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The Effect of Aeration on Sonochemical Oxidation in a Pilot-Scale Sonoreactor

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1. Introduction

It is well-known that acustic cavitation induced by ultrasound with enough intensity can cause various chemical and physical effects. Chemical effects including pyroysis and radical reactions can be utilized for the removal of pollutants and the synthesis of nano materials while physical effects including microjet and shockwave can be applied for cleaning and extraction processes.[1)]

Environmental engineers have investigated sonochemical reactions to oxidize aqueous organic/inorganic pollutants such as phenols, chlorinated compounds, phamaceuticals, endoctrine disrupting compounds, and As(III). In order to enhance sonochemical oxidation, other AOPs (advanced oxidation processes), chemicals such as H_2O_2, and catalysts such as TiO_2 were combined with ultrasound technolgies and it was found that combination processes are very effective in terms of removal efficiency, operation time, and energy consumption.[2)]

Recently it was also reported that gas sparging could significantly enhance sonochemical reactions in a lab-scale sonoreactor.[3)] However it was not clear whether gas bubbling could be applicable in large-scale sonoreactors because much knowledge on gas bubbling has not been accumulated. Therefore, the purpose of this study was to understand the effect of gas bubbling on sonochemical oxidation and determine gas type, gas flow rate, and bubbling position in pilot-scale sonoreactors.

2. Experimental Methods

Fig. 1 shows an experimental setup of a pilot-scale sonoreactor equipped with a gas bubbling system. The sonoreactor consisted of an acrylic bath and ultrasound transducer module including nine transducers on the bottom. The applied frequency was 36 kHz and input electric power was 240 W. Gas bubbler was placed at the center of the reactor and near the wall. Five types of gases including air, N_2, N_2/O_2 (50:50), O_2, and Ar were applied and three kinds of gas flow rates including 3, 6, and 9 L/min for all gases were investigated.

Fig. 1. An experimental setup.

To quantify sonchemical oxidation, KI dosimetry was used. The concentration of KI was 1 g/L and the solution volume was approximately 12 L. The liquid height from the transducer module to the water surface was 25 cm (equivalent to 6λ, where λ is a wavelength of applied ultrasound). The concentration of triiodide ion was analyzed using a UV-vis spectrophotometer at 350 nm. The result of each condition was compared using the cavitation yield, which means the amount of sonochemical reaction product, as follows:

$$\text{Cavitation yield} = C V_L \qquad (1)$$

where C is the triiodide ion concentration (abs) and

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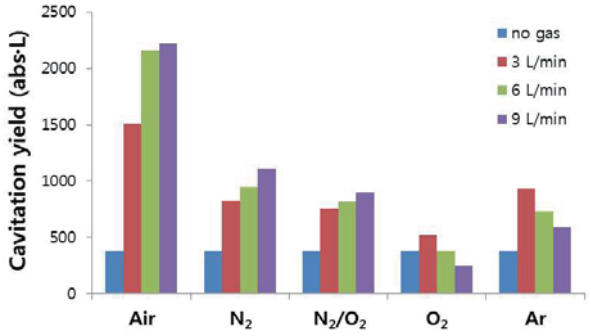
V_L is the liquid volume (L).[1, 4)]

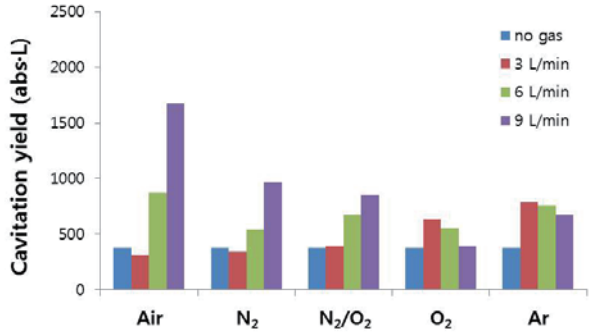
3. Results

Fig. 2 shows the variation of cavitation yields of sonochemical oxidation (the amount of triiodide ion generated) for air, N_2, N_2/O_2 (50:50), O_2, and Ar bubbling at the center of the reactor and near the reactor wall. It was revealed that gas bubbling could significantly enhance sonochemical oxidation for most cases and air bubbling was most effective among the five kinds of gases.

Fig. 2. The variation of cavitation yields for air, N_2, N_2/O_2 (50:50), O_2, and Ar gas bubbling at the center of the reactor (a) and near the reactor wall (b).



(a) At the center of reactor



(b) Near the reactor wall

It was expected that O_2 gas bubbling could enhance sonochemical oxidation because excessive oxygen supply can be a source of oxygen for the generation of highly reactive radicals such as hydroxyl radical as previous researcher reported.[3)] However excessive oxygen supply was not effective compared to other gas supply in this study. Moreover, high gas flow rates for O_2 and Ar were not beneficial while sonochemical oxidation was significantly enhanced as the gas flow rate increased for air, N_2, and N_2/O_2.

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