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Chemical Plant Waste Water Treatment Based on Ozonation Method

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This paper analyzes the use of ozone in treating waste water containing phenol organics based on experiment and theoretical research. It adopts experiments to learn the degradation effect of ozone on industrial waste water treatment under different conditions of ozone input amount, concentration level of phenol substance in solution, pH value, and reaction time, then compares the experiment results against the theoretical calculated results. When the initial concentration is 100 mg/L, ozone has good degradation effect on the phenol waste water. Degradation rate of ozone lowers as the concentration increases. The degradation rate also increases as the amount of ozone input increases. When pH value gradually raises, the degradation rate of waste water also improves, indicating that ozone has better degradation effect in an alkaline environment. The longer the reaction time is, the lower the phenol organic concentration in the waste water is. k_A value is in direct proportion to the pH value, and in reverse proportion to the phenol organic concentration. Based on the comparative results, the optimum value of is k_A witnessed at 0.00103.

1. Introduction

With fast growth of the global economies, the chemical, paper, textile, and smelting industries are expanding in sizes. These companies in the production process inevitably emit large amount of chemical industrial waste water with hazardous substance. The waste water contains various kinds of inorganic wastes and non-degradable organics (Busca et al., 2008). Phenol organics are typical toxic substance in waste water emitted by the chemical plants, and they are hard to degrade, highly toxic and complex in structures and component (Veeresh et al., 2005).

At present, the treatment methods on phenol compounds in industrial waste water include organic extraction, medium adsorption and microbial biodegradation (Wang and Han, 2012; Ramakrishnan and Gupta, 2008; Hajji et al., 2000). The organic extraction method introduces new pollutant source into the solution while degrading the compounds; the medium adsorption method has high costs, and after a while, chances are that the phenol substance will severely sabotage the medium (Pera-Titus et al., 2004); the microbial biodegradation method has strict criterion on the concentration levels of the pollutants in waste water, and the heavy metal ions and other inorganic wastes will cause irreversible damages to the microbial structures (Álvarez et al., 2005; García-Araya et al., 2003).

The ozonation-based treatment method is a new technique proposed for the industrial waste water treatment (Tan et al., 2013; Poznyak and Vivero, 2005; Kasprzyk-Hordern et al., 2003; Fontanier et al., 2006). It has advantages of pollution-free, fast treatment, not introducing new pollutants, and high degradation rates (Lei et al., 2011; Kreetachat et al., 2009; Fontanier et al., 2006). Previous research has been conducted by using ozonation treatment on benzene organics, microcystins, and azo two is butadiene nitrile with good results (Balcioğlu et al., 2007; Linda, 2000).

This paper analyzes the use of ozone in treating waste water containing phenol organics based on experiment and theoretical research. It adopts experiments to learn the degradation effect of ozone on industrial waste water treatment under different conditions of ozone input amount, concentration level of phenol substance in solution, pH value, and reaction time, then compares the experiment results against the theoretical calculated results. The research provides theoretical reference to application of ozonation in industrial waste water treatment.

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2. Materials and Method

The experiment materials include deionized water, pure ozone, NaOH, Ag_2SO_4, phenol, potassium dichromate, phenol waste water.

The waste water treatment device, illustrated in Figure 1, consists of pure ozone storage tank, flowmeter, reaction column and exhaust unit. The main reaction units have been cleansed for many times with deionized water before the phenol waste water is added to the reaction device for the experiment. Ozone is injected at the same time. Every 5 minutes, a sample is taken for analysis using the exhaust from the KI solution absorption reaction.

Phenol concentration in solution is determined via:

