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The Effect of Ultrasound Frequency on the Enhancement of Solar-Photocatalytic Degradation of Chloroform in TiO_2/CPC system

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1. Introduction

In recent years, TiO_2/Solar-photocatalysis has been researched and developed by many research groups in the area of water treatments as Advanced Oxidation Processes (AOPs). The semiconductor (TiO_2) is activated due to adsorption of shorter than 400 nm of UV light and directly oxidize or revivify contaminants by hole/electron pairs. In addition, it generates highly reactive OH radicals for degrading contaminants.

If the light source used from the sun, for activating semiconductor (TiO_2), the process is called Solar photocatalysis. Solar-photocatalysis has same mechanism to photocatalysis. Generally sunlight irradiating in Earth surface has wavelength from 300 nm to 2500~ nm. This process was reported as a highly effective and environmentally friendly technology [1-2]. Nevertheless, the process efficiency was influenced by weather condition (light intensity) [2]. Therefore, when light is weak on a cloudy day or a rainy day, the process needs a supporting process to maintain performance for practical application.

In order to maintain or enhance the performance of solar- photocatalysis for degrading contaminants, an ultrasound can be one choice as supporting process. In various ultrasound frequencies, the synergistic effect of ultrasound on the photocatalysis, which is called as “sonophtocatalysis”, has been studied and has been reported that the results were more effective than each process alone [3-6].

Therefore, in this research, to evaluate applicability of ultrasound as a supporting process of solar –photocatalysis (when UV-A of solar-light is poor) and to verify the enhancement of ultrasound combined solar-photocatalysis, chloroform which are issued in drinking water treatment was treated under 35 KHz and 283 KHz frequencies in Compound Parabolic Concentrator Systems (CPCs). In addition, to know an influence of frequency on the kinetic of chloroform removals ,kinetics was studied for each and combined processes.

2. Experimental Methods

Chloroform (C2432, Sigma-Aldrich, USA) was used as the target compound. Commercially available TiO_2 powder (Degussa P25) was used as the catalyst.

Fig. 1 shows a schematic of the experimental set-up. 2 sets of metalhalide lamps (400 W, 250 W, Osram, Slovakia) were placed 60 cm up from the CPC reactor at the top of the chamber as artificial solar light. Its UV-A intensity was 12±2 W/m^2 which correlated cloudy day’s UV-A intensity.

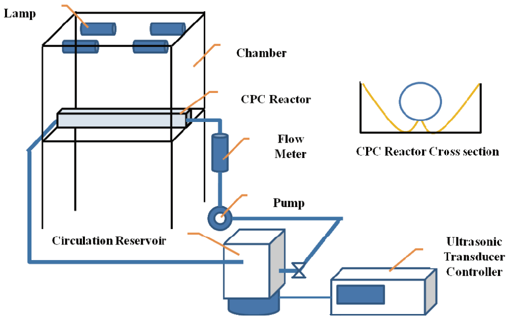

Fig. 1. Schematic of CPCs for sonophotocatalysis.

The CPC reactor consisted of one quartz tube (length of 120 cm, diameter of 3 cm, thickness of 1.5 mm) and one acrylic module which had reflector made of polished aluminum. 4 L of sample solution was re-circulated by a magnetic centrifugal pump (MD-40, Iwaki, Japan) from reservoir to CPC reactor. The system was implemented with a closed loop for preventing volatile losses of chloroform. 35 kHz, 283 KHz of two ultrasonic transducer modules (Mirae Ultrasonic Tech., Korea) was placed under reservoir. The ultrasonic power was 80 W and the power density was 0.02 W/ml. The water temperature was maintained at 20 ± 3 ℃ using recirculation cooling system. The concentration of chloroform was measured by a purge and trap (Velocity XPT, Teledyne Tekmar, USA) and a gas chromatograph (6890N,Agilent, USA) was equipped with a flame ionization detector (FID).

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3. Results and Discussion

10 ppm of chloroform was treated by US, US/TiO_2, Photo/TiO_2, Photo/US/TiO_2 process, to verify the enhancement of solar-photocatlaysis in CPCs **Fig. 2** shows removal efficiency of US, US/TiO_2, Photo/TiO_2, Photo/US/TiO_2 process under 35 KHz of ultrasound frequency. Chloroform was degraded 49 %, 46%, 41% and 80%, respect with US, US/TIO_2, Photo/TIO_2, Photo/US/TIO_2 during 200 min.

