic oxygen with the α -conjugation effect, which makes the salicylhydroxamic acid to be strongly adsorbed on the mineral surface [3, 4], thus improving the mineral flotation efficiency. However, the hydroxyamidine group and a stable alkyl benzene ring in the molecular structure of salicylhydroxamic acid causes a certain degree of biological toxicity and poor biodegradability. The common treatment methods for flotation wastewater in practical engineering are natural sunlight degradation, coagulation, and flocculation, which are difficult to achieve the removal effect.

In recent years, advanced oxidation processes (AOPs) were considered as methods with application prospect to

transform nonbiodegradable pollutants into harmless substances [5]. The AOPs can effectively mineralize a variety of organic pollutants by generating highly active and nonselective free radical like hydroxyl radical ($\cdot\text{OH}$) [6]; meanwhile, the AOPs attract a wide spread attention to the treatment of industrial wastewater containing toxic organic pollutants [7]. The reaction mechanism of Fenton oxidation mainly involves the production of $\cdot\text{OH}$ by Fe^{2+} and H_2O_2 under acidic conditions [8]. The oxidation capacity of $\cdot\text{OH}$ is about $10^6\sim 10^9$ times stronger than O_3 or oxygen. The $\cdot\text{OH}$ oxidation process is nonspecific [9] and can effectively degrade residual organic contaminants in wastewater. Ozone oxidation technology is also based on the hydroxyl radical with a higher redox potential to degrade organic pollutants which can greatly shorten the reaction time [10, 11] and achieve the purpose of harmless mineralization of refractory organics [12]. There are few researches at present on the AOPs applied in salicylhydroxamic acid wastewater from W-Mo mineral processing. This study focused on the removal effect of W-Mo mineral flotation wastewater treatment with different processes such as advanced oxidation and natural photodegradation, moreover optimized process parameters, and provided reference for practical treatment project of salicylhydroxamic acid wastewater from W-Mo mineral processing.

2. Materials and Methods

2.1. Synthetic Salicylhydroxamic Acid Wastewater. The experimental wastewater prepared with salicylhydroxamic acid simulated the wastewater quality of a tungsten-molybdenum polymetallic ore tailings reservoir in Hunan province. Meanwhile, taking into account the residual ratio of the main flotation reagents in the actual flotation wastewater, the simulated wastewater was prepared with four flotation reagents such as salicylhydroxamic acid 50 mg/L, No. 2 oil 50 mg/L, sodium oleate 100 mg/L, and butyl xanthate 100 mg/L, which brought 300 mg/L COD_{Cr} concentration.

The water quality of the simulated salicylhydroxamic acid wastewater, the first-grade discharge standard in the Integrated Wastewater Discharge Standard (GB 8978), and the water quality of the reuse of urban recycling water-water quality standard for industrial uses (GB/T 19923) are listed in Table 1.

2.2. O_3 Treatment Procedure. The experimental scheme of O_3 oxidation is as shown in Figure 1. The reactor setup included a reactor made of high borosilicate glass to prevent oxidation and chemical corrosion and an ozone generator (3S-A5, China). The height, outer diameter, and inner diameter of the reactor was 1000 mm, 70 mm, and 60 mm, respectively, and the effective volume was 2.8 L. The gas distributor in the reactor was a titanium plate with about 20–30% open porosity, and the average pore size of micropores was about 17 μm .

The O_3 treatment procedure was intermittent operation. The simulated wastewater was injected into the reactor through a peristaltic pump, then turned on the ozone

TABLE 1: The water quality of simulated flotation wastewater and standard concentration limits.

Items	pH	BOD ₅ (mg/L)	COD _{Cr} (mg/L)	NH ₃ -N (mg/L)	TP (mg/L)
Simulated wastewater	9.5~10	60~70	300~350	8.5~9	<0.01
Discharge standard	6~9	30	100	15	0.5
Reuse standard	6.5~8.5	10	60	10	1

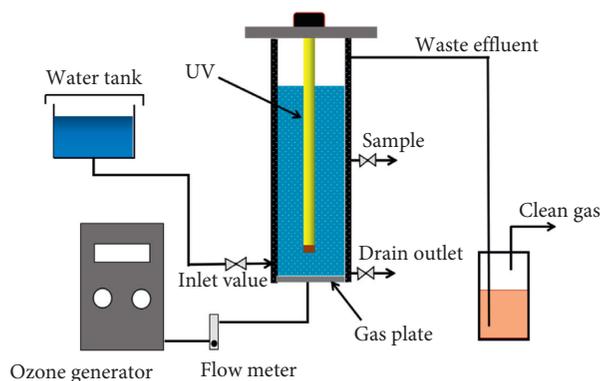


FIGURE 1: Schematic diagram of experimental devices used in O_3 oxidation.