$$\gamma = 1 - [\text{Phenol}]_t / [\text{Phenol}]_0 \quad (1)$$

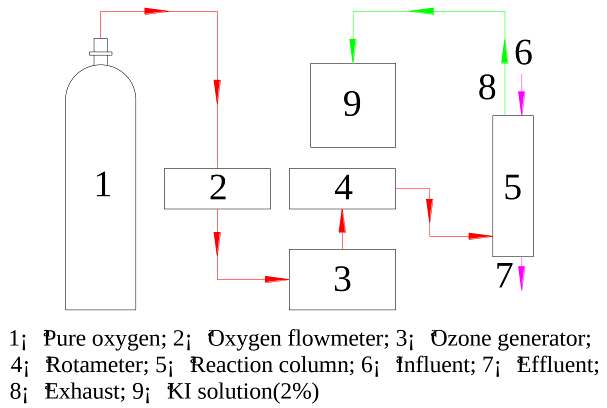

Figure 1: Phenol Waste Water Ozonation Treatment Device

3. Results and Analysis

Figure 2 shows the degradation results of ozone in phenol waste water treatment under different initial phenol concentrations. The input of ozone is 9.2 mg/min. From the results, we can see that when the initial phenol concentration is 100 mg/L, ozone has high degradation rate on the waste water. 40 minutes into the reaction, the degradation rate is as high as 98%. But as the phenol concentration increases, the degradation effect of ozone lowers. When the initial concentration is at 250 mg/L, the degradation rate is only 67.3% after 40-minute reaction. It indicates that the degradation rate of ozone on organics is in reverse proportion to the phenol concentration levels in waste water.

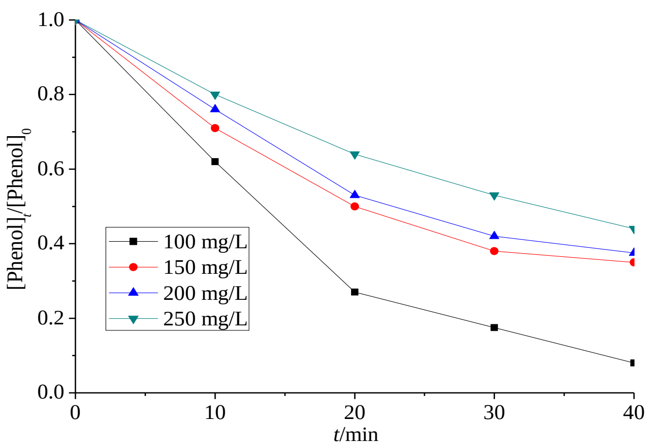

Figure 2 Degradation Results under Different Phenol Concentrations

Figure 3 displays the degradation results on phenol waste water when different amount of ozone is used. From the results, as the ozone input amount increases, the degradation rate also increases. Under three input amounts, the degradation rates are 65.9%, 77.3% and 98.6% after 40 minutes of reaction. The increased ozone concentration in solution accelerates the decomposition of ozone and results in a large amount of OH⁻ in solutions. An enhanced level of OH⁻ in turn accelerates the reactions with phenol organics, and thereby improving the degradation efficiency.
The initial phenol concentration in waste water is set as 100 mg/L, input of ozone at 8.5mg/min for observing the degradation effect. From Figure 4, along with the increase of pH value, the degradation rate also improves. When pH value is 11, the overall degradation rate is 99.2%, meaning ozone has better degradation effect in an alkaline environment.

