Effect of Ultrasound on Persulfate Activation for the Removal of BPA in 20 kHz Probe Sonoreactors

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1. Introduction

Persulfate lasts longer than ozone and hydrogen peroxide, and is attracting attention as an alternative to them. Although persulfate has high oxidation power, the oxidation reaction rate is slow and used in the form of sulfate radical, and the persulfate is mainly activated by heat, ultraviolet rays and transition metals. Recently, research has been progress to activate persulfate with ultrasonic waves while using persulfate as an oxidizing agent to improve the chemical effect of ultrasonic waves.

When ultrasonic waves are irradiated to a liquid, conversion to thermal energy occurs through molecular friction due to ultrasonic irradiation, and the temperature of the liquid phase increases. While the efficiency of ultrasonic waves is known to decrease as the temperature of the liquid increases, thermal activation of the persulfate in the mixing process of persulfate and ultrasonic waves may occur and the decomposition of pollutants may be accelerated. In this study, we eliminated such thermal activation and confirmed whether persulfate can be activated only by the cavitation effect of ultrasonic waves.

In this study, the chemical effects of ultrasonic waves due to ultrasonic reaction conditions (liquid volume, injection position of prube chip) were analyzed, and BPA was selected as the substance to be decomposed by ultrasonic and persulfate. Furthermore, the concentration of sulfate ions is measured to observe the degree of activation of persulfate.

2. Materials and Methods

In this experiment a 20 kHz soul-shaped VC 750 model (Vibracell, Sonics & Materials Inc.) was applied, and a circular constant temperature tank and a double glass cylindrical (internal size: D 12 cm×H 24 cm) reactor were used to control and maintain temperature. The diagram of ultrasonic equipment and reactor is shown in **Fig. 1**. In order to select the reaction conditions for maximizing ultrasonic chemical effect, the liquid volume and the depth of the probe injection were changed using the KI dosimetry. The liquid volume is 200 mL, 300 mL, 400 mL, and 500 mL, and the position of the probe shall be the upper, middle, and lower levels based on the height of the water surface.

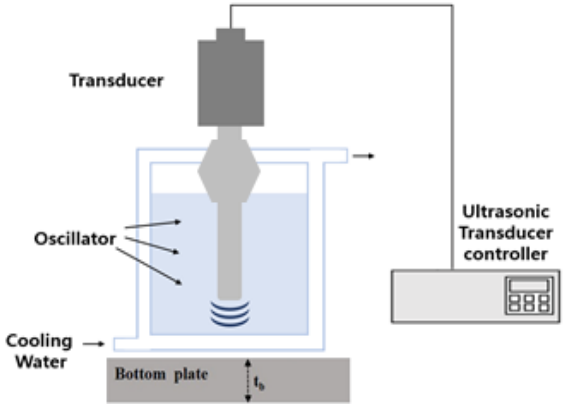

Fig. 1 A schematic of the typical horn-type sonicator.

3. Results and Discussion

As shown in **Fig. 2**, the KI dosimetry confirmed that the volume of the reaction solution and the location of the probe tip changed the amount of I_3^- ion production, and the formation of I_3^- ion was maximized when the liquid volume was 400 mL and the probe position was bottom. In the existing study, the deeper the injection depth regardless of the volume (0.4 L and 2 L), the greater the amount of oxidative radical produced by ultrasonic cavitation and the larger the chemical reaction area. This is because the deeper the injection depth of the probe device, the higher the conversion rate from the used electric energy to the ultrasonic energy, the decrease of the attenuation phenomenon of ultrasonic waves, and the reflection effect in the reactor. As a result, in this study, the optimum cavitation effect is shown when the liquid volume is 400 mL and the probe position is bottom.

