The Influence Factors of Phenol Wastewater Treatment Using Persulfate Activated by Fe^0

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Abstract
It has become the new focus in the field of water treatment to deal with the difficult degradable organic pollutants using the transition metal and the transition metal ion. This paper examined a new activator of Fe^0 in persulfate ($K_2S_2O_8$) activation based on strong oxidizer of sulfate radicals ($SO^{4\cdot}$-) for catalytic oxidation of phenol. Discuss the reaction time, activator dosing amount, $K_2S_2O_8$ dosing quantity, pH value, and initial concentration of phenol in detail for the research of phenol wastewater treatment, and obtain the best operating conditions through orthogonal test. It had been verified by tests that when the reaction temperature reached 35 ℃, the pH value was equal to 3, the reaction time lasted 180 min, the activator of Fe^0 adding quantity was 200 mg/L, the $K_2S_2O_8$ dosing quantity was 200 mg/L, the phenol initial concentration got to 150 mg/L, the phenol removal rate could reach 78.27%. The results showed that the activation phenol wastewater treatment technology using persulfate activated by Fe^0 could be applied to small phenol treatment system.

Keywords
Phenol; activated persulfate; influencing factors

INTRODUCTION

At present, with transition metal and transition metal ions as activator for persulfate to deal with the difficult degradable organic pollutants degradation has become a hot in the field of water treatment. According to previous research results, persulfate activation effect by the heavy metal ions was more outstanding, but the heavy metal ions could cause secondary pollution of water resources, and were not conducive to the long-term development of the society and human beings. Fe^{2+}, as a kind of cheap, common, sources, environment friendly activator for persulfate, has obvious advantages, but many problems also exist inevitably. In order to make up for the defect of Fe^{2+}, Fe^0 whose principle was similar to Fe^{2+} became the first choice of replacement as activator. It could further reduce the agent cost of inputs by using Fe^0, also could avoid disturbance to the system by other anions. At the same time, Fe^0 also became effective medium to accelerate the circulation between Fe^{3+} and Fe^{2+}. Fe^0, so to speak, as a kind of ideal persulfate metal activator, in the field of organic pollution of waste, wastewater treatment had a very good development prospect.

In this paper, the reaction time, activator dosing quantity, $K_2S_2O_8$ dosing quantity, pH value, and phenol initial concentration on the effect of phenol wastewater treatment will be discussed and the optimum operation parameters will be obtained. Therefor, a small-scale phenol wastewater treatment will be implemented.

MATERIALS AND METHODS

Raw water

Artificial wastewater was used to simulate the phenol wastewater in this experiment.

Methods

Add 100 ml phenol wastewater into several flasks of 250 ml, with a moderate amount of $K_2S_2O_8$

and Fe^0. Discuss the treatment effect under different reaction time, Fe^0 dosing amount, $K_2S_2O_8$ dosing quantity, pH value, phenol initial concentration and reaction temperature. Take samples from the supernatant liquid level at 1 cm for 3 times. Then COD value and phenol value could be measured respectively, and the corresponding removal rate could be calculated.

Use 4-AAP direct photometric method to determine the phenol concentration, and the fast airtight catalytic decomposition method for COD.

RESULTS AND DISCUSSION

The influence of reaction time on the treatment effect

Add 100 ml phenol wastewater to 250 ml flask of initial phenol wastewater concentration of 200 mg/L and $K_2S_2O_8$ standard fluid of 0.05 mol/L to ensure $m(K_2S_2O_8):m(C_6H_6O)=1$. Add Fe^0 to ensure $m(K_2S_2O_8):m(Fe^0)=1$. Adjust the water pH value to ensure pH=3 and the temperature of 35℃. Test result was shown in figure 1. The results showed that the Fe^0 had played a good role in $K_2S_2O_8$ activation, and the degradation of phenol wastewater basically completed till the reaction lasted 180 min. By the end of the reaction, the phenol and COD removal rate were 82.15% and 72.74% respectively.