The expected results were, the removal efficiency of US/TiO_2 would be better than US, by nuclei of cavities which increase the production and stability of cavities [6]. But obtained results showed that the two processes were not much different. The degradation of chloroform by Photo/US/TiO_2 was twice better than the other process. It is not only considered simply one process adding effect but also ultrasound enhanced following solar-photocatalysis by reducing particle size (increasing surface area of catalysis) and by increasing dispersion of catalyst [4,5].

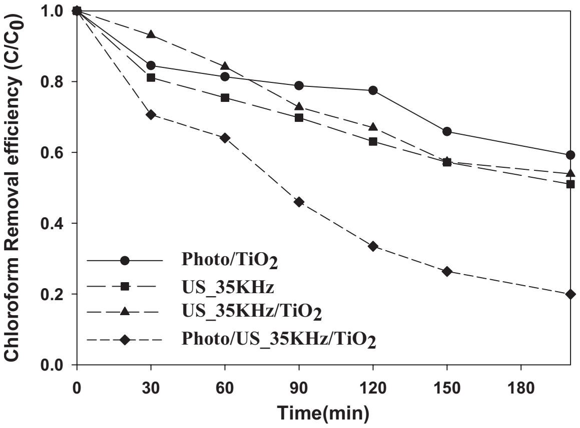

Fig. 2. Chloroform removal efficiency at US, US/TIO_2, Photo/TIO_2,Photo/US/TIO_2 (TIO_2 dose = 0.2 g/L, Frequency =35 KHz)

Table Ⅰ. Pseudo-first-order reaction rate constant k (10^3 min^{-1}) of chloroform under 35 KHz and 283 KHz.

Frequency	283 KHz		35 KHz	
Process	**K**	**R^2**	**K**	**R^2**
US	3.7	0.96	3.7	0.94
US/TiO_2	3.5	0.92	3.3	0.97
Photo/TIO_2	2.6	0.92	-	-
Photo/US/TiO_2	5.6	0.83	8.5	0.98

To verify the enhancement of ultrasound combined solar-photocatalysis for chloroform degradation in CPCs, the kinetics was studied at each and combined process under two frequencies and the result is presented in **Table Ⅰ**. The kinetic has followed pseudo-first order and Photo/US/TiO_2, >US,>US/TiO_2,>Photo/TiO_2. were ordered according to their fastness.

The effective frequency on the solar-photocatalysis combined in series with ultrasound for degrading chloroform was confirmed from the result in **Fig. 3**. The 35 KHz was more effective than 283 KHz in Photo/US/TiO_2. However, chloroform removal efficiency in US/TiO_2 has not showed much difference between 35 KHz and 283 KHz. It is considered that 35 KHz has more violent physical effects than 283 KHz, which might have enhanced the photocatalytic activity in CPC reactor. It is due to reducing particle size of TIO_2 (increasing surface area of catalysis) and by increasing dispersion [4,5] than 283 KHz.

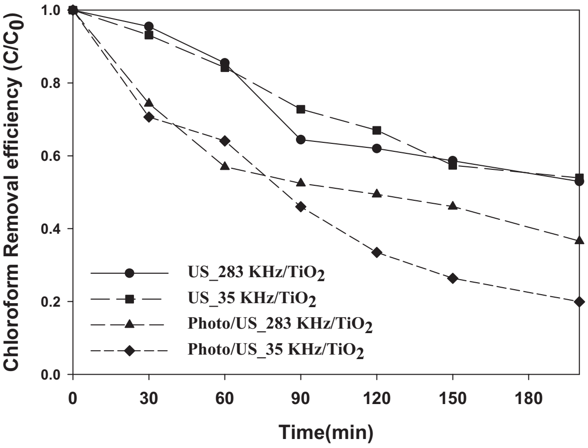

Fig. 3. Comparison of chloroform removal efficiency between 35 KHz and 283 KHz in US/TiO_2, Photo/US/TiO_2 (TiO_2 dose = 0.2 g/L)

Acknowledgment

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