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Ultrasonically Enhanced Diesel Removal from Soils

Younguk Kim, Ji-Ho Park (Myongji Univ., Dept. of Civil & Environ. Eng.),
Sun-Mee Kim[†], Jeehyeong Khim[*] (Korea Univ., Dept. of Civil & Environ. Eng.)

1. Introduction

Petroleum hydrocarbons are commonly found in the ground of urban and suburban areas due to the leakage of gasoline, motor oils, and diesel fuel from UST (underground storage tanks). It is necessary to clean the polluted ground in order to avoid potential hydrocarbon contamination of ground water aquifers which can directly impact human health. For the development of an effective clean-up technology, we focused mainly on physical methodology instead of chemical additions, as they may result in secondary contamination. Recent data has shown that ultrasonic waves are capable of removing contaminants from soils.

The effect of ultrasound on flow rate through soils was reported by Kim et al.[1)]. However, available information about the effects of ultrasound on the extraction of contaminants from porous media is limited and piecemeal. Iovenitti et al. [2)] reported a 6-26% improvement in surrogate contaminant extraction using ultrasound. Kim and Wang[3)] studied the application of ultrasound to enhance the extraction of a surrogate contaminant from soils. However, the above experiments were conducted on a surrogate contaminant using opposite gradients of acoustic pressure and head loss. In order to apply ultrasound to contaminant removal in the field, general laboratory experiments should be conducted with real contaminants and the same gradient of acoustic pressure and head loss (i.e. the same direction of flow). This study investigated the effect of ultrasound on real contaminant, i.e., diesel removal from soils through laboratory experiments, keeping in mind the aforementioned limitation of the previous studies.

2. Laboratory Experiments

The test soils were commercially available Joomoonjin sand, Granite residual soil SW (under natural conditions) and Granite residual soil SP (under adjusted conditions), which are very common in the Korean peninsula. SP and SW stand for poor-graded and well-graded sand, respectively. For these soil samples, the effective grain sizes (D_{10}) were 0.20, 0.18, and 0.15 mm, respectively. Initial void ratio of all specimens was maintained at 0.60.

Laboratory experiments involved a constant head test using specially designed and fabricated test equipment, which is shown schematically in Figure 1. As shown in the figure, the test setup was composed of four parts: a test chamber, water reservoir, peristaltic pump and ultrasonic processor. The test chamber was made of an acrylic container having an inside width of 5 cm with a height of 20 cm. In the end parts of the container are installed an inlet, overflow and an outlet tube. The inlet tube was connected to a reservoir of water with a pump, which was connected to the water tap. The overflow tube was used to maintain constant heads by allowing overflow of excess water. The outlet tube was connected to a graduated cylinder to measure removed contaminant concentration in the flushing water. The test soil was situated in the middle part of the test chamber at a height of 4.5 cm, with porous screens and wire meshes (#100) at both ends.

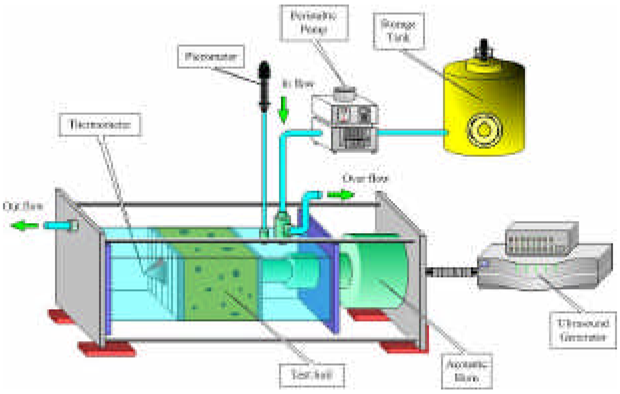


Fig. 1 Schematic of Laboratory Experiment

The ultrasonic processor device was a 500 W-Ultrasonic processor manufactured by Cole - Parmer International. The entire apparatus was composed of a generator, a converter, an acoustic horn and a flat tip. The generator (power supply)

[*]hyeong@korea.ac.kr

converted the conventional 60 Hz AC at 220 V to a 20-kHz electrical energy at approximately 1,000 V. The high-frequency electrical energy was fed to the converter to transform it into mechanical vibration. The vibrator was turned to vibrate at 20 kHz. The acoustic horn and flat tip amplified the longitudinal vibration of the converter.