Transition metal activator quantity's influence on the treatment effect

Vary the Fe^0 dosing quantity by keeping the other reaction conditions unchanged to ensure $m(Fe^0):m(K_2S_2O_8)=0.2\sim2$. The initial phenol wastewater concentration was 200 mg/L. Test result was shown in figure 2. The figure 2 showed that as the Fe^0 dosing quantity increasing, $K_2S_2O_8$ activation by Fe^0 effect was increased, the removal rate of phenol and COD had been higher and higher, and the degradation effect was improved obviously. Furthermore, adding more Fe^0 was not benefit to the phenol and COD removal. Therefore, set the reasonable ratio of metal activator and oxidant about 1:1.

$K_2S_2O_8$ dosing quantity's influence on the treatment effect

Vary the $K_2S_2O_8$ dosing quantity by keeping the other reaction conditions unchanged to ensure $m(K_2S_2O_8):m(Fe^0)=1$. The initial phenol wastewater concentration was 200 mg/L. Test result was shown in figure 3. When $K_2S_2O_8$ dosing quantity was not enough, phenol wastewater treatment effect was not ideal. When $K_2S_2O_8$ dosing quantity increased, the phenol wastewater treatment effect was significantly better. When $m (K_2S_2O_8):m (C_6H_6O)=1.0$, the phenol and the COD removal rate had risen to 76.38% and 64.61%. After $K_2S_2O_8$ continued to increase, growth was not obvious, and phenol and the COD maximum removal rate were 79.35% and 68.79%. Considering the economy and the treatment effect, $m (K_2S_2O_8):m (C_6H_6O)=1.0$ as a reference type dosing ratio was more appropriate.

The influence of pH value on the treatment effect

The initial phenol wastewater concentration was 200 mg/L. And adjust water pH to make the pH value of sampling points including most of acidic, neutral and alkaline pH range. Test result was shown in figure 4. With the increasing of pH value, the phenol and the COD removal efficiency increased accordingly. When pH value was equal to 3, phenol wastewater treatment experiment achieved the best effect, and the phenol and the COD removal rate reached the maximum at the same time, 78.66% and 68.61%.

Initial phenol concentration on the influence of treatment effect

The initial phenol wastewater concentration was in the range of 50mg/L to 300mg/L. Test result was shown in figure 5. It showed that initial phenol concentration had a greater influence on the effect of the reaction.

The orthogonal experiment for the optimum reaction conditions

According to the result of single factor experiment, $L_{16}(4^5)$ orthogonal experiment was done with the varieties of the reaction time, activator dosing amount (Fe^0), $K_2S_2O_8$ dosing quantity, pH value and initial phenol concentration. Levels and factors of orthogonal experiment were shown in table 1, the test results in table 2, and the mathematical analysis in table 3.

RESULTS

Under the medium temperature (35℃), influence factors of phenol wastewater treatment using persulfate activated by Fe^0 were studied. Discuss the reaction time, activator dosing quantity, $K_2S_2O_8$ dosing quantity, pH value, and initial concentration of phenol in detail for the research of phenol wastewater treatment, and obtain the best operating conditions through orthogonal test.

When the initial phenol concentration was 200 mg/L, the reaction time lasted 180 min, the pH value was 3.0, m ($K_2S_2O_8$):m (C_6H_6O)=1, activator and oxidant ratio was 1:1, the phenol and the COD removal efficiency were the highest, which reached 78.66% and 68.61%.

Analyse the $L_{16}(4^5)$ orthogonal experiment with the varieties of the reaction time, activator dosing amount (Fe^0), $K_2S_2O_8$ dosing quantity, pH value and initial phenol concentration. The phenol wastewater treatment using persulfate activated by Fe^0 effect was more ideal, when the reaction temperature was 35℃, the pH value was equal to 3, the reaction time lasted 180 min, the Fe^0 activator dosing quantity was 200 mg/L, the $K_2S_2O_8$ dosing quantity is 200 mg/L, and the phenol initial concentration was 150 mg/L.