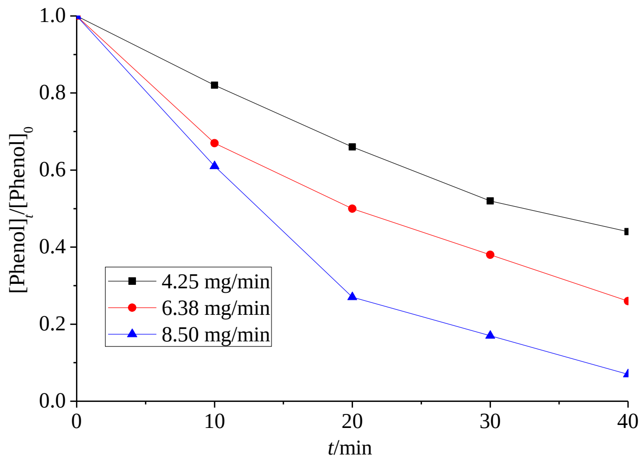

Figure 3: Degradation Results under Different Ozone Inputs

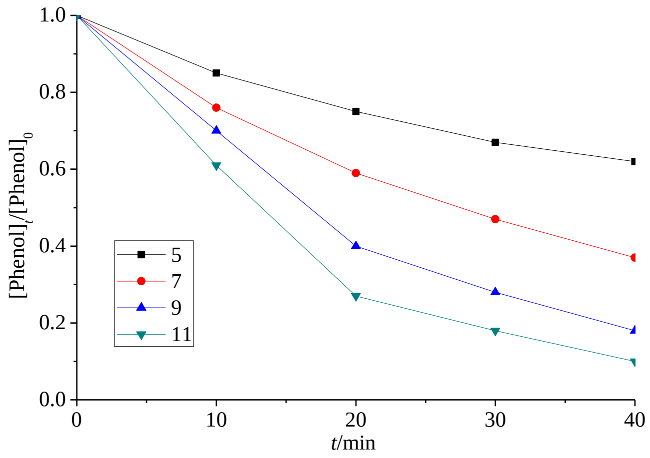

Figure 4: Degradation Results under Different Initial pH Values

Figure 5 shows the influence of reaction time on ozone degradation used in phenol waste water treatment. From the fig, as the reaction time increases, the phenol concentration in waste water is lower. When reaction time exceeds 40 minutes, the concentration of phenol organics is below 0.3 mg/L, lower than the relevant standards on waste water remittance.
Figure 6 shows the influence the effects of usage of deionized water and domestic water on degradation rates. From the results, during the initial stage of reactions, the degradation effect is significantly higher if the waste water has domestic water as the background rather than the deionized water. Along with the increase of reaction time, the gap of degradation efficiencies is narrowed. By the time of 40 minutes of reaction, the degradation efficiencies are basically the same. It indicates that substance in domestic water catalyzes the degradation effect of ozone.

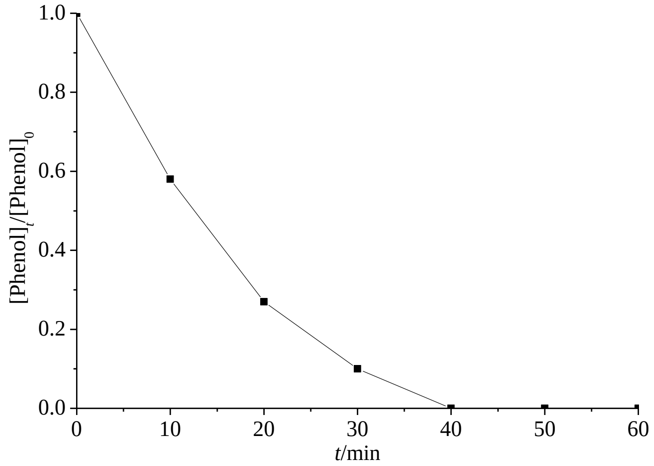

Figure 5: Degradation Results under Different Reaction Times

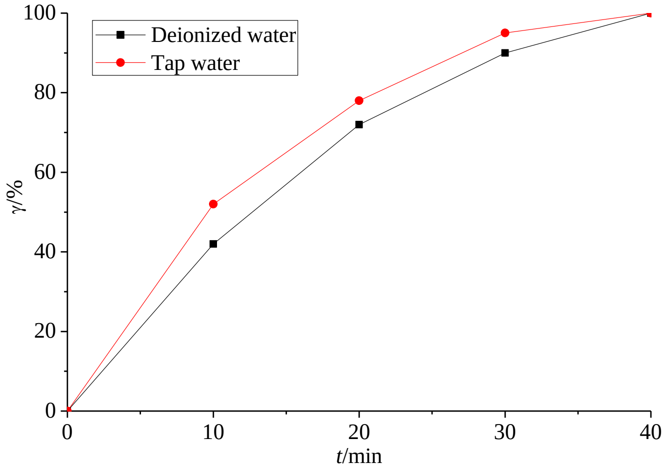

Figure 6: Deionized Water and Domestic Water on Ozone Degradation Effect

4. Theoretic Dynamics Research on Phenol Waste Water Treatment Using Ozonation

Theoretically, the degradation of phenol organics is expressed as:

$$-\frac{d[\mathrm{Phenol}]}{dt} = k_{O_3}[O_3][\mathrm{Phenol}] + k_{\cdot OH}[\cdot OH][\mathrm{Phenol}] \tag{2}$$

Modify formula 2 based on the reaction dynamics equation for the degradation formula of phenol waste water.

$$-\frac{d[\mathrm{Phenol}]}{dt} = k_A[\mathrm{Phenol}] \tag{3}$$

$$k_A = -\ln\left(\frac{[\mathrm{Phenol}]_t}{[\mathrm{Phenol}]_0}\right) \times \frac{1}{t} \tag{4}$$

Based on Formula 2 and 4, the theoretic fitted curve of ozonation degradation of phenol waste water is obtained and shown in Figure 7.

The phenol organic concentration, pH value, reaction time, and ozone input is set as the same levels as in Figure 3. Under the three conditions, a fitted curve is obtained in Figure 8. By comparing Figure 3 and Figure 8, the theoretic calculation has good fitting. It means phenol degradation meets the preliminary dynamic reaction patterns in Formula 2 and 4. As the input of ozone increases, the calculated value of k_A also increases, indicating a proportional relation between ozone input and k_A value.