The amount of diesel extracted from contaminated soil was estimated by the Rotary Evaporator Iyely-n 1000 method. The conditions were 30℃, 30 min. duration, 80 rpm and a vacuum pressure of 23.9 kPa.

3. Results and Discussion

Figure 2 shows the contaminant removal from Joomoonjin sand with different ultrasonic power intensities of electrical output energy. The initial diesel contamination in the soil was 30% of pore volume(PV). The figure shows that the diesel removal increased as the ultrasonic power was increased. After flushed with 2 PV of water, contaminant removal remained constant.

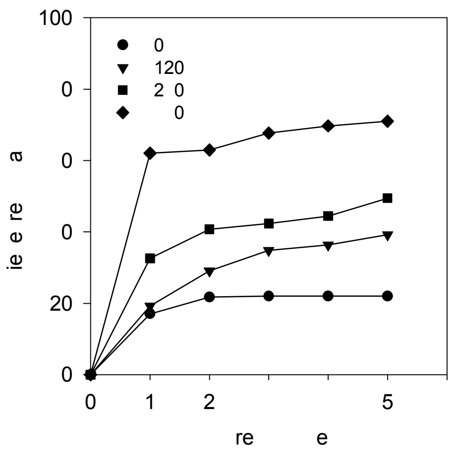
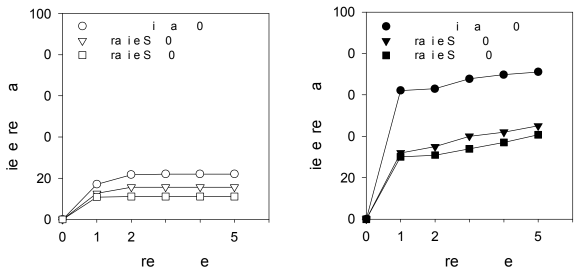


Fig. 2. Effect of ultrasonic radiation power intensity on diesel

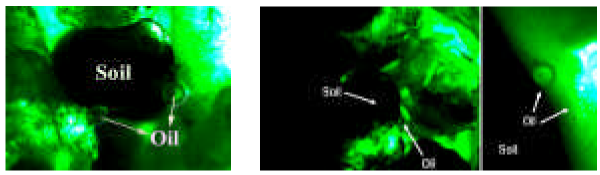
The results of experiments with three different particle size fractions are shown in Figure 3. As seen in the figures, the percentage diesel removal decreased with a decrease in particle size. This is to be expected, owing to the higher surface areas of the finer particles which mean smaller capillary tubes. Under the same dragging forces driven by water flushing, it is easier to decontaminate coarse materials than fine ones. Still application of ultrasound increases diesel removal significantly.

Figure 4 represents a variation of trapped oil drop. The pictures were taken using Optical microscope(Model: OLYMPUS BX51) and Camera of Pixelink(Model: PL-A662). In application of ultrasound, a drop is set vibrating and its displacement gradually increases. As a result, a large droplet can break into smaller droplets(Fig. 4 (b)). Figure 4 (c) shows enlarged pictures near soil particle in Figure 4 (b). Parts of the oil drop(c) might escape from the capillary force. Therefore, the percentage of diesel removed would be higher for the broken small droplets.



(a) without ultrasound (b) with ultrasound

Fig. 3. Effect of particle size on diesel removal



(a) without ultrasound (b)with ultrasound (c)detailed

Fig. 4. Variation of oil droplet due to ultrasound

4. Conclusions

The effects of ultrasound on diesel removal from soils were investigated in this study. Laboratory soil-flushing experiments were conducted for a range of conditions involving ultrasonic power, particle size, and contaminant, diesel. The test results indicated that the rate of contaminant extraction increased significantly with increasing ultrasonic power. The efficiency of diesel removal was significantly affected by particle size and intensity of ultrasonic energy. Diesel was more easily removed from relatively coarse particles because of their lower surface areas.

References

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