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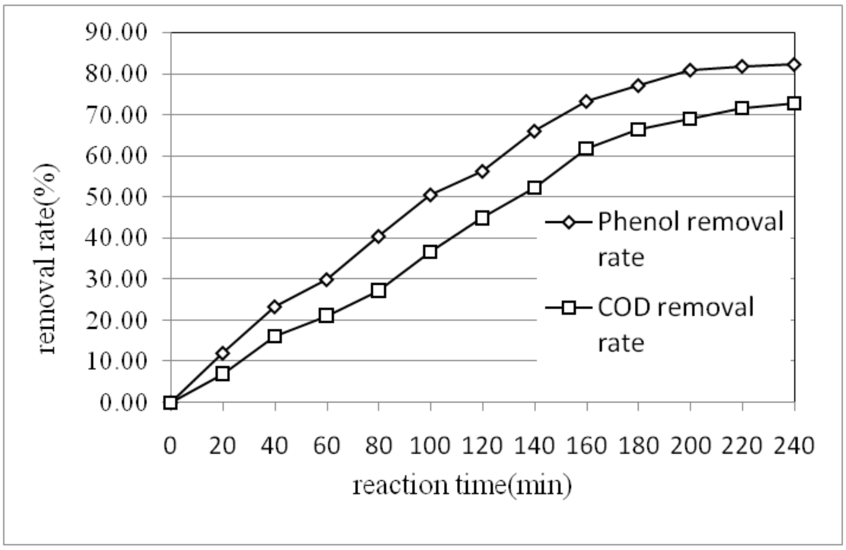

