

The Study of Combined Process of Microwave and Thermal Desorption for Treating the Oil - Contaminated Soil

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ABSTRACT: The thermal desorption is being studied as a effective method for treating petroleum-contaminated soil. However treatment efficiency is rapidly reduced when moisture in petroleum- contaminated soil so that pre-treatment and moisture removal process are needed. This study on combined process of microwave and temperature desorption of remediation of petroleum-contaminated soil. When the moisture content was 30%, the most effective condition were 6kW (electric power of microwave) and 600°C (temperature of thermal desorption). But the optimum condition were 4kW of microwave electric power and 300°C of thermal desorption temperature, in consideration of cost. Calculation of cost by combined process was lowest 4 kW, 300°C as \$18.67, but removal rate is similar to other conditions. When viewing the petroleum-contaminated soil by TPH component, most of the components were gasoline. TPH removed over 70% during microwave pretreatment process. We studied TPH removal rate according to particle size of contaminated soil. The removal efficiency is similar according to particle size of soil except 2.35mm size.

Key words: TPH, Thermal Desorption, Microwave

1. INTRODUCTION

Due to the increase in the number of gas stations by increase in automotives and industrial development, etc, oil consumption amount tends to increase each year. And as of 2002, Korea's per capita oil consumption amount, 2.14TOE, is higher than other countries such as Germany 1.56TOE, France 1.49TOE, U.K. 1.32TOE and Japan 2.0TOE.¹⁾ Oil facilities also tend to increase to quote 11,306 facilities in 2003 and 11,810 facilities in 2006, and among these oil polluted facilities increased from 325 locations in 2003 to 982 locations in 2006.

Techniques to restore oil polluted soil include various methods such as soil vapor

extraction method, bio purification method, incineration, thermal desorption, chemical oxidization, etc.^{2,3)} And among these, thermal desorption is a method proven in its economic advantage and efficiency.⁴⁾

Treatment of soil polluted by media like oil in thermal desorption method gives effective results in short period.⁵⁾ Even in case of high concentration of contamination, the efficiency is good and it gives the advantage that it is safer and discharges less polluted materials than other methods.^{6,7)}

While thermal desorption temperature range is 100~900°C, but low temperature thermal desorption is treated at 100~400°C range⁸⁾, so it is reported to be economical, and report has it that at 300°C temperature

thermal desorption furnace, 90% was treated within 30 minutes.⁹⁾ However, it is reported that in case of water content of over 20%, low temperature thermal desorption efficiency decrease, so pre-treatment is necessary.¹⁰⁾

Pretreatment processes include hot wind drying, microwave, direct heating, etc, however among these in the case of microwave, since it has high treatment efficiency and can remove water content in short time, which is the advantage, so it is used as pre-treatment process.¹¹⁾

Therefore, this research used low temperature thermal desorption process to treat polluted soil, and in case water content exists, the research intends to restore oil polluted soil through associated processes using microwave process as pre-treatment process.

2. EXPERIMENT MATERIALS AND EXPERIMENT DEVICE

2.1 Experiment Materials and Experiment Method

The oil polluted soils used in this research were collected from the city of OO in Korea, and the initial concentration of the polluted soil was 40,697mg/kg. OO area is a place that has been used as oil storage base of military troop since 1940s, and a place where oil storage tanks have been installed to be used as oil storage facility. Production was done at water content rate 30% by adding purified water to the collected specimen, and at this time, TPH (Total Petroleum Hydrocarbon) concentration was analyzed 34,457mg/kg. And to review the efficiency of associated process by soil particle diameter, treatment efficiencies were experimented by classifying raw specimen whose soil particle diameters were not classified with sieve to 11.8mm, 4.72mm and 2.35mm. According to USCS classification method,¹²⁾ since 11.8mm is classified as gravel, and 4.75mm and

2.35mm as sand, research was done by the soil types.

2.2 Experiment Device

Microwave and low temperature thermal desorption combined process is as shown in Figure1. It is a process that treats in thermal desorption after microwave pre-treatment.

In case water content rate is low, the designing was done so that only transfer is possible by setting microwave pre-treatment process as off.