generator, and maintained the flow rate of O_3 gas at 100 mL/min by controlling the gas flow meter. Ozone mixture was introduced into the gas distribution plate after the gas flow was stable and then adjusted the power knob of the ozone generator to control the dosage of O_3 in the range of 1~10 mg/L. A series of batch tests were employed to determine the degradation of pollutants under different stepwise reaction times, initial pH value, and O_3 dosages.

2.3. Fenton Treatment Procedure. Samples of 450 mL simulated salicylhydroxamic acid wastewater were adjusted to preselected pH value with 10% H_2SO_4 or NaOH and then put into the reactor. Different dosages of $\text{FeSO}_4\cdot 7\text{H}_2\text{O}$ and H_2O_2 (mass concentration was 30%) were added into the former solution. Samples were collected at different reaction times, and the pH was adjusted to 7~9 with 10 mol/L NaOH solution and then settled for 30 minutes. The supernatant was sampled and treated with 50°C water bath and heated for 2 hours to ensure the residual H_2O_2 in the solution completely volatilized [13]. COD_{Cr} or BOD₅ of treated supernatant was analyzed to evaluate the treatment effect.

2.4. Chemicals and Analyses. Analytical grade salicylhydroxamic acid and sodium oleate were purchased from Aladdin (Shanghai, China). Industrial grade butyl xanthate sodium and No. 2 oil were purchased from Zhuzhou mineral processing reagent company (Hunan, China). Analytical grade ferrous sulfate heptahydrate, sulfuric acid, sodium hydroxide, potassium iodide, soluble starch, and sodium

thiosulfate were purchased from Sinopharm (Beijing, China). The pH value was measured by pH meter (PHS-3C, Raytheon, China), COD_{Cr} was analyzed with UV-Vis spectrophotometer (UV3000PC, Mapada, China), BOD₅ was detected with five-day biochemistry culture method, and O₃ concentration in gas was measured by iodometry [14].

3. Results and Discussion

3.1. Degradation of Simulated Wastewater by Natural Sunlight. A beaker containing 500 mL simulated wastewater was put in natural sunshine outside and irradiated for different times. A control group was put in a place without natural light exposure. The COD_{Cr} removal ratio of the wastewater is shown in Figure 2. Natural light degradation had a limited removal effect on organic pollutants in simulated wastewater. The COD_{Cr} removal ratio increased gradually with the extension of the sun illumination time. When the sun illumination time was 30 h, the COD_{Cr} removal ratio reached the highest 25.99% mainly due to easy degradation of butyl xanthate under sunshine which was in accordance with the phenomena recorded in the literature [15]. Without sunshine radiation, the COD_{Cr} removal ratio of the control group increased to about 5% within 6 h.

In order to further explore the change in organic matter structure in the wastewater illuminated by sunlight, infrared spectrum analysis was performed on the simulated wastewater before and after sunlight degradation and the results are shown in Figure 3. Compared the infrared spectra of the wastewater before and after degradation with sunlight, the characteristic absorption peak positions did not change obviously, no new absorption peaks appeared, and the intensity of the absorption peak of the benzene ring C–C skeleton was almost unchanged; it meant that sunlight degradation could not greatly change the molecular structures of organic matters in simulated wastewater, especially the benzene ring structure could not be destroyed. Thus, natural sunlight has limited ability to degrade pollutants in the flotation wastewater, and the treated effluent could not meet the discharge or reuse standard requirements.

3.2. O₃ Oxidation Degradation of Simulated Wastewater

3.2.1. Effect of Reaction Time on Treatment. The experimental conditions were set as O₃ dosage = 2.4 mg/L and pH = 4, 6, and 10, respectively; the COD_{Cr} removal ratio of simulated wastewater by O₃ oxidation is shown in Figure 4.