Figure 1. Influence of reaction time on the phenol wastewater treatment

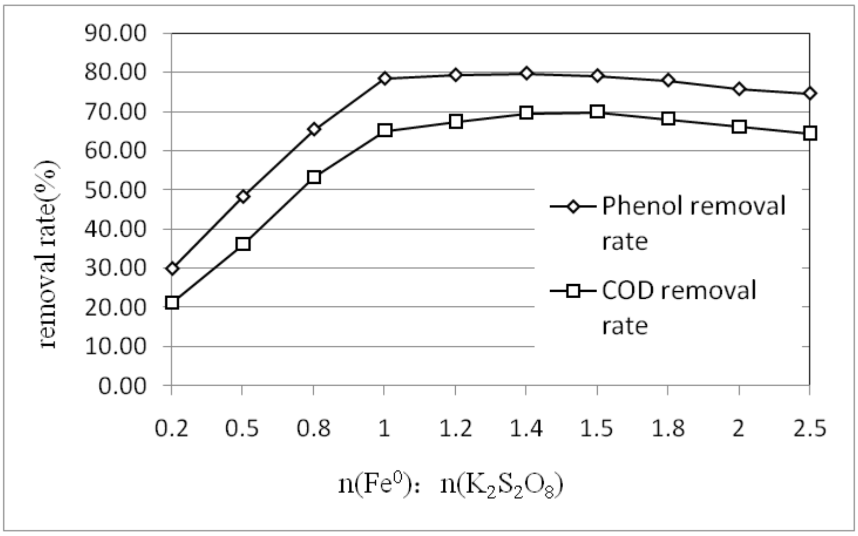

Figure 2. Influence of dosage of Fe^0 on the phenol wastewater treatment

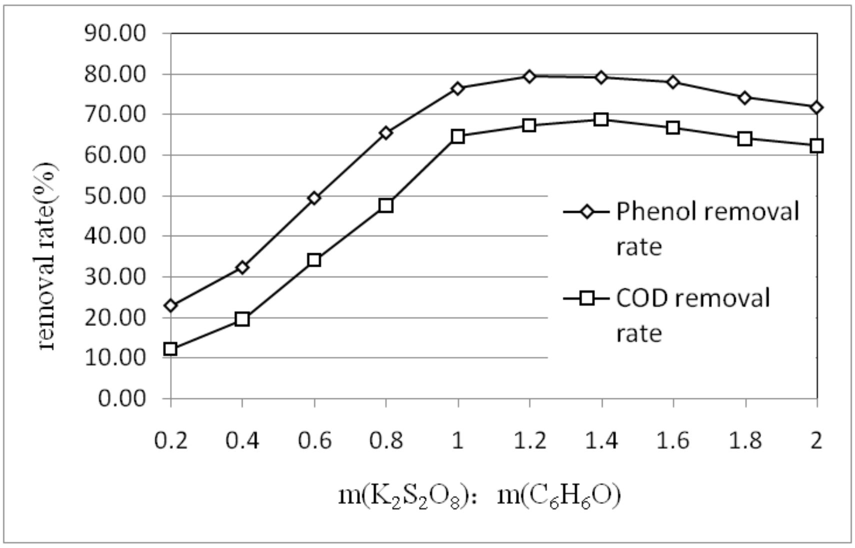

Figure 3. Influence of dosage of $K_2S_2O_8$ on the phenol wastewater treatment

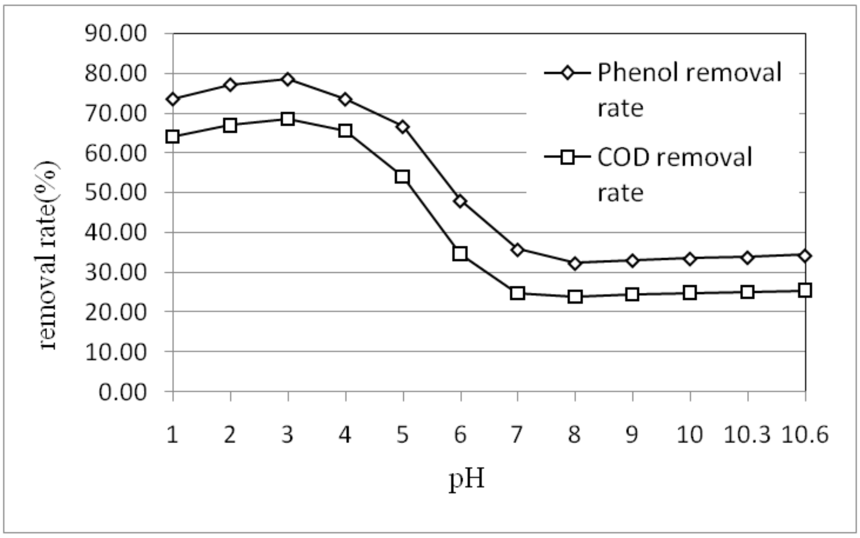

Figure 4. Influence of pH on the phenol wastewater treatment

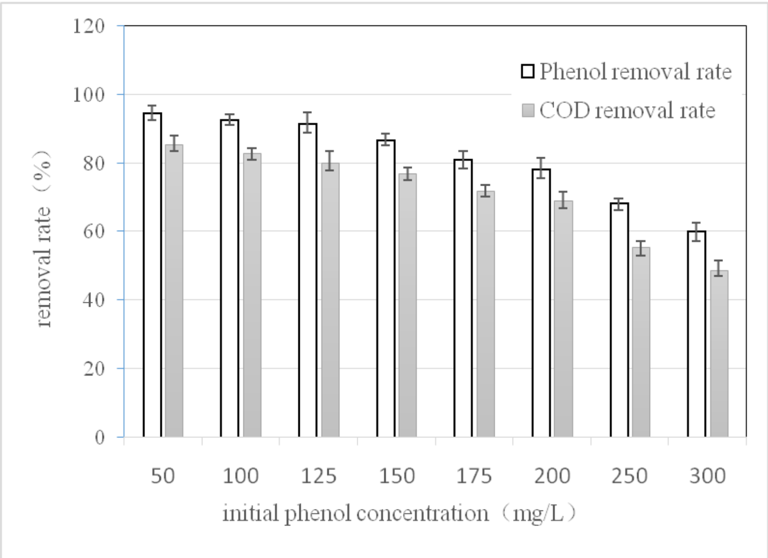

Figure 5. Influence of initial phenol concentration on the phenol wastewater treatment

