

# Study on Photo-catalytic Degradation of Odor Compound in Fresh Water

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**Abstract**—The odor episode events caused by the odor compounds in water have profoundly influenced the ways people live and work, whereas there are few effective approaches to tackle this problem. In this paper,  $\beta$ -Ionone was taken as object to study the basic law of its photo-catalytic degradation with nanometer Titanium dioxide. The optimal initial concentrations of odor compound, dosage of the photo-catalyst and pH in water have been deeply discussed. The results indicate that the photo-catalytic degradation kinetics of  $\beta$ -Ionone follows the pseudo first-order reaction.

**Keywords**— $\beta$ -Ionone; Photo-catalytic Degradation;  $\text{TiO}_2$

## I. INTRODUCTION

Recently, odor emission bursts out frequently due to the increasing eutrophication of water. However, despite not being a direct cause of disease, long-term exposure to such odorants can have a negative side-effect on human beings[1]. Generally, the odorants in water can be divided into human factors and natural factors. Some odor emissions from agriculture, industry and domestic sewage with inefficient treatment are regarded as human factors[2], while those released from algal cells, plankton and actinomycetes[3] as well as metabolic products of microorganisms are the natural factors[4, 5].

In China, the technology of odor removal is just at the beginning stage. Chemical oxidation, physical treatment and biological technologies are mainly treatment for odor removal[6].  $\text{TiO}_2$  photo-catalysis has been investigated because of its attractive properties in waste water purification as well as renewal energy[7]. Owing to its nontoxicity, oxidizing power, low costs and relatively larger band gap

energy(3.2 eV),  $\text{TiO}_2$  has been a broadly studied field in last decades[7-10]. Particularly,  $\text{TiO}_2$  presents a precious property which is unselective during the oxidation reactions[11]. Much particular interest has been devoted to the optimal conditions of experimental parameters which are catalyst loading, light intensity, initial concentration of substrates, initial pH, temperature and mineral salt etc.[12, 13].

In previous investigation, industrial wastewater has been mainly addressed the photo-catalytic degradation owing to the stringent regulation on it[14, 15]. However, photo-catalytic degradation of odor compounds in drinking water is not totally studied. According to the study of monthly report, this paper was mainly focused on the optimal condition in the photo-catalytic degradation of  $\beta$ -Ionone and exploring the degradation kinetics of  $\beta$ -Ionone in  $\text{TiO}_2$  suspension.

## II. EXPERIMENTAL

### Material

Sodium Hydroxide and Sulfuric Acid were purchased from Nanjing Chemical Reagent Co., Ltd. (analytical grade).  $\beta$ -Ionone (>97%) was obtained from Sigma-Aldrich Co., Ltd. Degussa P25 (mostly anatase, purity >95%) catalyst provided by Degussa Company.

### Apparatus and Analyses

Photo reactor: All reactions were performed in a home-made batch reactor. The reactor was a 2.5L glass vessel with three necks at the top used to monitor pH, add the lamp and sampling. The 18 W/cm<sup>2</sup> lamp (primary radiation is emitted at 365nm) was placed about 5cm underneath the bottom of glass vessel.

Degradation: Appropriate quantity of the  $\text{TiO}_2$  was suspended in 2L of  $\beta$ -Ionone solution by stirring magnetically and staying for 4h in dark for adsorption equilibrium. The

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initial pH was adjusted by using a sulfate acid or NaOH solution. The reaction started by turning on the lamp. 10mL of the samples were withdrawn and filtered by 0.45 $\mu$ m membrane to separate the catalyst.

Analysis: Disappearance of  $\beta$ -Ionone is measured by a UV Detector (Cary 100, Varian) with the absorbance at 305nm.

### III. RESULTS AND DISCUSSION

#### Photodegradability of $\beta$ -Ionone

Initially the control of experiments were carried out under the following conditions: (a) self-photolysis of  $\beta$ -Ionone with UV; (b) under UV with TiO<sub>2</sub> and (c)  $\beta$ -Ionone with catalyst in dark. The results are shown in Figure 1. After 150min of magnetic stirring without UV irradiation, about 5% disappeared owing to the adsorption of  $\beta$ -Ionone on the surface of TiO<sub>2</sub>. The degradation in UV and UV with TiO<sub>2</sub> were about 94% and 80% respectively. Figure 2 indicates the changes in the optical conditions under different times.

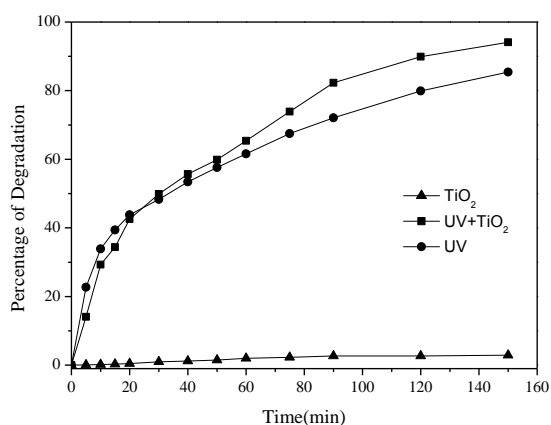


Fig.1 Photodegradability of  $\beta$ -Ionone. TiO<sub>2</sub>=80mg/L, [ $\beta$ -Ionone]=8mg/L, pH=2.