The removal ratios of COD_{Cr} all rose rapidly under different pH conditions within the first 15 min of ozone oxidation reaction, and it was mainly due to the higher initial concentration of aromatic compounds, unsaturated bond-containing compounds, and heterocyclic compounds capable of providing electron groups (–OH and –NH₂) in the wastewater. Meanwhile, O₃ molecules and ·OH were electrophilic to easily oxidize the pollutants; thus, the removal ratio of COD_{Cr} increased rapidly. Prolonging the reaction time from 15 to 60 min, the COD_{Cr} removal ratio increased less than 10%. Continuously increasing the reaction time could not change the COD_{Cr} removal ratio significantly

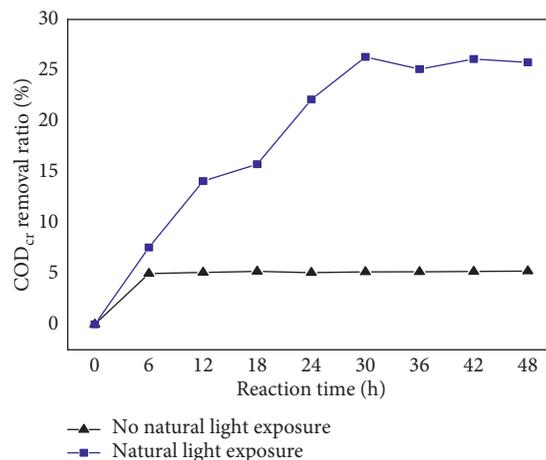


FIGURE 2: Effect of sunlight illumination time on COD_{Cr} removal.

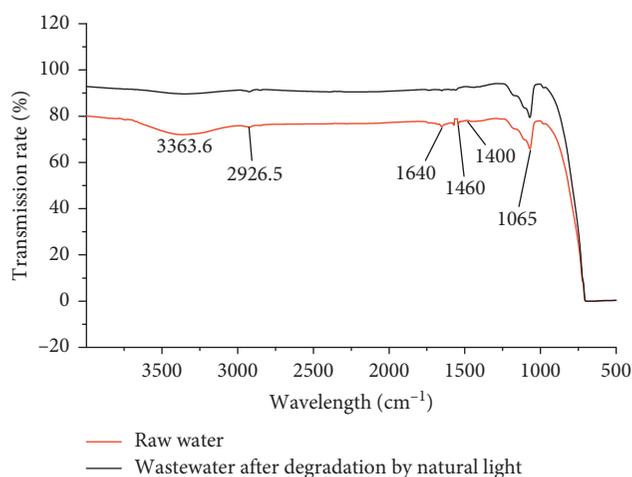


FIGURE 3: The infrared spectrum of simulated wastewater before and after natural sunlight irradiation for 48 hours.

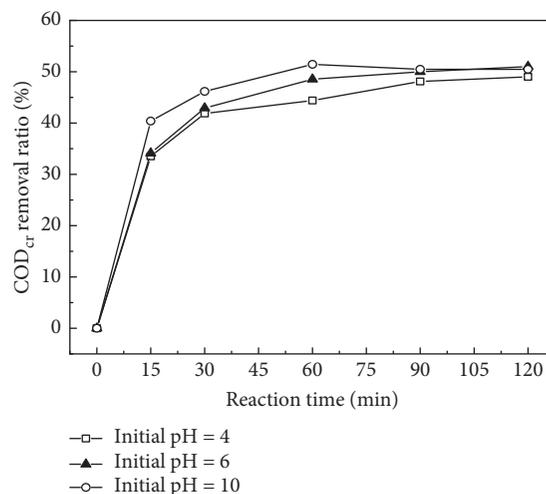
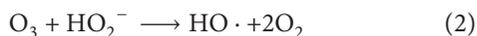
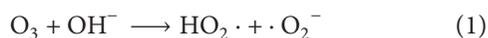


FIGURE 4: Effect of reaction time on COD_{Cr} removal by ozone oxidation.

because of the residual organic pollutants in the wastewater mainly being small organic molecules such as formaldehyde and formic acid which were difficult to be mineralized by O_3 .

3.2.2. Effect of Initial pH on Treatment. The treatment of ozone oxidation on COD_{Cr} removal was explored by controlling the dosage of O_3 2.4 mg/L, reaction time 60 min, and adjusting pH 2, 4, 6, 8, and 10, respectively, as the results in Figure 5.