Soil influx is done through the hopper of ① of Figure 1, and microwave polluted soils are moved on the conveyor belt as schematized in ② of Figure 1, while microwave is projected. After microwave treatment, the soils flow into thermal desorption furnace inlet of ④ shown in Figure1 through the microwave outlet port schematized in ③ of Figure1. And through the screw type soil conveyor path of Figure1 ⑤, they flow into the thermal desorption furnace process of Figure 1 ⑥. Figure1 ⑦ is the screw that conveys soil, and after the treatment, the soil flows out through outlet port.

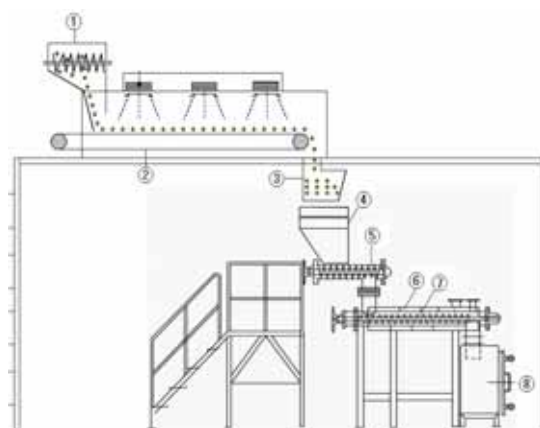


Figure 1; Schematic of continue microwave and thermal desorption combined process used in this study.

(① Inlet of microwave process ② conveyor belt of microwave process ③ Outlet of microwave process ④ Inlet of thermal

desorption ⑤ screw shaft ⑥ thermal desorption furnace ⑦ screw shaft ⑧ Outlet).

As for the operation conditions of this process, as shown in Table 1, the total treatment time upon treatment of 30kg polluted soil was 30 minutes, microwave treatment time 15 minutes and thermal desorption treatment time 15 minutes. The treatment times were set up based on the research that removal is barely made after 15 minutes of microwave treatment, and the 15 minutes of thermal desorption operation time also was based on such research.

Microwave electric powers were set to 4kW and 6kW, and thermal desorption temperatures to 300°C and 500°C for operation.

Table 1: Experimental conditions of thermal desorption used in this study

Parameters		Conditions
Thermal desorption	Temperature (°C)	300°C, 500°C
	Operation time (min)	15 min
Microwave	Electric power (kW)	4 kW, 6 kW
	Operation time (min)	15 min

3. RESULT

3.1 Removal Characteristics by combined process

Figure 2 shows the TPH concentration by the time at microwave electric power of 4kW and thermal desorption furnace temperature of 300°C.

Also upon treatment of microwave treatment, 70% of TPH were removed, and while 2.34mm of removal rate by soil particle diameter showed lowest treatment

efficiency, the removal efficiency of original specimen removal rate was the highest. It is determined that since heats are transferred from inside to outside in case of microwave heat transfer method, in case particle diameter is small, the path through which heat moves is narrow, not reserving the heat, and consequently the treatment efficiency drops compared to original specimen.

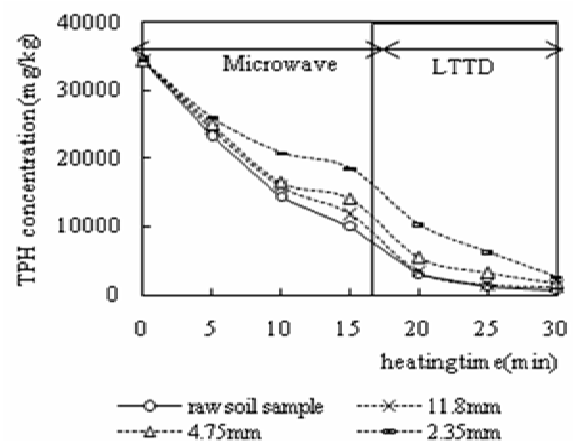


Figure 3: Variations of TPH concentration as various soil particle size by combined process of microwave at 4 kW and thermal desorption at 300°C.