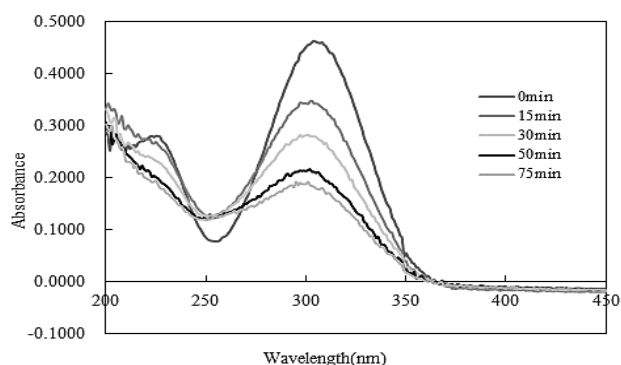


Fig.2 Typical UV spectrum profiles the degradation of  $\beta$ -Ionone on P25 catalyst.

#### Effect of Catalyst Loading

The degradation efficiency rises with the increasing concentration of TiO<sub>2</sub> and approaching to a limiting value at high concentration [16]. However, it is essential to find the optimal amount of TiO<sub>2</sub> to get efficient degradation. Figure 3 suggests the effect of TiO<sub>2</sub> loading on the degradation efficiency. As the concentration of catalyst added from 0 to 100mg/L the degradation efficiency increased from 85% to 90%, reaching the peak at 92% with 80mg/L of P25.

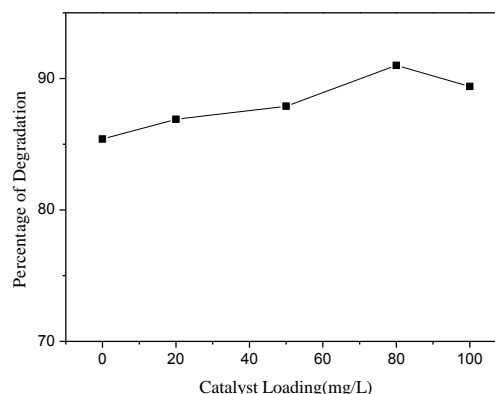


Fig.3 Effect of Catalyst Loading on the degradation efficiency

#### Effect of Initial Concentration of $\beta$ -Ionone

The effect of various initial concentrations on the degradation was investigated ranging from 5 to 10 mg/L. The results are shown in Table I. It can be seen that with the increasing of  $\beta$ -Ionone concentration, the degradation efficiency and removal rate increased as well. After the peak (8mg/L), the removal rate and efficiency decreased with the increase in concentration of  $\beta$ -Ionone. That higher pollutant concentration may impede the photon entering into the solution, which also reduces the catalytic efficiency [17].

TABLE I. Effect of initial concentration of  $\beta$ -Ionone, TiO<sub>2</sub>=80mg/L, pH=2

Initial Concentration of $\beta$ -Ionone/mg L <sup>-1</sup>	5	7	8	10
Removal Rate/10 <sup>-2</sup> min <sup>-1</sup>	1.54	1.44	1.80	1.64
Degradation Efficiency	88.6%	89.3%	94.1%	91.0%

#### Effect of Initial pH

The effect of different initial pH value of  $\beta$ -Ionone on the efficiency and removal rate has been shown in Table II. By increasing the pH from acidic to alkaline resulted in

significant reduction in degradation efficiency and removal rate, from 92.4%(pH=2) to 74.8%(pH=12) and from 0.0245min<sup>-1</sup>(pH=2) to 0.0108 min<sup>-1</sup>(pH=12), respectively. Previous studies shows when pH>6.8, TiO<sub>2</sub> surface becomes negative and repulsive to the negatively charged β-Ionone. Lower of the pH motivates the TiO<sub>2</sub> particles to aggregate and reduce the adsorption on the TiO<sub>2</sub> surface[18].

TABLE II. Effect of initial pH of β-Ionone on the efficiency and removal rate with different time

Reaction Time/min	pH=2	pH=5	pH=7	pH=9	pH=12
0	0.0%	0.0%	0.0%	0.0%	0.0%
30	74.5%	61.0%	49.9%	28.1%	27.2%
60	85.9%	77.7%	65.4%	48.5%	45.8%
90	89.5%	84.9%	82.3%	66.1%	61.3%
150	92.4%	92.8%	94.1%	81.9%	74.8%
Removal Rate/min <sup>-1</sup>	0.0245	0.0170	0.0180	0.0119	0.0108

#### Degradation Kinetics of β-Ionone

In this study, a series of experiment was carried out. When pH=2, initial concentration of catalyst was 80mg/L, the degradation kinetics of β-Ionone was obtained:

$$\ln(C_0/C_t) = 0.018t + 0.0894 \quad (1)$$

The equation indicates the kinetics follows the pseudo first-order reaction. And  $t_{1/2} = 38.51$  min,  $R^2 = 0.9924$ .

#### IV. CONCLUSION

In this study, a meaningful kinetic expression for the degradation of β-Ionone was obtained. The equation is reliable because it was obtained under a variety of different experiment conditions. It can be found that the degradation rate of β-Ionone is approximately pseudo first-order because of its concentration optimized. The catalyst loading and initial pH were also studied, which indicated the photodegradation was suitable at low pH value. And optimal TiO<sub>2</sub> loading was 80mg/L.

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