The initial pH of the wastewater had a significant effect on COD_{Cr} removal by O_3 oxidation. The COD_{Cr} removal ratio reached the maximum 51.19% when pH increased from 2 to 8, but it decreased when the initial pH rose to 10. In acidic conditions, $\cdot OH$ generation was inhibited, and O_3 molecules played an active role in the oxidation process which was selective and low reaction to make the organic pollutants degradation rate slower. Under weak alkaline condition, it was more conducive to the oxidation degradation of organic pollutants in wastewater by ozone, and it should owe to the increase in the concentration of hydroxide ion as the pH value enhanced which acted as the initiator to promote O_3 molecule and generated the $\cdot OH$ through the reactions as follows:



Under the weak alkaline condition, the organic pollutants' degradation reaction is mainly based on the indirect oxidation of OH , the reaction rate was faster, and the oxidation ability was stronger, thus improving the removal effect of organic pollutants. When pH was higher to 10, on the one hand, the generation rate of $\cdot OH$ by ozone decomposition was too higher, which resulted in quenching reaction occurred among the excessive generation of radicals as $\cdot OH$ to reduce the removal efficiency of ozone on organic pollutants. On the other hand, CO_2 generated from organic pollutants mineralized could not effectively overflow from wastewater in the strong basic condition; therefore, HCO_3^- and CO_3^{2-} were the main existence forms which could quickly consume the radicals as $\cdot OH$. Meanwhile, some of the decomposition products of organic pollutants like aromatic group might inhibit the radicals generated. These factors led to the decrease in COD_{Cr} removal efficiency.

3.2.3. Effect of O_3 Dosage on Treatment. At the optimum conditions such as reaction time 60 min, pH 8, and O_3 mixture flow 100 mL/min, O_3 dosage was controlled within 1–10 mg/L by regulating the power of the O_3 generator and influent COD_{Cr} concentration 300–350 mg/L; the removal of COD_{Cr} from wastewater by ozone oxidation is displayed in Figure 6.

As the dosage of O_3 increased from 1.3 mg/L to 5.5 mg/L, the removal ratio of COD_{Cr} gradually improved from 40.37% to 55.46% and then tended to be stable by continuously adding O_3 dosage. Low dosage of O_3 produced less strong oxidation substances such as $\cdot OH$ in the wastewater which caused poorer oxidation effect and longer reaction time. With the increase in O_3 dosage, more $\cdot OH$ was produced and the oxidation rate increased. Until the O_3 dosage was added to 5.5 mg/L, the

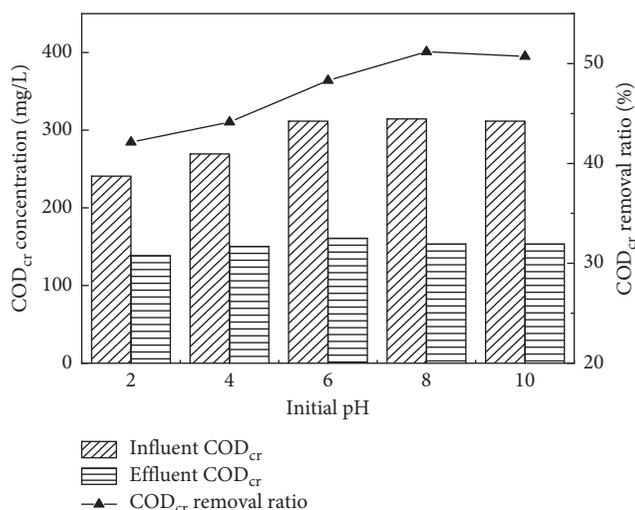


FIGURE 5: Effect of initial pH on COD_{Cr} removal by ozone oxidation.

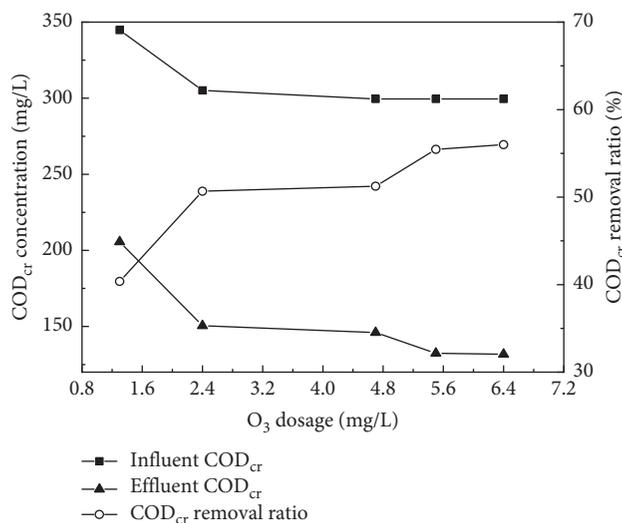


FIGURE 6: Effect of O_3 dosage on COD_{Cr} removal by ozone oxidation.

dissolved amount of O_3 molecules in the wastewater tended to be saturated, the excess O_3 gas could not be used effectively, and the effluent still could not meet the discharge or reuse standard requirements. Ozone oxidation might be an assistant treatment for flotation wastewater.

