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Ultrasonically Enhanced Effectiveness of Various Surfactants on Diesel Removal from Contaminated Soil

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The use of ultrasound to enhance the efficiency of surfactant-aided soil washing was investigated with a series of laboratory tests on diesel contaminated soil. Test conditions included the power and duration of sonic energy, the surfactant type, and mixing duration. The results of the study show that the ultrasound used in the soil-washing process enhanced remediation of the contaminated soil significantly. The degree of enhancement varies with sonication energy, treatment time, and mixing duration.

KEYWORDS: contaminated soil, diesel, remediation, soil washing, sonication, surfactant, ultrasound

Petroleum related contaminants are commonly found in the ground due to leakage from underground storage tanks. The contaminated soil needs to be cleaned to avoid potential pollution of ground water. Among various remediation technologies, soil washing with surfactant is gaining popularity due to its simplicity and effectiveness[1)]. The technique has been successfully applied to remove contaminants from soils[2)]. The mechanism of remediation using surfactant is a decrease of the interfacial tension between the contaminants and soil particles. However, the use of surfactant may cause the secondary contamination to the ground due to the residual of hazardous element of the surfactant. Bio degradation of the surfactant is another factor which should be considered for application of the technique. A number of studies[3-6)] have investigated the beneficial effects of ultrasound to increase of the efficiency of water flow and contaminants removal. Available information about sonication effects on surfactant-aided soil washing is limited and piecemeal[7)]. In this study, the use of ultrasonic excitation to increase contaminant removal during the surfactant aided soil washing process was investigated with various surfactants. In laboratory experiments, the levels of ultrasonic energy, ultrasonic irradiation time, and mixing time were varied.

The test specimens were prepared using a granitic soil which is very common in the Korean peninsula. The physical properties of the soil are summarized in Table I. Diesel fuel with a specific gravity of 0.85 was mixed with the air-dried soil and aged for six months at room temperature. The amount of diesel in the soil was subsequently measured before testing. Experiments were conducted both with and without the application of ultrasonic energy. Bath type processor (Dongshin, Ltd., Model DSG-1528, 50 X 50 X 50 cm^3) with a maximum output power of 1500 kW in conjunction with a 20 kHz frequency, as shown in Fig. 1 was used to apply ultrasonic energy to the soil sample during surfactant aided washing. The acoustic pressure (the root mean square) at the bath was 69 Pa which obtained using a hydrophone (GRAS 10CC). Sodium dodecyl sulfate (SDS), Triton X-100 (X-100), and tri-sodium salt of the spiculisporic acid (S-3Na) which is known as bio-surfactant were used as the surfactant. The degree of bio-degradation of the surfactant, an indicator of environmental friendly, is the greatest in S-3Na and the smallest in X-100.[1]

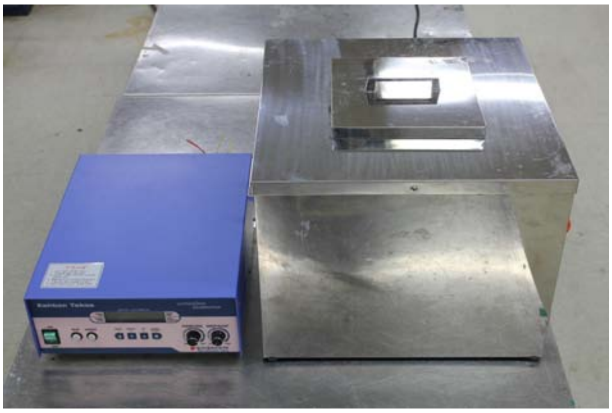

Fig. 1. Ultrasonic processor.

Table I. Physical properties of soil sample.

Specific gravity	Plastic index (%)	Frictional angle (degree)	Median particle size (mm)	Soil classification
2.61	13	39	1.4	Poorly graded Sand

The major steps involved in the experiments are as follows. 20 g of contaminated soil and 100 ml aqueous solution with a surfactant or without surfactant was added. After sonication, soil particles were separated, and the concentration of diesel in the soil was obtained by the measuring the total petroleum hydrocarbon (TPH) with methylene chloride extracting. The concentrations of TPH were analyzed using HP 6890 GC/FID. Test conditions summarized in Table II.

Table II. Test conditions.

Surfactant type	Output power (Watt)	Irradiation time (min)	Mixing time (min)
SDS, X-100, S-3Na	150, 300, 1200, 1500	2, 5, 20, 40	10, 20

The removal efficiencies of diesel from the soil after 20 min. mixing in conjunction with irradiation of ultrasound (1,500 watts) and without sonication are shown in Fig. 2. At all surfactants, the enhancement by ultrasound in the removal efficiency was significant. The initial concentration (TPH) of diesel contaminated soil was 2,250 mg/kg.