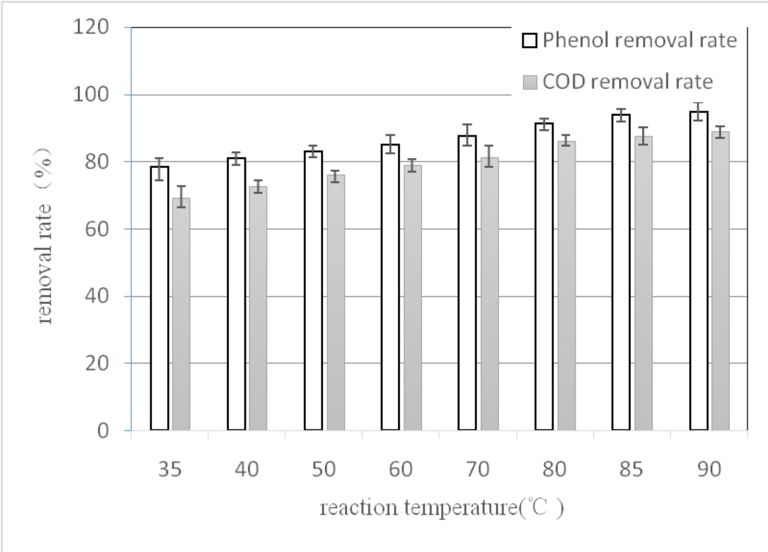

Figure 6. Influence of reaction temperature on the phenol wastewater treatment

Table 1. Level factor f orthogonal experiment

Factor level	A pH	B time (min)	C Fe^0 (mg/L)	D $K_2S_2O_8$ (mg/L)	E C_6H_6O (mg/L)
Level 1	1	120	50	50	50
Level 2	2	140	100	100	100
Level 3	3	160	150	150	150
Level 4	4	180	200	200	200

Table 2. Results of orthogonal experiment

NO.	A pH	B Time (min)	C Fe^0 (mg/L)	D $K_2S_2O_8$ (mg/L)	E C_6H_6O (initial) (mg/L)	C_6H_6O removal rate (%)
1	1	120	50	50	50	70.52
2	1	140	100	100	100	72.11
3	1	160	150	150	150	72.74
4	1	180	200	200	200	73.18
5	2	120	100	150	200	70.45
6	2	140	50	200	150	68.87
7	2	160	200	50	100	59.69
8	2	180	150	100	50	76.54
9	3	120	150	200	100	74.04
10	3	140	200	150	50	73.38
11	3	160	50	100	200	61.57
12	3	180	100	50	150	70.78

13	4	120	200	100	150	69.65
14	4	140	150	50	200	56.24
15	4	160	100	200	50	75.41
16	4	180	50	150	100	69.88

Table 3. The analysis of orthogonal experiment

Factor	A pH	B Time (min)	C Fe^0 (mg/L)	D $K_2S_2O_8$ (mg/L)	E C_6H_6O (mg/L)
$\bar{K}_1$	72.17	71.17	67.71	69.10	73.96
$\bar{K}_2$	68.89	67.65	72.19	69.97	68.93
$\bar{K}_3$	69.94	67.35	69.89	71.61	70.51
$\bar{K}_4$	67.80	72.60	68.98	72.88	65.36
R	4.34	5.25	4.48	3.78	8.60
Primary and secondary factors	EBCAD				