3.2.4. Effect of O_3 Oxidation on the Biodegradability of Wastewater. The biodegradability of simulated wastewater by O_3 oxidation at different times was discussed based on the experimental conditions such as O_3 dosage 1.3 mg/L and pH 8; the results are shown as Figure 7. O_3 oxidation could obviously increase BOD_5/COD_{Cr} value of wastewater to higher than 0.3 when the reaction time was 15 min and reached the maximum value 0.549 as the reaction time prolonged to 30 min. O_3 and $\cdot OH$ had a strong oxidation effect and could break down the hard-degradable organics

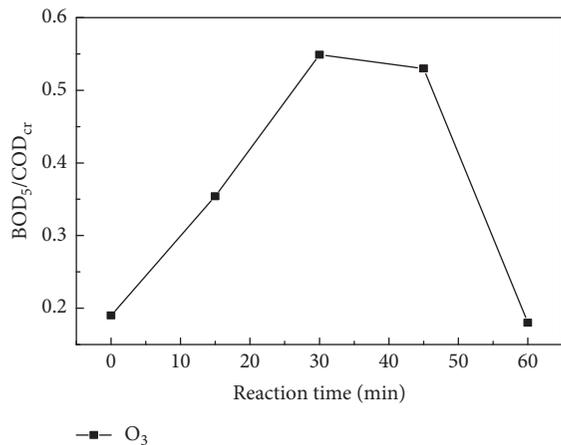


FIGURE 7: Effect of O₃ oxidation on biodegradability of wastewater.

into small-molecule intermediates by chain-breaking and ring-opening to increase the biodegradability of wastewater. As the reaction time was up to 60 min, the intermediate product from oxidative degradation played the dominant role which lead to faster degradation of BOD₅ and a corresponding decrease of BOD₅/COD_{Cr} value in the wastewater.

3.3. Fenton Oxidation of Simulated Wastewater

3.3.1. Effect of Reaction Time on Treatment. The experimental conditions of Fenton oxidation were initial pH = 4, H₂O₂ dosage = 0.48 g/L, and Fe₂SO₄·7H₂O dosage = 0.196 g/L (the molar ratio of H₂O₂ to Fe²⁺ was 5:1); the reaction time was 15 min, 30 min, 60 min, 90 min, and 120 min, respectively. The experimental results of COD_{Cr} concentration and the removal ratio are shown in Figure 8.

According to the reaction time, the COD_{Cr} removal effect of Fenton oxidation was obviously divided into two stages: COD_{Cr} removal ratio rapidly increased to more than 60% within 15 min, while the increasing trend was slowly during 15 to 120 min. In the initial stage of Fenton reaction, the catalytic reaction rate was faster and the production of ·OH was more due to the high concentration of H₂O₂ and Fe²⁺; most of the organic pollutants in the wastewater were effectively degraded. With increasing reaction time, the H₂O₂ concentration decreased which caused the reduction of ·OH generation and the degradation rate slowed down gradually. Based on comprehensive consideration of economy and efficiency, the optimum reaction time was selected as 90 min, and COD_{Cr} removal ratio reached 79%.

3.3.2. Effect of Molar Ratio of H₂O₂ to Fe²⁺ on Treatment. The initial conditions were set as pH = 4 and H₂O₂ dosage = 0.48 g/L; the dosage of FeSO₄·7H₂O was changed to different molar ratios of H₂O₂ to Fe²⁺ 1:1, 2:1, 5:1, 10:1, and 20:1, respectively. The effect of reaction time on COD_{Cr} removal ratio by Fenton oxidation is shown in Figure 9. The changing trends of the COD_{Cr} removal ratio with the reaction time at different molar ratios of H₂O₂ to Fe²⁺ had

