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Enhanced soil-washing process by ultrasound for the diesel-contaminated soil

Jihoon Cha‡, Younggyu Son, Sang-gun Nam , Sang-hyun Cho, Mingcan Cui, Jeehyeong Khim†
(Department of Civil, Environmental and Architectural Engineering, Korea University)

1. Introduction

Soil and groundwater contamination with diesel is caused by underground storage tanks run out. Diesel contains a complex mixture of compounds, mainly petroleum hydrocarbons (PHCs). The main environmental concern with diesel is that, if not handled carefully, soil remediation can lead to long term contamination of ground water by rainfall, and as a result, it may pose significant danger to human health and the earth's ecology [1].

Various soil remediation technologies have been used, for example, vapor extraction, pump and treat, flushing, and washing. Of these technologies, soil washing has the shortest process time and the highest efficiency. However, a technology that can be efficient and economical for a widely range of places is not yet available [2]. Therefore, many studies have been carried out on various remediation technologies for diesel-contaminated soil.

Recently, ultrasound has been used for soil remediation l (diesels, heavy metals, etc.) [2-5]. Ultrasound causes physical effects (microjet, microstreaming, shock wave) due to acoustic cavitation. These effects can enhance the mass transfer from the solid phase to the liquid phase.

Studies have been carried out on the efficiency of diesel removal by ultrasonic irradiation according to many variables (soil and liquid ratio, power intensity, surfactants etc.) [2-5]. However, limited research has been done on the comparison of the removal efficiency of diesel contaminated soil by mechanical stirring only with that by mechanical stirring with ultrasound.

In this study, we compared the effects of diesel removal in soil by continuous stirring with those by stirring with ultrasound. After a stirring, i conducted the experiment changing the water constantly because after a stirring, the water may be saturated and the reaction time was 1 minute. In the research on ultrasonic irradiation, the efficiency of diesel removal by surfactants(SDS) injection was investigated.

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hyeong@korea.ac.kr

2. Experimental procedures

The sonoreactor used herein consisted of a stainless steel reactor of pentagon shape and an ultrasonic transducer module (Mirae Ultrasonic Tech.) placed on the reactor wall. Each transducer module contained three PZT transducers (Tamura corp.) and could produce ultrasounds of 35, 72, 110 and 170 kHz. The maximum power of the transducer module was 500 W. The reactor was filled with 5 L of tap water. A 50 mL reactor cell containing contaminated soil and washing water was submerged in the sonoreactor. Fig. 1 shows the schematic of the experimental apparatus.

Jumunsin sand was sieved using a mesh whose size ranged from 30 to 40 , so the particle size ranged 0.4~0.6 mm. The soil was contaminated with diesel (using n-pentane) for 15 days. The initial concentration of diesel in the soil was 7,000 mg/kg.

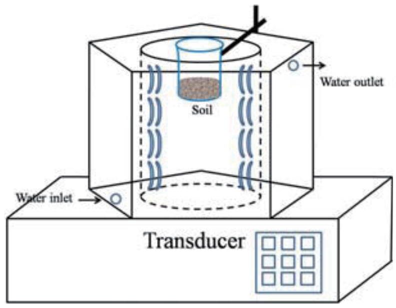

Fig. 1 schematic of reactor

An ultrasound irradiation experiment was carried out after the n-pentane in the soil had completely evaporated. The bath type sonicator (Flexonic, Mirae Ultrasonic Tech.) with a frequency of 35 kHz and power of 400 W was used. A mixture of 10mg contaminated soil and 20mL water was added into a 100mL cylindrical bath reactor and sonicated for 1min. The effect of the surfactant was observed by using 8mM sodium dodecyl sulfate (SDS) . The reaction temperature was kept constant at 25±2℃ by a water cooling system.

After sonication, the sample was placed into a centrifuge operated at 4000 rpm to separate the solid and liquid phases. The diesel concentration in the solid phase was then extracted by using dichloromethane and measured for total petroleum hydrocarbon content (TPH) with a GC-FID (Agilent, 6890).

3. Results and Discussion

In order to compare the removal efficiency of the diesel contaminated soil by mechanical stirring only with that by mechanical stirring with ultrasound, stirring velocity was set to 60rpm and ultrasound of 35 kHz and 400W was applied. In this case, if the reaction time is long, the diesel removal efficiencies of both reactions maybe very high. Therefore, the reaction time was set to 1 minute. During the experiment, the water was changed constantly after stirring because of possible saturation of water after stirring.

Fig. 2 shows that as stirring was repeated, the rate of diesel removal increased but the rate of increase reduced. In conclusion, the diesel removal by five repeated stirrings was found to be similar to that by stirringwith ultrasound.

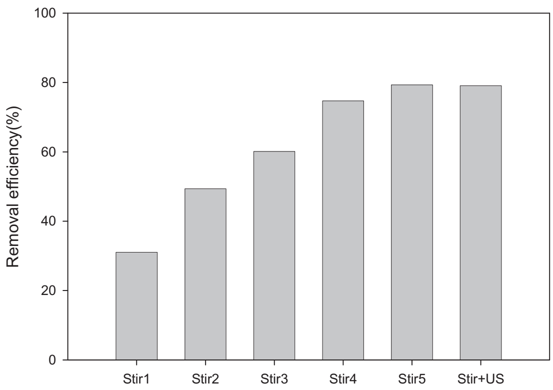

Fig. 2 Comparision of stirring of repeated and stirring with ultrasound

Previous results have shown that when stirring and ultrasound were adjusted simultaneously, the removal of diesel increased. Furthermore, we investigated the improvement of removal efficiency by the addition of surfactants. The SDS that used in previous research was applied.The properties of the surfactant are shown Table 1.

Surfactant	CMC (mass %)	Surface tention (mNm^{-1})	Interfacial tention (mNm^{-1})	Sorption to soil (%)
SDS	0.2	35	7	33

Table 1. Surfactant (SDS) properties adopted from Urum et al. (2003, 2004)

Experiments were carried out at the same concentration with ultrasound for one minute. The results are shown in Fig. 3. The removal efficiency with SDS was higher than that without SDS. And the rate of increase of the removal efficiency by

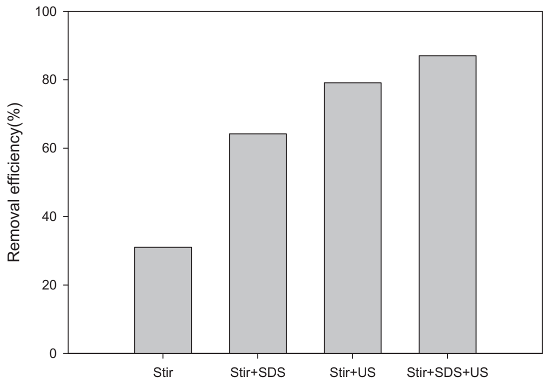

Fig. 3 Effect of surfactant(SDS)

mixing only was higher than that by mixing with ultrasound.

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