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# Geometric Optimization of 28-kHz Double-Bath Systems for Enhancing Sonophysical and Sonochemical Effects

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## 1. Introduction

When ultrasonic waves are applied to a liquid phase, cavitation occurs, and various physical and chemical effects occur. Previous studies have shown that sonochemical effects varies with probe injection depth, probe horizontal position, injection power, liquid height, and bottom thickness.[1)] Other studies have also investigated the sonochemical and sonopysical effects with probe injection depth in homogeneous system (only liquid) heterogeneous system (solid and liquid).[3)]

This study aimed to investigate the difference between sonochemical and sonophysical effects in a Double-Bath-Type Systems depending on the external solvent height and the distance from ultrasonic transducer module. This is a basic study to evaluate and optimize the physical effects of solvent height and distance from the ultrasonic transducer module in the sonoreactor, and is expected to be applicable to ultrasound-assisted soil washing process in Double-Bath Systems.[4)]

## 2. Materials and Methods

The schematic of ultrasound system is shown in **Fig. 1** acrylic sonoreactor (L × W × H: 32 cm × 32 cm × 21.5 cm) equipped with a 28 kHz ultrasonic transducer module (Mirae Ultrasonic Tech., Bucheon, KOR) at the bottom. And cylindrical glass vessel manufactured same diameter of 500 ml laboratory beaker (H: 21.5 cm) was placed in the center of sonoreactor. $h_{in}$ is the height of the solution when 150 ml of tap water is placed in the vessel, which is 3 cm in all cases. $h_{out}$ is the height of the liquid in the sonoreacter. $h_0$ is $h_{out}$ that is the same as the height when $h_{in}$ + $d_{TR}$. And the subscript $\pm \mathcal{X}$ means that $h_{out}$ is the same height $h_0 \pm \mathcal{X}$ cm. $d_{TR}$ means the distance between the cylindrical glass vessel and the ultrasonic transducer module.

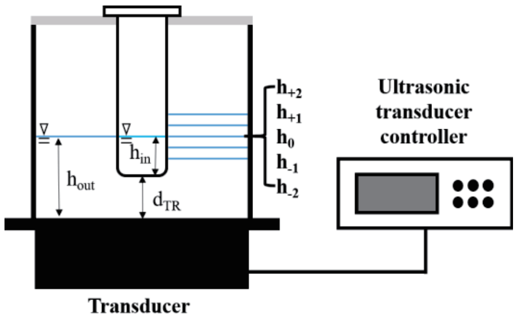


**Fig. 1** Schematic of the 28 kHz Double-Bath systems

The working input electrical power, measured using a power meter (HPM-300A, ADpower, KOR), was 315 ± 5 W. The sonoreactor was filled with tap water, and fresh tap water was used for each experiment. The ultrasonic energy, termed as calorimetric power in this study, was calculated using the following calorimetric equation.

$$P_{cal} = \frac{dT}{dt} C_p M \quad (1)$$

where $P_{cal}$ is the ultrasonic/calorimetric energy; dT/dt is the rate of increase of the liquid temperature; $C_p$ is the specific heat capacity of the liquid [water: 4.19 J/(g·K)]; and M is the mass of the liquid.[2)] Under the condition that $d_{TR}$ was 3 cm, $P_{cal}$ was calculated 8.05 ± 0.5 W.

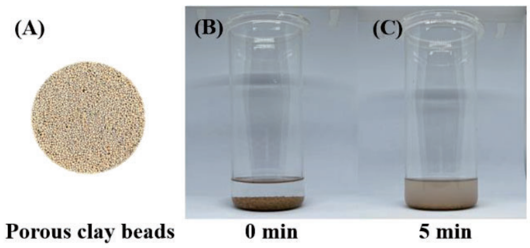


**Fig. 2** (A) Porous clay beads (B) imege before Ultrasound irradiation (C) image after 5 min of ultrasound irradiation

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Porous clay beads (diameter: 0.71 – 2 mm)(**Fig. 2**)was used to quantification of the sonophysical effects. The solid : liquid ratio was 1 : 5 (weight : volume). The solid was used 30g and liquid was used 150ml in for each experiment t. To quantitatively analyze the sonophysical effects, the vessel containing the porous clay beads was immersed in the reactor and the turbidity was measured. The ultrasonic irradiation time was 5 minutes. Turbidity Was measure using UV/VIS Spectrophotometer (Vibra S60, Biochrom Ltd., UK). Under the same conditions, images of the SCL were obtained to qualitatively assess the sonochemical effects and compare it to the impact of sonophysical effects. SCL images were obtained using an exposure-controlled digital camera (DSC-RX100M7; Sony Corp., Japan) in a completely dark room. The exposure time was 30 s.

## 3. Results and Discussions

The turbidity occurred by ultrasonic irradiation under various geometric conditions as shown in **Fig. 3**. Based on our previous research [3-5], it was expected that a smaller $d_{TR}$, make the higher turbidity by sonophysical effects. However, the highest turbidity was obtained at a $d_{TR}$ of 7 cm for the case of $h_{out} = h_0$ (abs.: 0.395) and $h_{-1}$ (abs.: 0.594). In addition, the physical effects varied with $h_{out}$, even when $d_{TR}$ was the same.

As shown in **Fig. 4**, depending on the geometric conditions, different sonochemical active zones were observed. There was a difference between the sonochemical and physical effects in each condition. This could be due to various causes, including energy distribution, the presence or absence of particles and etc.

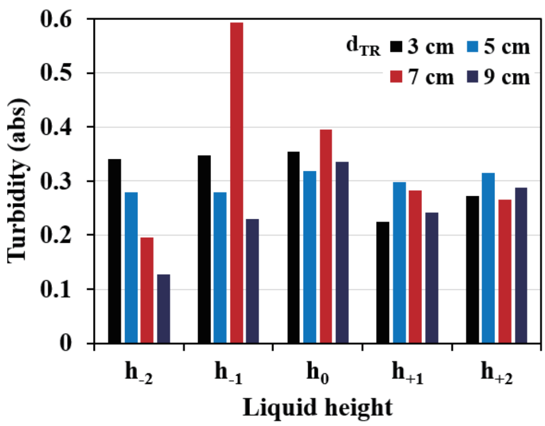


**Fig. 3** Sonophysical desorption activity for various $d_{TR}$ and Liquid Height in Double-Bath-Type sonoreactor. The solid : liquid ratio was 1 : 5 (weight : volume).

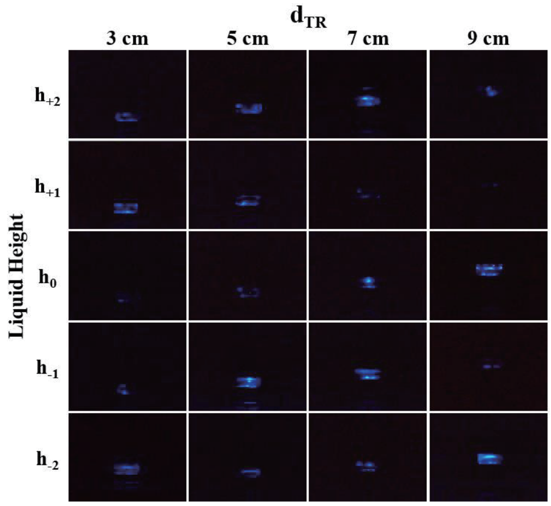


**Fig. 4** SCL images in 28 kHz Double-Bath systems during ultrasound irradiation at $d_{TR}$ and Liquid Height in homogeneous system (only liquid).


## Acknowledgment

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