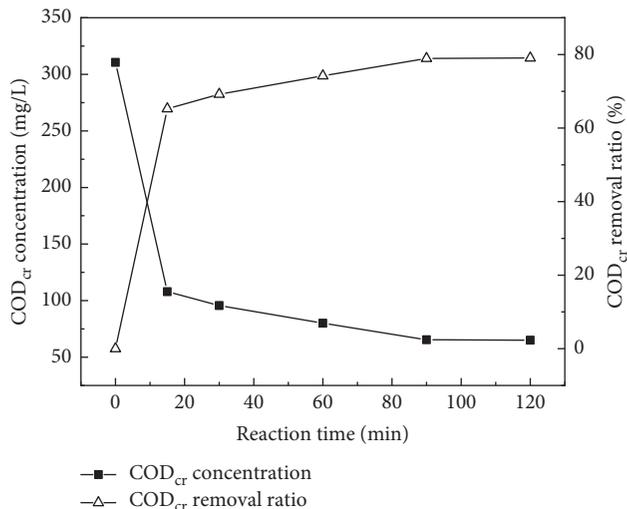


FIGURE 8: Effect of reaction time on removal of COD_{Cr} by Fenton oxidation.

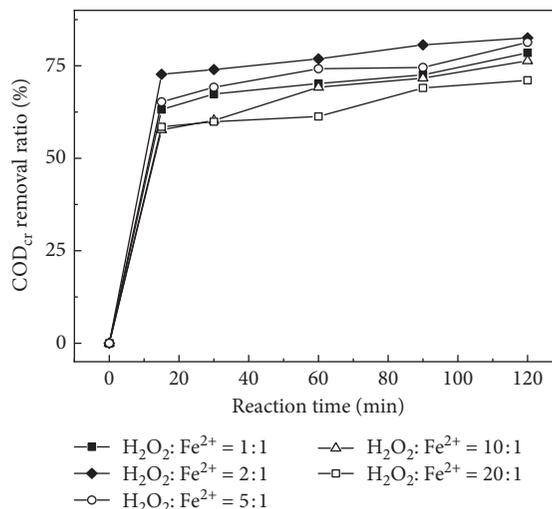
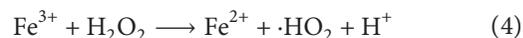
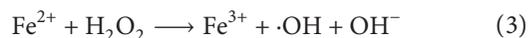


FIGURE 9: Effect of molar ratio of H₂O₂ to Fe²⁺ on COD_{Cr} removal ratio.

almost the similar tendency, within the first of 15 min reaction time; the removal ratio of COD_{Cr} increased rapidly and then improved slowly during 15 to 120 min reaction time. When the molar ratio of H₂O₂ to Fe²⁺ was 2:1 and the reaction time was 90 min, the COD_{Cr} removal ratio reached the maximum value of more than 80%.

The ·OH generation during the reaction process mainly included two stages as follows:



Fe²⁺ in the wastewater acted as catalyst. When molar ratio of H₂O₂ to Fe²⁺ was 2:1, it just met the theoretical demand for Fe²⁺ in the ·OH generation reaction, and the catalytic efficiency of Fe²⁺ and the production of ·OH could achieve

the highest level. If the molar ratio was greater than 2:1, the concentration of Fe^{2+} in the system was lower to decrease the rate of catalysis, the $\cdot\text{OH}$ yield, and the removal rate in the wastewater. When the molar ratio decreased to 1:1, the concentration of Fe^{2+} in the system was too higher, the excess Fe^{2+} would also react with $\cdot\text{OH}$ to cause redox reaction which promoted the decomposition of H_2O_2 and declined the removal efficiency of organic pollutants.

3.3.3. Effect of Initial pH on Treatment. The initial pH was one of the important factors indirectly affecting the activity and production of $\cdot\text{OH}$ and resulting in a certain limitation on the oxidative capacity of Fenton reaction [16]. The initial conditions were set as H_2O_2 dosage = 0.48 g/L, the molar ratio of H_2O_2 to $\text{Fe}^{2+} = 2:1$, and reaction time = 90 min; pH was adjusted to 2, 3, 4, 5, and 6, respectively. The experimental results are displayed in Figure 10. Fenton oxidation generally possessed a better treatment effect on wastewater with the decrease in pH. The best removal ratio of COD_{Cr} was 84.4% at initial pH = 3, and the concentration of COD_{Cr} was lower than 48.36 mg/L. As the pH value was higher than 3, the concentration of hydroxide in the wastewater increased gradually and the generation of $\cdot\text{OH}$ was inhibited; meanwhile, Fe^{2+} precipitated and affected catalytic efficiency. When the pH was lower than 3, the H^+ concentration in the system increased which inhibited the reduction of Fe^{3+} to Fe^{2+} and hindered the conversion equilibrium between Fe^{3+} and Fe^{2+} and thus reduced the efficiency of the catalytic reaction [17].

