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Ultrasound assisted Soil washing for removal of Diesel with Surfactant

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1. Introduction

Generally mechanical mixing was a key process in conventional soil washing process and sometimes anionic or non-ionic surfactants was injected to enhance mass transfer of pollutants from soil to aqueous phase [1, 2]. Recently it was found that ultrasound could increase removal efficiency significantly. When ultrasound was irradiated in water or slurry, cavitation events occurred and sonochemical and sonophysical effects were induced. In soil washing process sonophysical effects such as micro-jet and micro-streaming could enhance mass transfer of organic/inorganic pollutants from soil phase to aqueous phase [3-5]. The purpose of this study was to compare ultrasonic soil washing process with conventional mechanical soil washing process and to understand the mechanisms of each process.

2. Experimental Methods

Fig. 1 shows a schematic of the experimental set-up. The pentagon-shape sonoreactor consisted of a stainless steel reactor and five ultrasonic transducer modules (Mirae Ultrasonic Tech.) which was placed on each side wall. Each transducer module contained three lead zirconate titanate (PZT) transducers (Tamura) which could produce four frequencies of 35, 72, 110, and 170 kHz. In this study 35 kHz was used and input power was 400 W. A 400 mL pyrex vessel containing target materials was placed at the upper position of the sonoreactor. The reactor was filled with 5 L of tap water and the water temperature was maintained at 25 ± 2 ℃ using recirculation cooling system.

The electric input power for the whole sonoreactor was measured by a multi-meter (M-4660M, METEX). The water temperature in the vessel was measured for calorimetry during ultrasound irradiation using a thermometer (DTM-318, Tecpel) and effective ultrasonic power in the vessel was obtained using following equation:

$$Ultrasonic\ Power = (dT/dt)\,c_p\,M \qquad (1)$$

where dT/dt was rate of temperature increase in the solution, c_p was heat capacity of solution (water), M was mass of solution

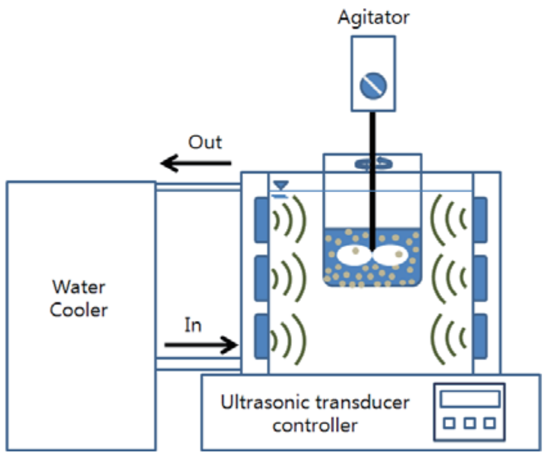

Fig. 1 Schematic of sonoreactor for soil washing processes

Joomunsin sand commercially available in Korea was sieved to the particle size of 0.24~2 mm. The sieved soil was contaminated with diesel and then aged over 15 days in the dark vessel at room temperature. The initial concentration of diesel in the soil was 20,000 mg/kg.

For all experimental sets the soil-water ratio was 1:3 (a 10 g of soil was used) and mechanical mixing using agitator with Teflon blade was applied at the speed of 160 rpm. The electric power consumed by agitator was measured using the multi-meter. After 1 min washing process the residual diesel concentration in terms of total petroleum hydrocarbons (TPH) was measured according to the Korean standard method for soil pollution [6]. The slurry sample in the vessel was dehydrated using anhydrous sodium sulfate and then residual diesel was extracted from the soil using dichloromethane under ultrasonic irradiation for 10 min. The extraction solution was filtered by disposable syringe filter and injected into a gas

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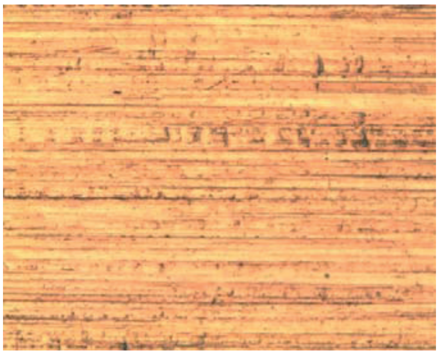
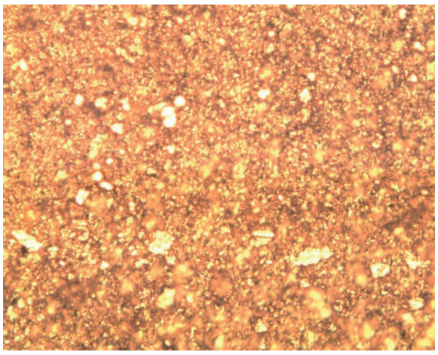
chromatography (Agilent Technologies 6890N) equipped with a flame ionization detector and a DB-TPH column (30m × 0.32mm × 0.25 mm).
The surfactants used herein were sodium dodecyl sulfate (SDS) and Triton X-100. Both chemicals were purchased from Sigma-Aldrich.

3. Results and Discussion

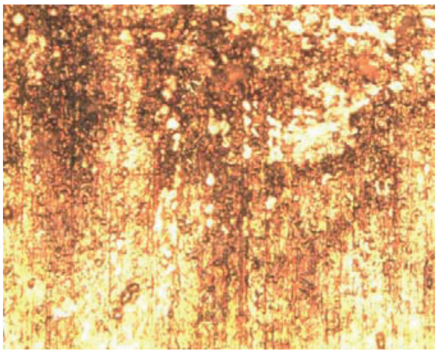
Fig. 2 shows damage images of aluminium plate (thickness was 2 mm) and the damage on the plate was caused by micro-jet, one of sonophysical effect.



(a) Before irradiation



(b) 1 hr after irradiation



(c) 2 hr after irradiation

Fig. 2 Damage images (400× magnification) of aluminium plate after ultrasound irradiation using high power optical microscope (N8 NEOS, Pucotech).

Fig. 3 shows removal efficiency in various soil washing processes. Application of ultrasound and mechanical mixing spontaneously resulted in high removal efficiency. Surfactants injection enhanced removal efficiency in mechanical mixing while there was no significant increase of removal efficiency by injection of surfactants in ultrasonic/mechanical soil washing process.

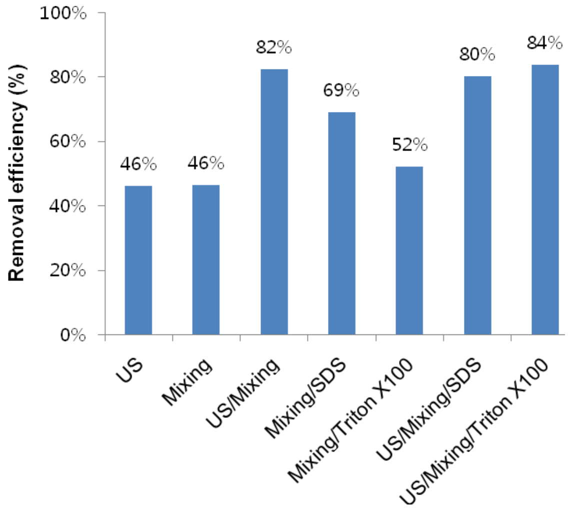


Fig. 3 Removal efficiency under various soil washing conditions.

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