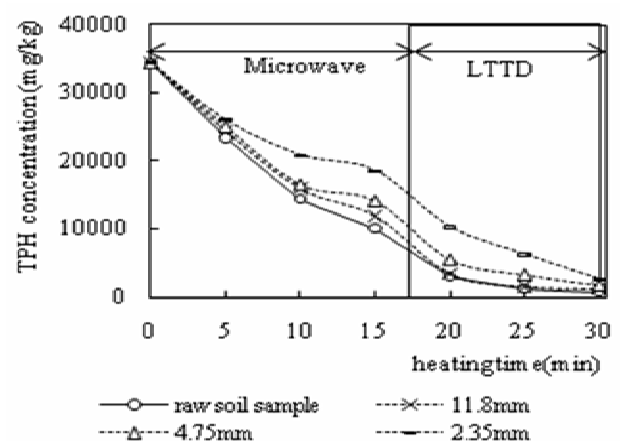


Figure 4: Variations of TPH concentration as various soil particle size by combined process of microwave at 4 kW and thermal desorption at 500°C.

It is shown that in Figure 4, the

concentration of TPH not removed after microwave treatment during the operation at 4kW, 500°C decreases to 3,065mg/kg upon 5 minutes treatment at 10,095mg/kg, 500°C. It indicates that most of TPH, 98%, are removed at 500°C in 15 minutes of thermal desorption.

Table 2: Variation of moisture contents as condition of combined process

particle size heating time		raw soil sample	11.8 mm	4.75 mm	2.35 mm
Microwave 4kW	5	13.7	17.0	20.3	27.4
	10	10.2	16.3	20.1	26.3
	15	9.4	15.5	18.8	24.1
LTTD 300°C	20	8.3	9.1	12.2	20.4
	25	7.2	8.2	15.2	18.7
	30	7.1	7.4	13.4	17.3
LTTD 500°C	20	8.1	8.3	11.1	15.3
	25	3.7	6.66	8.4	12.2
	30	0.7	2.37	6.2	10.6
Microwave 6kW	5	13.7	17.0	20.3	27.4
	10	10.2	16.3	20.1	26.3
	15	9.4	15.5	18.8	24.1
LTTD 300°C	20	8.3	9.1	12.2	20.4
	25	7.2	8.2	15.2	18.7
	30	7.1	7.4	13.4	17.3
LTTD 500°C	20	8.1	8.3	11.1	15.3
	25	3.7	6.66	8.4	12.2
	30	0.7	2.37	6.2	10.6

In case 4kW microwave electric power, water content reduced from 30.2% to 9.4% in the case of original specimen as shown in Table 2, and in the case of 2.35mm particle diameter soil whose heat transfer furnace is relatively small, only 17.3% were reduced. It was shown Table 2 that also upon thermal desorption process, if the particle diameter of polluted soil is small, the thermal desorption furnace cannot remove remnant

water content completely.

As shown in Table 2, also in case of 6kW of microwave electric power, water content removal rate was not significantly different from 4kW.

From the analysis of original specimen by the components of TPH upon microwave 4kW treatment, most of them were gasoline as shown in Figure 6. As is shown from Figure 6 which shows the removal rates by the components of original specimens which were not classified with sieve, most of the components removed from microwave were shown to be gasoline. In the case of gasoline whose boil point is relatively low, removal is fast, and in the case of kerosene and diesel whose boil point is high, removal is not completely done even at thermal desorption furnace.

Figure 5 and Figure 6 shows the TPH concentration change after operation at 500°C of thermal desorption after pre-treatment of 6kW microwave electric power.

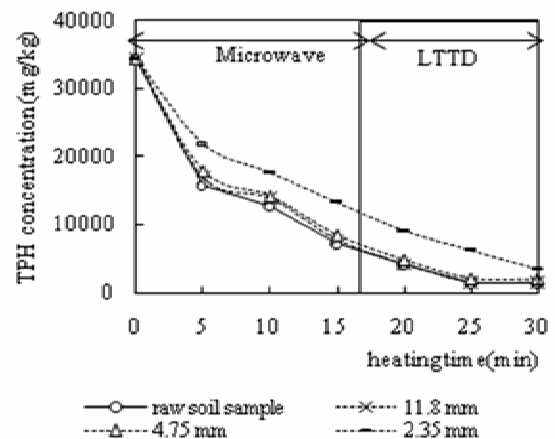


Figure 5: Variations of TPH concentration as various soil particle size by combined process of microwave at 6 kW and thermal desorption at 300°C.