3.3.4. Effect of H_2O_2 Dosage on Treatment. The experimental conditions were selected as follows: pH = 3, the molar ratio of H_2O_2 to $\text{Fe}^{2+} = 2:1$, and reaction time = 90 min; the dosage of H_2O_2 was 0.24 g/L, 0.48 g/L, 0.72 g/L, 0.96 g/L, and 1.2 g/L, respectively. The effect of Fenton oxidation on COD_{Cr} is shown in Figure 11. When the dosage of H_2O_2 was increased from 0.24 to 0.96 g/L, the COD_{Cr} removal ratio increased rapidly from 71.63% to 90.43% and the COD_{Cr} was decreased from 85.1 mg/L to 28.7 mg/L. When the dosage of H_2O_2 was continuously increased to 1.2 g/L, COD_{Cr} removal ratio decreased obviously. When the dosage of H_2O_2 was less than 0.96 g/L, the reaction rates of equations (5) and (6) became slower and the amount of $\cdot\text{OH}$ produced decreased and reduced the removal ratio of COD_{Cr} . With the increase in H_2O_2 dosage, the concentration of $\cdot\text{OH}$ in the system increased and the degradation rate of organic pollutants accelerated. The oxidation reaction of $\cdot\text{OH}$ was not selective, the excess dosage of H_2O_2 resulted in reaction equations (3) and (4) which became the dominant reactions in the system, and H_2O_2 acted as a scavenger to reduce the concentration of $\cdot\text{OH}$ [18]:

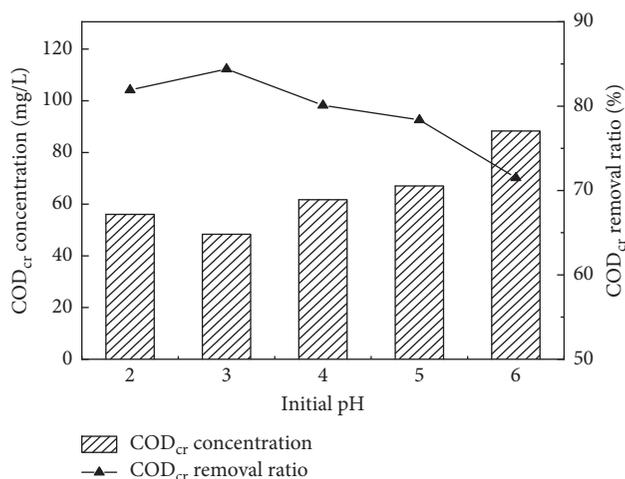


FIGURE 10: Effect of initial pH on COD_{Cr} removal.

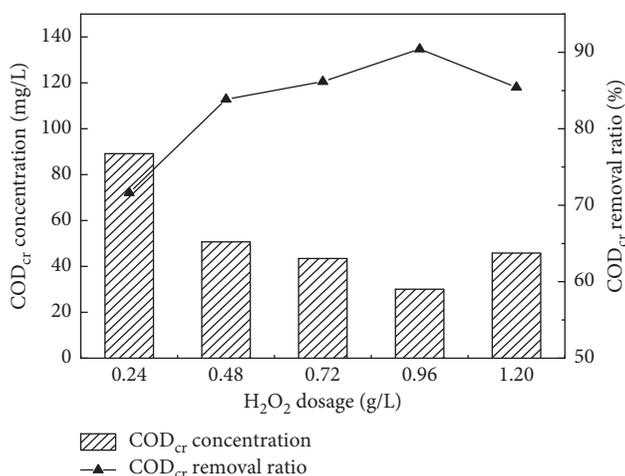


FIGURE 11: Effect of H_2O_2 dosage on COD_{Cr} removal.

3.3.5. Effect of Fenton Oxidation on Biodegradability of Wastewater. The concentrations of COD_{Cr} and BOD_5 of the simulated wastewater were 320 mg/L and 61.18 mg/L; the $\text{BOD}_5/\text{COD}_{\text{Cr}}$ was 0.19. The effect of Fenton oxidation on the biodegradability of wastewater was discussed under the experimental conditions as pH = 3, the molar ratio of H_2O_2 to $\text{Fe}^{2+} = 2:1$, and the dosage of $\text{H}_2\text{O}_2 = 0.96$ g/L; reaction time was 15 min, 30 min, 45 min, 60 min, and 90 min, respectively. The results are exhibited in Figure 12.