However, note that the result of the experiments is a function of not only the power of ultrasound but also the mixing and irradiation time and volume of soil sample to be remediated. Therefore, the applied ultrasound energy level per volume of soil specimen could be expressed in terms of the specific supplied energy parameter, which is defined as

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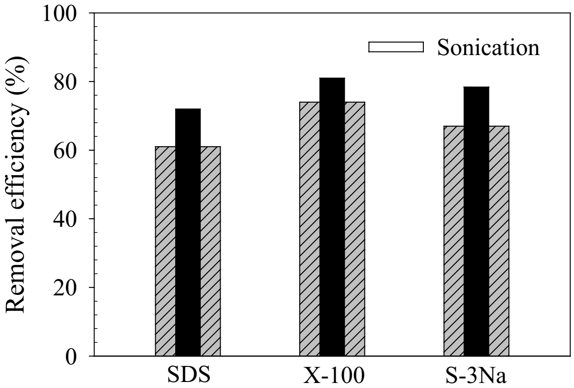

Fig. 2. Removal efficiency with various surfactants.

$$E_{us} = \frac{p \times t_i \times t_m}{v_{soil}} \qquad (1)$$

where P is the consumed ultrasonic power (kW), V_{soil} is the total volume of the soil sample (g), and t_i is the ultrasonic irradiation time (min), and t_m is the mixing time of contaminated soil and surfactant (min). Fig. 3 shows that the contaminant removal using SDS with the parameter E_{US}. Test A indicates simultaneous application of ultrasound and surfactant whereas ultrasound was irradiated after 20 min mixing the contaminated soil with surfactant in Test B. It can be inferred from the Fig. 3 that ultrasound cause insignificant effects on specimen after the chemical reaction and in the low level of input energy parameter.

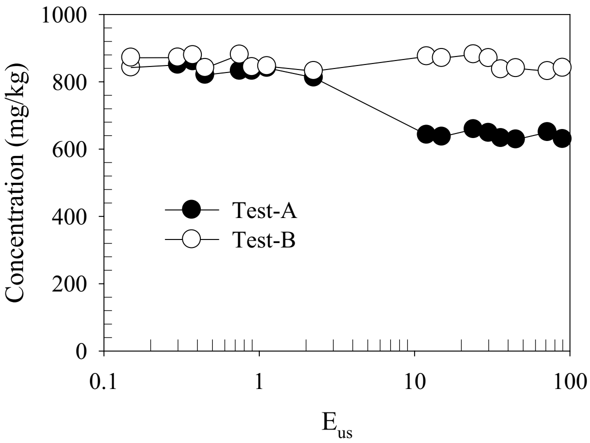

Fig. 3. Effect of energy level on contaminant removal (surfactant: SDS, initial concentration: 2250 mg/kg, average removal of zero energy level: 877 mg/kg).

The contaminant removal using different surfactant is illustrated in Fig. 4. Test A which is aforementioned was adapted in this experiments. As shown in the figure, ultrasound starts affecting markedly the efficiency of contaminant removal using surfactant over the energy level parameter of around 3. However, the effect of ultrasound on the X-100 aided soil washing is not significant. It can be attributed to the interaction between the soil particle and the diesel. The bonding force between the soil and diesel is stronger than that between contaminants. At lower concentration of contaminant, ultrasonic energy was not enough to break the bonding between the soil particle and the diesel. The results are accordance with the postulation presented by Na *et al*.(2007).

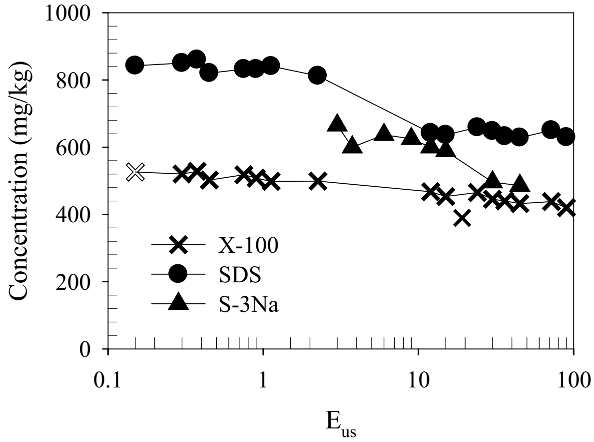

Fig. 4. Contaminant removal with energy level (initial concentration: 2250 mg/kg, average removal of zero energy level: 877 mg/kg(SDS), 568 mg/kg(X-100), 741 mg/kg(S-3Na)).

The surfactant-aided soil washing is widely used remediation technology. Its application however may cause the secondary contamination due to surfactant itself. This study investigated the use of ultrasound to enhance the efficiency of the surfactant aided soil washing for the purpose of reduction in surfactant usage. A series of laboratory experiments on diesel contaminated soil was conducted, and the conditions of the tests included the power and duration of sonic energy, the surfactant type, and mixing duration. The results of the study show that the ultrasound enhanced remediation of the contaminated soil significantly in the surfactant aided soil-washing process. The degree of enhancement varies with sonication energy, treatment time, and mixing duration. It might be correlated with the energy level parameter. Thus, further studies are warranted to reduce the usage of surfactant and develop an eco-friendly remediation methodology.

1) J. Lee, M. Hsu, H. Chao, H. Huang, and S. Wang: J. Hazard. Mater. **114** (2004) 123.
2) M. Chang, C. Huang, and H. Shu: Chemosphere **41** (2000) 1295.
3) R. Duhon: Ph. D. Thesis, University of Oklahoma (1964)
4) L. Reddi, S. Berliner, and Y. Lee: J. Environ. Eng. **119** (1993) 746.
5) Y. Kim and M. Wang: Ultrasonics **41** (2003) 539.
6) Y. Kim, T. Hoang, Y. Chun, and Z. Ming: Jpn. J. Appl. Phys. **51** (2012) 07GD12-1.
7) S. Na, Y. Park, A. Hwang, J. Ha, Y. Kim, and J. Khim: Jpn. J. Appl. Phys. **46** (2007) 4775.