In case of microwave treatment, removal rates did not show significant changes by particle diameter except for 2.35mm. This indicates that since microwave electric power is great, the amount of penetrating electric power is large even if particle

diameter is small, so treatment efficiencies are not significantly different depending on particle diameter relatively. However, in the standpoint of removal rate, 6kW removal rate was more excellent about 8 to 10% when compared with 4kW.

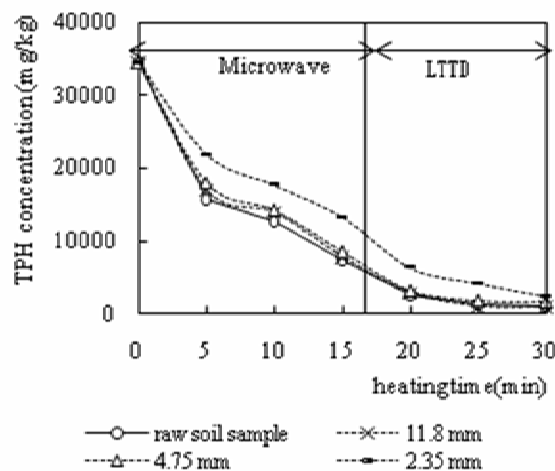


Figure 6: Variations of TPH concentration as various soil particle size by combined process of microwave at 6 kW and thermal desorption at 500°C.

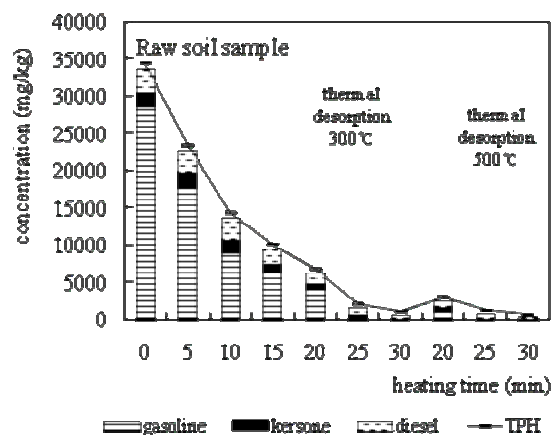


Figure 6: TPH concentration on different type of petroleum in raw soil sample by combined process of microwave at 4 kW and thermal desorption.

In case of 6kW of microwave electric power, the results of analysis of original specimen by the TPH components shows Figure 6 that most were gasoline, and unlike

4kW treatment, kerosene and diesel were removed. This is determined to be because upon 6kW penetration, heats are reserved within the soil, and when heats are given from thermal desorption furnace, soil heat transfer amounts are large.

3.2 Calculation of Cost by the Combined Process Conditions

In case of microwave electric power, since the electric power cost as of January, 2008 is 53.24won/kWh¹³⁾, the electricity cost for treatment for 15 minutes at 4kW is 53.24won, and in the case of 6kW, 79.86won is consumed.

When operating at 300°C, the amount of LPG used per unit time is about 1.22m³/h, and in the case of 500°C, the amount of LPG used per unit time is about 2.826m³/h. Since 1kg of LPG is evaporated to 0.481m³, the LPG used amount at 300°C is 2.54kg, and that at 500°C is 5.88kg.

Table 3: Comparison of combined process and thermal desorption

(unit : won)				
Process	4 kW		Thermal desorption	
	300°C	500°C	300 °C	500 °C
Total cost*	18,682	37,532	43,441	99,931

* unit: won/ton

* won means Korea currency

1\$ = 1000.76 won

1998.01.01~1996.05.31 average

As LPG unit price as of January 2007 is 920won per kg, in case of 300°C, 584won is consumed for 15 minutes, costing 1,352won. Therefore, the overall efficiencies by microwave electric power and thermal

desorption temperature are similar, but the costs make significant difference, so it was shown that in associated process, the most economical is to treat by 300°C thermal desorption after 4kW microwave pre-treatment.

4. CONCLUSION

In case of associated process, as for the effects by particle diameter, treatment efficiencies were lowest when particle diameter is 2.35mm, which is the smallest. And the optimal operation conditions for microwave electric power and thermal desorption temperature are 4kW of microwave electric power and 300°C of thermal desorption temperature.

When viewing the polluted soil by the TPH components, most of the components were gasoline, and since in the case of 4kW, 70.9% of TPH were removed during microwave pre-treatment as well, oils with low boiling point are partly removed during pre-treatment.

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