With the increase in reaction time, the concentrations of COD_{Cr} and BOD_5 in wastewater declined continuously. Within 60 min reaction time, the declining rate of COD_{Cr} concentration was significantly faster than BOD_5 , $\text{BOD}_5/\text{COD}_{\text{Cr}}$ value increased rapidly from 0.19 to 0.382, and the biodegradability of wastewater was improved. While the reaction time was prolonged to 90 min, $\text{BOD}_5/\text{COD}_{\text{Cr}}$ value dropped off rapidly to 0.17. Within the first 60 min reaction, difficult-to-biodegrade pollutants in the wastewater were rapidly degraded to biodegradable intermediates, and a

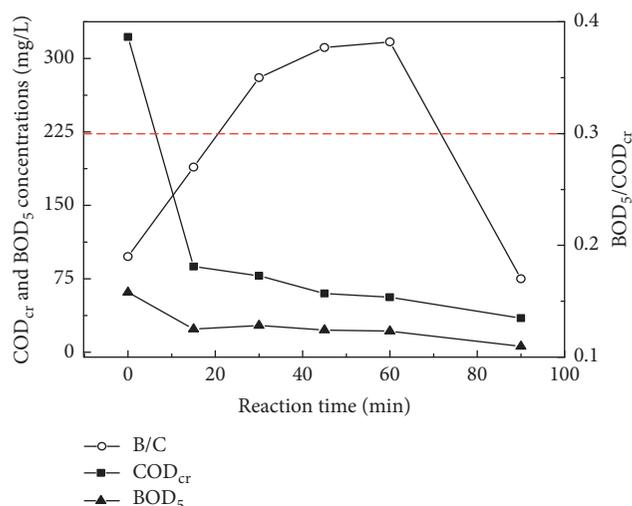


FIGURE 12: Effect of Fenton reaction time on biodegradability of wastewater.

portion was directly mineralized to CO_2 and H_2O which resulted in increased $\text{BOD}_5/\text{COD}_{\text{Cr}}$. Due to prolonged reaction time, the concentration of strong oxidation substances and macromolecular organic pollutants decreased, and the reaction in the system was dominated by the oxidative decomposition of intermediate products. The removal rate of COD_{Cr} was lower than the BOD_5 ; thus, the $\text{BOD}_5/\text{COD}_{\text{Cr}}$ value declined.

4. Conclusions

Salicylhydroxamic acid wastewater from the W–Mo ore flotation process is difficult to be treated by coagulation-settlement technology, and the effluent is difficult to meet the requirements of the first-grade discharge standard in the Integrated Wastewater Discharge Standard (GB 8978) and the water quality of the reuse of urban recycling water-water quality standard for industrial uses (GB/T 19923). In practical engineering, tailing reservoir is generally used for a final section to treat the flotation wastewater by natural sunlight degradation, but it was proved in this paper that the degradation of natural sunlight had a limited effect on the simulated flotation wastewater, the COD_{Cr} removal ratio could reach the highest 25.99% after 48 h sun illumination, and sunlight could not degrade the mineral processing reagent with benzene ring structure. Sunlight degradation was not an effective treatment method for practical flotation wastewater. Under varied operation parameters of reaction time, initial pH, and O_3 dosage, ozonation was proved to be effective for simulated salicylhydroxamic acid wastewater, the COD_{Cr} removal ratio could reach the maximum 55.46% at the optimum experimental conditions, and the $\text{BOD}_5/\text{COD}_{\text{Cr}}$ value increased to 0.549 after 30 min reaction. But the effluent could not reach the discharge or reuse standard, and ozonation could be the prepositive disposal combined with biochemical treatment. Ozonation is a high-power consumption treatment method, treatment cost was necessary to be considered in actual engineering, and the $\text{BOD}_5/$

COD_{Cr} value could be controlled as 0.35 after 15 min reaction to meet the demand of biochemical treatment. Fenton oxidation was more effective than sunlight and ozonation process, under the experimental conditions such as pH 3, H_2O_2 dosage 0.96 g/L, the molar ratio of H_2O_2 to Fe^{2+} 2:1, and the reaction time 90 min; COD_{Cr} concentration and the removal ratio in the flotation wastewater were 30.07 mg/L and 90.43%, which was far below the prescribed emission or reuse standards. Fenton oxidation could be of single-use to treat the salicylhydroxamic acid wastewater which was more simple than the ozonation process, but the consumption of H_2O_2 and $\text{Fe}_2\text{SO}_4 \cdot 7\text{H}_2\text{O}$ was large, and massive precipitate was generated which brought inconvenient operation in practical engineering.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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