KINETICS ANALYSIS FOR ULTRASONIC DEGRADATION OF ORGANIC COMPOUNDS

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Abstract

Ultrasound has been found to be an attractive advanced technology for the degradation of hazardous organic compounds in water. The kinetics of ultrasonic degradation has been investigated, and the model for estimating the apparent degradation rate constant using ultrasonic power, sonochemical efficiency value, initial concentration, and sample volume is proposed. In this study, the application of this model to degradation of other organic compounds by other research groups has been investigated such as phenol. Especially, we focused on the effects of power, frequency, and initial concentration of organic compounds on the apparent degradation rate constant, and the model for estimating the apparent degradation rate constant can be applied to other organic compounds degraded by hydroxyl radical reaction.

Keywords

Ultrasonic degradation, Organic compound, Frequency, Initial concentration

Introduction

Recently, ultrasound is used in various applications, and a frequency between 20 kHz and 2 MHz is mainly used in chemical reaction process such as synthesis and decomposition. Ultrasound has also been found to be an attractive advanced technology for the degradation of hazardous organic compounds in water. The kinetics of ultrasonic degradation has been investigated, and the model for estimating the apparent degradation rate constant of methylene blue as model hazardous organic compounds using ultrasonic power, sonochemical efficiency value, initial concentration, and sample volume is proposed (Kobayashi et al., 2014). In this study, the application of this model to degradation of other organic compounds by other research groups has been investigated such as phenol. Especially, we focused on the effects of frequency, power, and initial concentration of organic compounds on the apparent degradation rate constant.

Theory

The sonochemical degradation of hazardous organic compounds is typically reported to be a pseudo-first-order chemical reaction. Eq. (1) define a variation in organic compound concentration (C) during ultrasonic irradiation time (t).

\[ C = C_0 \exp(-k_{app}t) \]  

(2)

Here, \( k_{app} \) and \( C_0 \) represent the apparent degradation rate constant and initial concentration of organic compound. We have proposed the formula for estimating the apparent degradation rate constant of methylene blue as shown in Eq. (2) (Kobayashi et al., 2014).

\[ k_{app} = \alpha \frac{SE_{k1}P}{C_0V} \]  

(2)

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Here, $a$, $SE_{KI}$, $P$, and $V$ represent constant of proportionality, sonochemical efficiency value (Koda et al., 2003), power, and sample solution volume, respectively.

**Effects of Operation Conditions on Degradation Rate**

**Effects of Ultrasonic Power**

Kobayashi et al. (2014) have been investigated the degradation of methylene blue using indirect ultrasonic irradiation method. The initial concentration and sample solution volume were 0.0105 mol/m$^3$ and 100 $\times$ 10$^{-6}$ m$^3$. The ultrasonic frequency was changed between 20 kHz and 1640 kHz. Figure 1 shows the effect of ultrasonic power on apparent degradation rate constant of methylene blue. A linear relationship between the apparent degradation rate constant and the ultrasonic power is also observed at each frequency.

![Figure 1. Effect of power on apparent degradation rate constant of methylene blue for various frequencies](image)

**Effects of Ultrasonic Frequency**

Pétrier and Francony (1997) have been investigated the degradation of phenol and carbon tetrachloride using direct and indirect ultrasonic irradiation methods. The ultrasonic power, initial concentration of phenol, initial concentration of carbon tetrachloride, and sample solution volume were 30 W, 1 mol/m$^3$, 0.4 mol/m$^3$, and 300 $\times$ 10$^{-6}$ m$^3$, respectively. Figure 2 shows the effect of sonochemical efficiency value on the apparent degradation rate constant of phenol. A linear relationship between the apparent rate constant and the sonochemical efficiency value is observed, and this phenomenon agrees with our proposed model. On the other hand, the apparent degradation rate constant of carbon tetrachloride increases with increasing ultrasonic frequency. Carbon tetrachloride is a more volatile and hydrophobic compound than phenol, and carbon tetrachloride is considered to decompose inside the bubble of cavitation.

![Figure 2. Effect of sonochemical efficiency value on apparent degradation rate constant of phenol](image)

**Effects of Initial Concentration**

Jiang et al. (2006) have been investigated the degradation of 4-chlorophenol using direct ultrasonic irradiation method. The frequency, ultrasonic power, and sample solution volume were 500 kHz, 30 W, and 250 $\times$ 10$^{-6}$ m$^3$, respectively. Figure 3 shows the effect of the inverse of initial concentration on the apparent degradation rate of 4-chlorophenol. The initial concentration and the apparent degradation rate constant have a relation of an inverse proportion.

![Figure 3. Effect of inverse of initial concentration of 4-chlorophenol on apparent degradation rate constant](image)

**Conclusions**

The degradation rate of organic hazardous compounds was influenced by operation conditions, and our proposed model for estimating the apparent degradation rate constant using ultrasonic power, sonochemical efficiency value, and initial concentration is applicable to the ultrasonic degradation of nonvolatile and hydrophilic compounds.

**References**