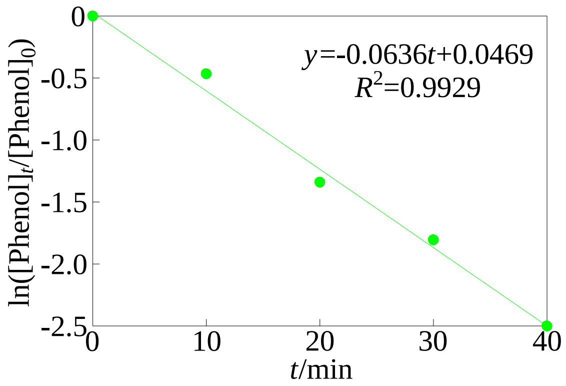

Figure 7: Theoretic Fitting Curve of Ozonation Degradation

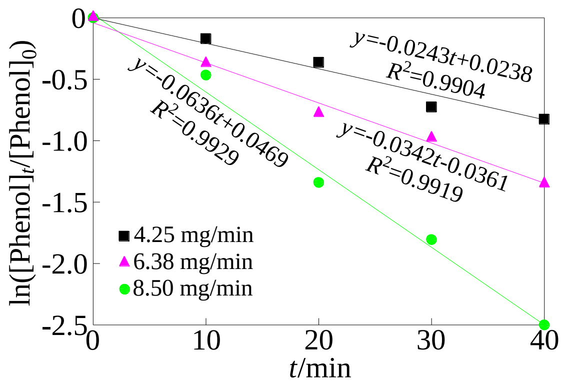

Figure 8: Theoretic Fitting Curve under Different Ozone Input

Through theoretic fittings of degradation effects under different initial phenol concentrations and initial pH values, the results match the experiment results. From below figs, the k_A value is in in direct proportion to pH value, and inverse proportion to phenol concentration. Based on Figure 8 to Figure 10, the optimum k_A value is 0.00103.

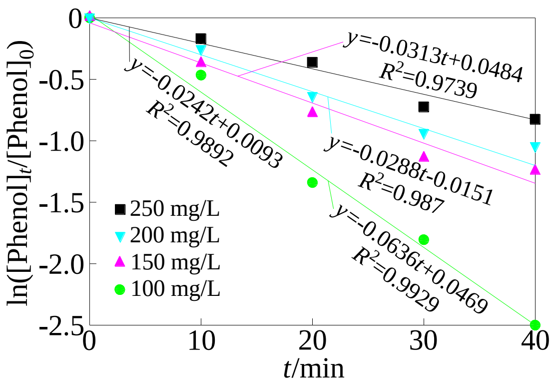

Figure 9: Theoretic Fitting Curve under Different Phenol Concentrations

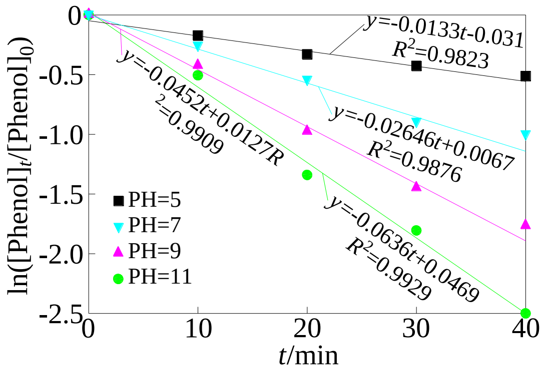

Figure 10: Theoretic Fitting Curve under Different pH Values

5. Conclusion

This paper analyzes the use of ozone in treating waste water containing phenol organics based on experiment and theoretical research. It adopts experiments to learn the degradation effect of ozone on industrial waste water treatment under different conditions of ozone input amount, concentration level of phenol substance in solution, pH value, and reaction time, then compares the experiment results against the theoretical calculated results. The conclusion is:

(1) When the initial concentration is 100 mg/L, ozone has good degradation effect on the phenol waste water. Degradation rate of ozone lowers as the concentration increases. The degradation rate also increases as the amount of ozone input increases. When pH value gradually raises, the degradation rate of waste water also improves, indicating that ozone has better degradation effect in an alkaline environment. The longer the reaction time is, the lower the phenol organic concentration in the waste water is.

(2) k_A value is in direct proportion to the pH value, and in reverse proportion to the phenol organic concentration. Based on the comparative results, the optimum value of is k_A witnessed at 0.00103.

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