

The Effect of High Speed Mixing on Sonochemical Oxidation Reactions in a 28 kHz Sonoreactor

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1. Introduction

Advanced oxidation processes (AOPs) are water treatment processes for the removal of nonbiodegradable and recalcitrant pollutants through using highly oxidizing species such as OH radicals. Ultrasonic technology can be considered one of useful AOPs and it is based on the cavitation phenomenon which induces various sonochemical and sonophysical effects. Volatile pollutants can be pyrolyzed inside the cavitation bubbles and semi-volatile and nonvolatile pollutants can be oxidized using $\cdot\text{OH}$, $\cdot\text{OOH}$, $\cdot\text{O}$, and H_2O_2 . Sonophysical effects including shock wave, microstreaming, and microjet can induce violent mixing in liquid phase.

In order to enhance sonochemical oxidation activity significantly, previous researchers investigated various methods including the combination of ultrasonic technology with other AOPs, gas saturation/sparging, addition of solid catalysts, and geometric optimization of sonoreactors. Recently, it was found that violent mixing also enhanced sonochemical oxidation activity. Kojima et al., reported that sonochemical oxidation activity increased as the mixing rate increased (0 – 350 rpm). Choi et al., compared gas sparging and mechanical mixing (0 – 400 rpm) in terms of pollutant removals. They found that the sonochemical active zone changed markedly as the mixing rate increased.

The purpose of this study is to investigate the effect of high speed mixing on sonochemical oxidation activity in a 28 kHz cylindrical sonoreactor. The oxidation activity was quantified using the KI dosimetry. The sonochemical active zone was

visualized and analyzed using the luminol method.

2. Materials and Methods

Potassium iodide (KI) was purchased from Junsei Chemical Co. Ltd.. Luminol (3-aminophthalhydrazide, $\text{C}_8\text{H}_7\text{N}_3\text{O}_2$) was acquired from Sigma–Aldrich Co.. Sodium hydroxide (NaOH) was acquired from Samchun Pure Chemical Co. Ltd.. All chemicals were used as received.

An cylindrical sonoreactor equipped with a 28 kHz transducer at the bottom was used in this study as shown in Fig. 1. A high speed homogenizer (X10, YSTRAL) was placed at the top of the reactor. The liquid height ranged from 2λ (107 mm, 1.8 L) to 4λ (214 mm, 3.7 L) calculated based on the applied frequency. The mixing rate ranged from 0 to 12,000 rpm.

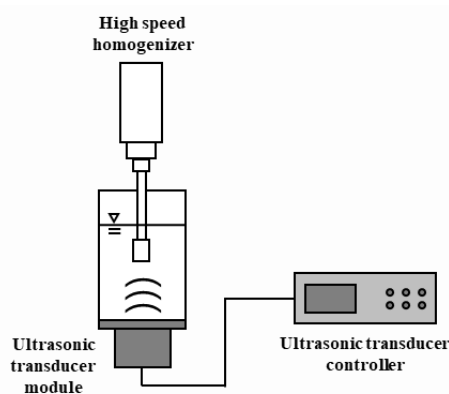


Fig. 1 A schematic of the sonoreactor with the high speed homogenizer used in this study.

Sonochemical oxidation was quantified using the KI dosimetry. The initial concentration of KI solution was 1 g/L. The concentration of sonochemically generated I_3^- ions was measured using a UV–vis spectrophotometer (Vibra S60, Biochrom Ltd.) The sonochemical active zone was

visualized using the luminol method (0.1 g/L luminol and 1 g/L NaOH). The SCL (sonochemiluminescence) image was obtained using a digital camera ($\alpha 58$; Sony Corp.) in a completely dark room.

3. Results and Discussion

Fig. 2 shows the sonochemical oxidation activity under various liquid height/volume conditions and mixing rates. The application of the high speed mixing resulted in significant increase in the sonochemical activity for all liquid height conditions (5 – 19 times higher activity was obtained). It was found that the optimal mixing rate was 3,500 rpm in this study. Higher mixing rates resulted in lower activity. No significant concentration of I_3^- ions was detected for only mixing.

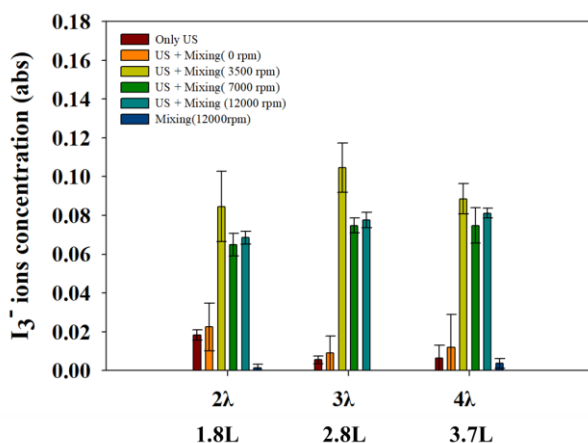


Fig. 2 Sonochemical oxidation activity using the KI dosimetry for various liquid height/volume conditions and mixing rates.

To understand the enhancement of the sonochemical activity visually, the SCL images were obtained as shown in **Fig. 3**. For the rates of 3,500 and 7,000 rpm, the standing wave field was observed. In addition, strong active zone adjacent to the transducer at the bottom was also detected. Interestingly, no standing wave field was formed and very strong active zone was formed close to the bottom for 12,000 rpm. Therefore, it was revealed that the application of high speed mixing induced

significantly high sonochemical activity due to the change of sonochemical active zone in terms of the extent and intensity.

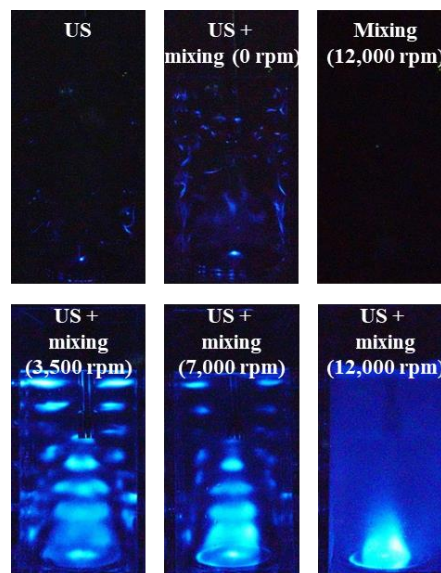


Fig. 3 SCL images for various mixing conditions (The liquid height was 4 λ.).

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