This study were conducted to determine whether persulfate can be activated by ultrasonic waves. The decomposition efficiency of BPA using temperature as a variable as confirmed by applying the same conditions that showed the maximum

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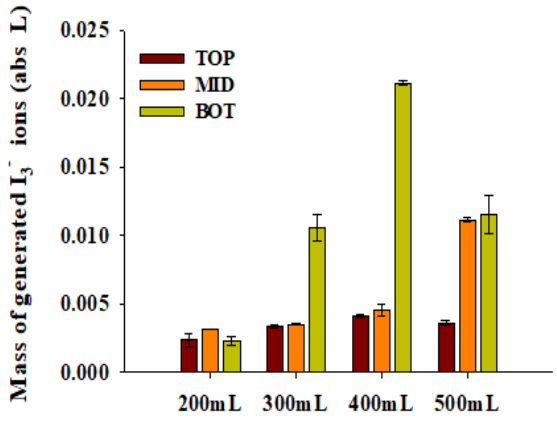

Fig. 2 The mass of I_3^- for various volume and probe position conditions (Input power : 50%)

cavitation effect. **Fig. 3** shows the decomposition efficiency of BPA and the amount of sulfuric acid ions (SO_4^{2-}) produced by sulfate activation at a specific temperature when the liquid temperature is controlled. The concentration of sulfuric acid ions to be theoretically produced is calculated from the amount of persulfate used at 72.61 mg/L SO_4^{2-}. BPA decomposition efficiency was similar to that of

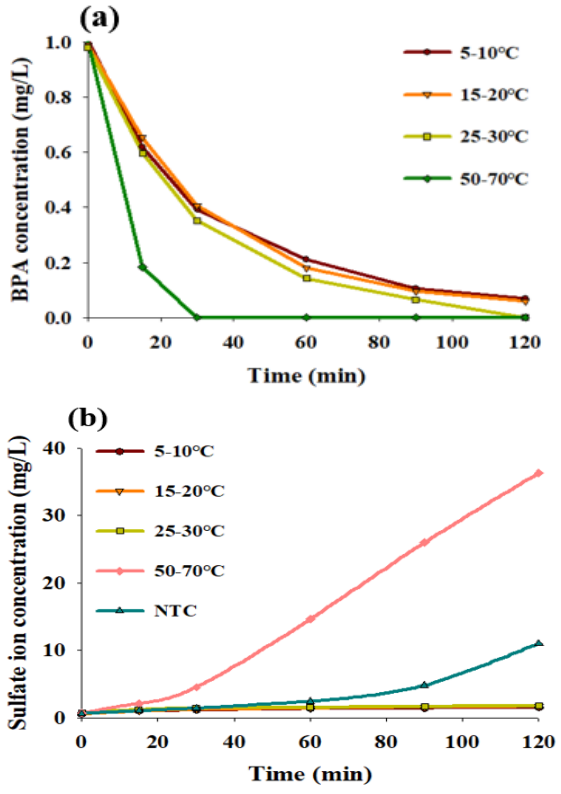

Fig. 3 (a) Effect of temperature on 1 mg/L BPA degradation with 90 mg/L PS, (b) The produced sulfate ion(SO_4^{2-}) concentration with different temperature(5-70°C) in US/PS(90 mg/L) process.

ultrasonic wave alone process, and the amount of sulfuric acid ions (SO_4^{2-}) was small. This is estimated to be due to little activation of persulfate under the applicable conditions, and the effect of sulfate radical on the decomposition of pollutants was not significant. At 50-70°C, the temperature of the liquid is increased by about 12 times compared to the ultrasonic wave alone process. In addition, about 50-60% of the theoretically calculated amount of sulfuric acid ions was generated, and about 50% of the persulfate used was activated. In other words, since the persulfate is hardly activated at a temperature below 30°C in a step of activating the persulfate with 20 kHz ultrasonic waves, it is judged that there is a limit to activating the persulfate only by ultrasonic cavitation phenomenon.

4. Conclusion

As the temperature increased, the BPA decomposition efficiency decreased in the ultrasonic alone process, but the decomposition efficiency increased in the process of using ultrasonic waves and persulfate together. In order to minimize the effect of heat on activating the persulfate, when the persulfate is activated by ultrasonic waves at a relatively low temperature of 5 to 20°C, the production amount of the persulfate ion (SO_4^{2-}) is small. Accordingly, it can be judged that it is unreasonable to activate the persulfate only by the ultrasonic cavitation effect.

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