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Oil-contaminated Soil Remediation Technology by Microwave Thermal Desorption

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Abstract. In this paper, the feasibility of microwave thermal desorption technology was investigated to treat the oil-contaminated soil in military base. In recent, microwave thermal desorption technology has been newly developed which can substantially reduce the remediation cost of oil-polluted soil with low electric power consumption in Korea. This technology uses MIP (Microwave Irradiated Pyrogen) or microwave absorber in the microwave thermal desorption system in order to effectively develop the microwave heating temperature to treat the oil-contaminated soil. From the lab test, it is found that this technology has a potential to rapidly complete the remediation process of the oil-contaminated soil with high efficiency.

Keywords: Oil-contaminated soil, microwave, thermal desorption, MIP, microwave absorber.

1. Introduction

Thermal treatment is one of the effective methods to rapidly treat the oil-contaminated soil. However this method costs much due to the high energy consumption comparing with other conventional treatments. Microwave is recently regarded as an energy source to enhance the energy efficiency for the thermal treatment of the oil-contaminated soil [1]. In this study, the indirect microwave thermal treatment was used as a microwave thermal desorption technology. In other words, microwave as an energy source heats the soil container other than soil itself. High temperature developed in soil container effectively reduced the level of TPH of the oil-contaminated soil.

2. Test Methods

2.1. Materials

The oil-contaminated soil tested in this study was collected from the military base in Korea as shown in Figure 1. The soil was dried and then sieved to less than 2.0 mm. The sample is classified as loam in triangular classification with a TPH level of 8,420 ppm and water content of 30.2 %. Table 1 and Figure 2 show the physicochemical properties and grain size cumulative distribution of the tested soil.

2.2. Experimental Program

In this study, the MIP (Microwave Irradiated Pyrogen [2] or microwave absorber was used to develop the microwave heating temperature transmitted to the oil-contaminated soil. In other words, MIP was filled in the cavity (space between inner soil container and outer container) for rapid and sufficient heating of soil container. The figure 3 shows the experimental setup. At the top, microwave heating assembly with

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magnetron (microwave generator) operating at 2.45 GHz was installed to supply microwave energy. A tested soil of 1.0 kg was placed in soil container of 0.008 m^3. The soil container was rotated with 3 to 5 rpm in order to uniformly heat the soil, and the treated soil was poured through the outlet channel after a desirable residence time (15, 30 and 60 minutes). During the test, the temperature in soil container was monitored with a type-k thermocouple [3].

Fig. 1: Oil-contaminated soil tested in this study

Table 1: Physicochemical properties of the tested soil

Total Organic matter Content (%)	TOC (%)	CEC (Cmol/kg)	Bulk Density (g/cm^3)	PH	True Specific Gravity (g/cm^3)	Total Nitrogen (mg/kg)	Total Phosphorus (mg/kg)
0.52	0.3	17.17	1.49	7.8	2.53	597	228

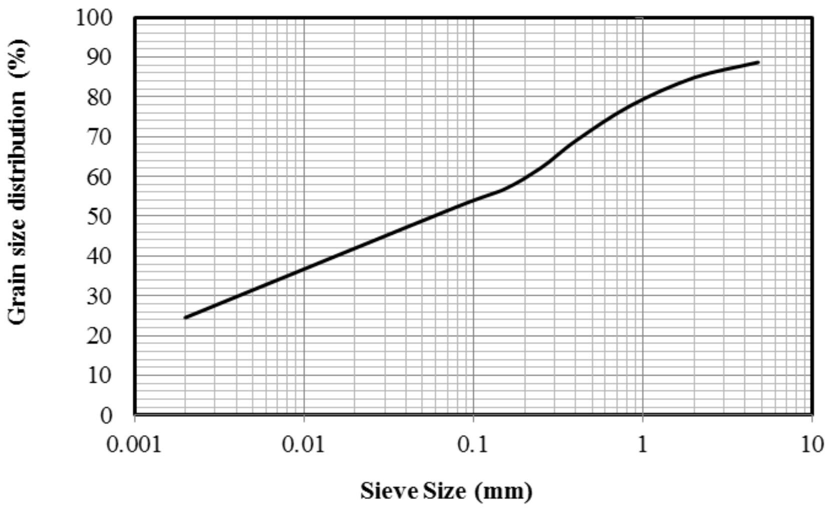

Fig. 2: Grain size cumulative distribution curve

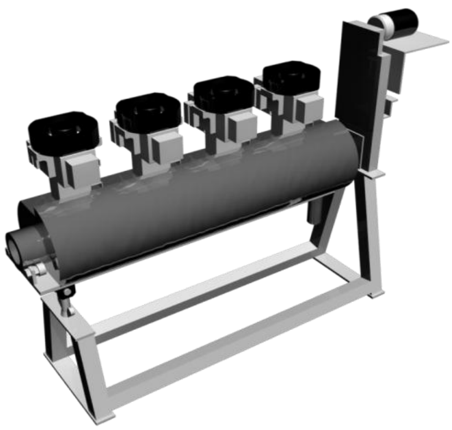

Fig. 3: Experimental setup

2.3. Analysis

Oil desorption in the tested soil was determined as TPH in accordance with KS IISO 16703 [4]. In order to measure the remain TPH concentration in the tested soil, 10 g of the soil was mixed with 50 mL of dichloromethane by ultrasonic-enhanced solvent extraction according to the Korean Standard Test Method. The water content of soil samples was estimated by drying at 105 ℃ for 24 hours. The solvent experimental stage of the slurry was divided by centrifugation, which was evaporated to a constant volume using a rotary evaporator. TPH was analyzed using a gas chromatography equipped with a flame ionization detector and VH-5 column.

