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# Heavy metals removal from fine soils in ultrasonic soil washing processes

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## 1. Introduction

Sonophysical effects induced by the acoustic cavitation can be applied in various environmental and chemical processes inclduing cleaning, washing, and extraction processes. The surface of solid materials are exposed by violent physical energy and substances such as dirt attached on the surface are effectively removed.

Recently it has been reported that ultrasound technology can be applied in soil washing processes for the removal of organic and inorganic pollutants including petroleum hydrocarbons and heavy metals. The pollutants strongly attached on the surface of soil particles and trenched in the soil pores, which are not easily removed in conventional mechanical washing processes, can be desorbed in ultrasonic soil washing processes.

Most previous researchers investigated the effect of ultrasound in the soil washing processes using a a horn-type sonicator in a relatively small scale. They could observe very high removal efficiencies because the horn-type sonicaotr induced very violent mixing in small-scale washing vessels and the soil particles could be exposed to powerful sonophysical effects more frequently.

However it did not seem to induce vigorous mixing in large-scale washing processes using the horn-type sonicator. Moreover the cavitational active zone is very limited to the small zone adjacent to the emitting tip of the sonicator. In our previous study, we tested ultrasonic soil washing processes for the removal of diesel using a submerged bath type sonoreactor and observed very low removal efficiencies (approximately 30 %) because violent mixing of soil particles was barely induced. The removal efficiencies could significantly increased up to about 70 % by adding mechanical agitation.

The purpose of this study is to investigate the effect of ultrasound on the removals of heavy metals from contaminated fine soils in ultrasonic/mechanical soil washing processes. It is generally known that longer operation time and more chemicals are required to remove pollutants from fine-grained soils in the soil washing processes. Various acidic conditions and soil:liquid ratios were tested in a relatively large sonoreactor and optimal washing condition was suggested.

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## 2. Methods and materials

**Fig. 1** shows the schematic of the experimental set-up used in this study. The sonoreactor consisted of a rectangular bath (200 X 200 X 200 $mm^3$) equipped with an ultrasonic module including five 28 kHz transducers and a washing vessel (150 X 150 X 150 $mm^3$). Both the bath and vessel were made of stainless steel. The electrical input power was 170 W measured by a multimeter. The temperature was maintained at 20 ~ 25 °C. The washing vessel was placed at 1.5 cm above the bottom of the sonoreactor. A mechanical agitator with the rate of 200 rpm was used to induce vigorous mixing in soil slurry phase.

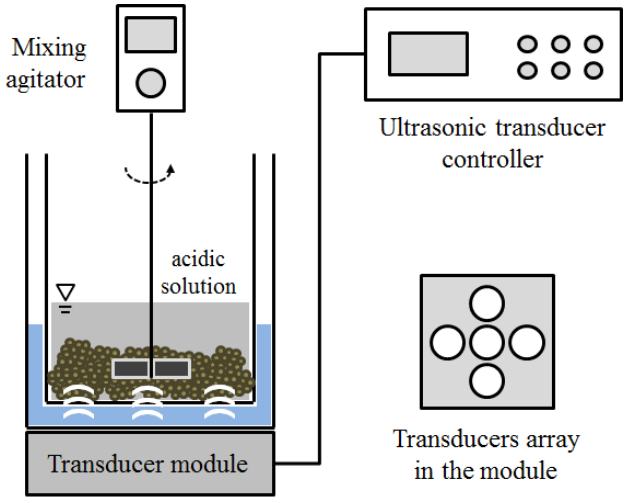


Fig. 1 The experimental set-up used in this study.

Heavy-metal contaminated soil was obtained from an old train station site in Korea and fine soil particles were separated for the washing processes in a pre-treatment process. The soil particle size distribution was analyzed using a particle size

analyzer (Malvern mastersizer 2000).

The soil sample was placed with a washing acidic solution (0.5 M HCl) in the vessel and the ultrasound and mechnical mixing were applied for 10 min. The soil:liquid ratio was 1:3 in mass. The washed soil particles were centrifuged at 4,000 rpm for 5 min and dried overnight. The heavy metal concentration of the soil sample was analyzed according to the Korean standard method of environmental pollution for soil pollution. It includes an extraction in highly acidic solution ($HNO_3$:HCl = 1:3) using a trace metal digetion system (Gerhardt SMA20A) and a filtration using a slurry filtration system (Wahtman filter paper No. 40). The filterred sample was quantitatively analyzed using an inductively coupled plasma-optical emission spectrometry (ICP-OES) (Varian 720-ES).

## 3. Results and discussion

**Fig. 2** shows the size distribution of the soil sample and D50 was determined as 4.6 μm. Fine particles deginated as clays can be separated by a #200 sieve (0.075 mm) and most soil particles in this study were smaller than this size. Therefore the soil sample considered as very fine particles. Dermont et al. reported that more chemicals/energy and longer operation time could be consumed to achieve high removal efficiency. The initial concentrations of Cu, Pb, and Zn were 37.6, 52.5, 13.4 mg/kg, respectively.

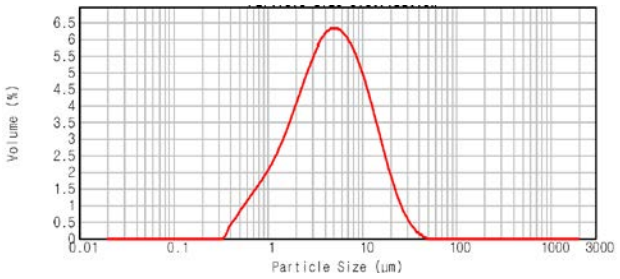


Fig. 2 The size distribution of the fine soil sample.

**Fig. 3** shows the initial concentrations and treated concentrations of heavy metals in the ultrasonic/mechanical soil washing processes with various soil amounts including 50, 100, and 200 g. The average removal efficiencies for 50, 100, and 200 g of soil were 35, 50, and 45 %, respectively. The heavy metals removal was due to the combination effect of the mechanical mixing in macro scale and the sonophysical effects in micro scale. The mechanical mixing induced frequent contacts between soil particles and acidic liquid. It also enabled the soil particles to migrate to the cavitational active zone where the pollutants strongly attached to the particles and trenched in the pores were removed by the sonophysical effects.

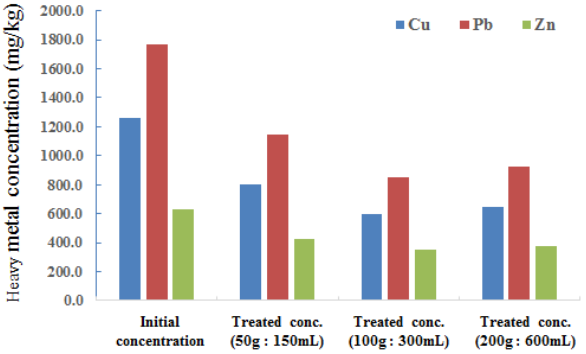


Fig. 3 The initial and treated concentrations in the ultrasonic/mechanical soil washing processes.


## Acknowledgment

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