3. Test Result and Discussion

At the preheating stage before remediation of the tested soil, the temperature monitored in soil container was measured around 550 ℃ (see Figure 4), which is much higher than the temperature (230 ℃) of the oil-contaminated soil directly irradiated by microwave from the previous research result [5]. MIP or microwave absorber used in this study efficiently enhanced the heating temperature for remediation of the oil-contaminated soil.

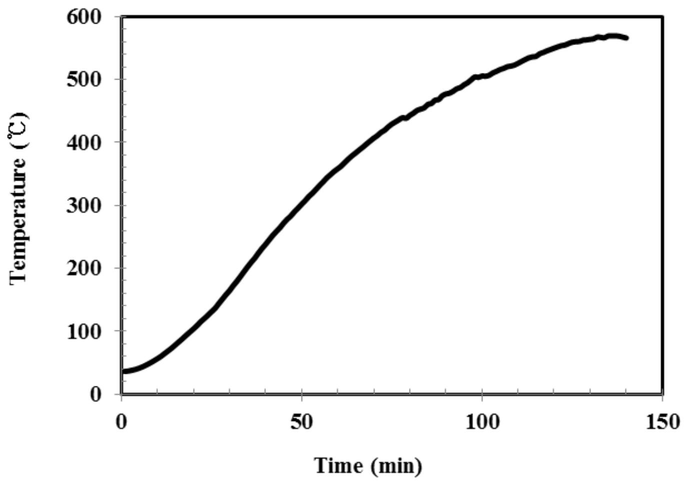

Fig. 4: Temperature profile in inner container

Figures 5 and 6 show the TPH of the tested soil treated by microwave thermal desorption and its removal efficiency with residence time. Final TPH with elapsed time of 15 to 60 minutes became 312 to 137 mg/kg. The corresponding removal efficiency for tested soil was estimated as 96 to 98 %.

As research results based on microwave thermal desorption technology, it is found that about 15 minutes is sufficient treatment time to satisfy the cleanup level, and the cleaning costs would be US$ 15.59/ton. For reference, the costs of cleaning oil-contaminated soil at a full-scale plant based on thermal desorption using conventional rotary kiln would be US$ 54.12/ton in Korea [6].

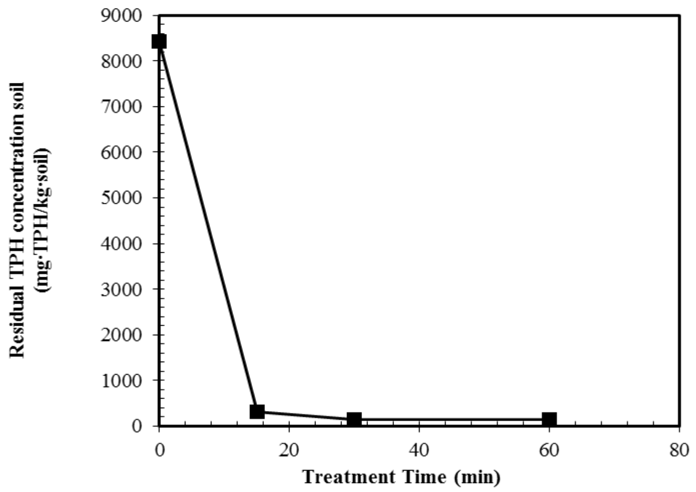

Fig. 5: TPH of the tested soil treated by microwave thermal desorption

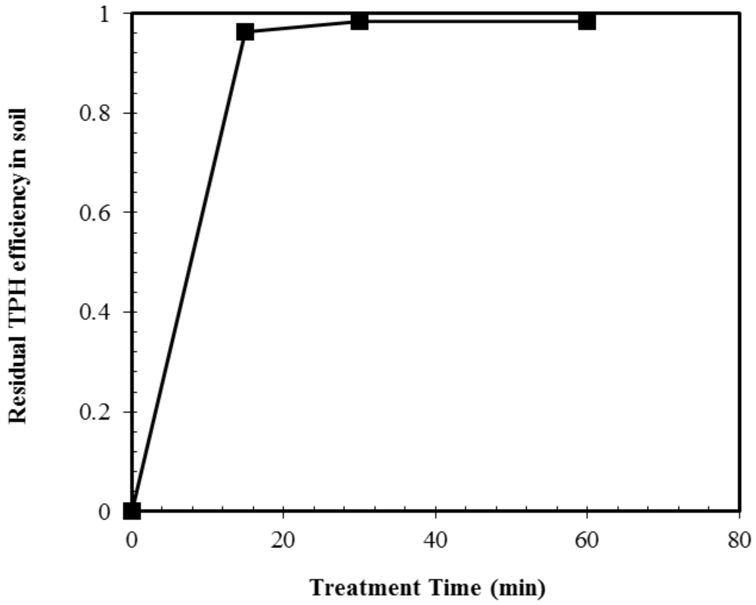

Fig. 6: Removal efficiency of the tested soil treated by microwave thermal desorption

4. Conclusion

The newly developed system for the microwave thermal desorption is used to substantially reduce the cleaning costs of oil-contaminated soil in this study. As research results, the cleaning costs is reduced by 77 % based on the microwave thermal desorption technology, which is resulted from the high performance of microwave and microwave absorber to effectively heat the soil container in the system.

5. References

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