

The Study of Microwave Process for Treating the Soil Contaminated by Oil - Contaminated Soil

Ha Sang-An¹ and Yeom hae-kyong² and Bae Sang-Dae^{3*}

^{1,3}Silla University, Busan, Korea

²Dong A geological engineering Co., Ltd., Busan, Korea

*Corresponding author: baesd@silla.ac.kr

ABSTRACT: In case of treating oil-contaminated soil which contains much water with thermal desorption process, any dry pre-treatment is necessary. There are some dry pretreatments such as hot air dry, microwave and direct heating. Among these treatments, microwave process spends a little time and cost compared to the other processes. To decide the optimal condition of microwave in this study, we analyzed TPH removal efficiency according to the height of the soil on the conveyer belt and the power degree of microwave while drying the soil with microwave. We set the height of the soil to 1cm, 2cm and 3cm to examine it, and did the strength of microwave to 2kW, 4kW and 6kW to do it. In case of 2kW microwave scanning, contamination removal rate of the soil showed little difference according to the height of the soil, in case of 4kW, the removal rate showed 72% at the soil of 1cm; 68% at 2cm and 58% at 3cm. In the examination according to the power of 6kW, TPH removal rate showed about 80% at 1cm of the soil; 70% at 2cm and 3cm from the test result, in respect of TPH removal efficiency, it was most efficient at the power of 6kW and the soil of 1cm height. However, when we considered the amount of energy consumption, the cost and the amount of the contaminated soil treatment from any efficiency almost same for each case, the optimal operating condition showed the optimal condition at the power of 4kW and the soil of 2cm height.

Keywords: TPH (Total Petroleum hydrocarbon), microwave

1. INTRODUCTION

In tune with increase in the number of gas stations by industrial development and automotive increase, consumptions of oil are growing¹⁾, causing increase in oil pollution. Most of the cases, oil pollution leads to soil and sewage water pollution, and since the polluted conditions are found late, the pollutions are likely to accumulate over time. In particular, in case of soil pollution by oil, immediate spotting of occurrence, even the conditions are not hard to find, and even if measures are taken, it takes a lot of time. The techniques to restore oil polluted soils include soil vapor extraction method, bio purification, incineration, thermal desorption and chemical oxidization, etc.^{2,3)} Among these, thermal desorption can treat effectively in short time regardless of pollution materials including oil, oil concentration characteristics, and even in case of high concentration of polluted soil, treatment efficiency is high but in case water content is over 20%, pre-treatment is necessary.⁴⁾ Pre-treatment method includes hot drying, direct heating, microwave, etc, and among these, microwave is economic and can be treated in short time. Let alone its ability to heat materials selectively, microwave has low energy consumption even in case of bulk heating, and it is reported to have high efficiency compared to other process.^{5, 6)}

In particular while it is used recently in treating volatile and semi volatile matters, PCB (polychlorinated biphenyl) polluted soil in original position technique.⁷⁾

Microwave is reported to be more efficient if water content exists in induction heating method.^{8, 9)} Even in case of drying water containing material, it takes less electric power cost of ash type microwave than hot wind drying, and takes less time in removing 10% water content.¹⁰⁾ Of course microwave converts

only 50 through 55% to heat while hot wind drying converts 100% to heat in the standpoint of electric power efficiency, however since heat transfer is slow with hot wind drying, the overall efficiency is shown to higher with microwave, and thus electric power consumption is less when treating in combination of both hot wind drying and microwave.¹¹⁾

Therefore, this research studied removal of oil polluted soil by using thermal desorption method which is economical and whose efficiency is proven to treat oil polluted soil, and intends to restore oil polluted soil through connected processes while removing the water content operating as negative factor for efficiency during low temperature thermal desorption process.

2. EXPERIMENT MATERIALS AND EXPERIMENT DEVICE

2.1 Experiment Materials and Experiment Method

While the polluted soil used in this research was collected frequently within the experiment period in the city of OO from the same area, the initial TPH concentration was 45,145 mg/kg, and the water content was 8.9%.

Since the experiment by water content change, electric power change and particle diameter can be deduced through ash type microwave device, this experiment studied TPH concentration changes by polluted soil thickness to examine the optimal polluted soil thickness while changing the electric power of continuous type device and operating continuous type microwave. The analysis method was the same as the above one.

2.2 Experiment Device

Microwave continuous type experiment device is as shown in Figure 1 and while polluted soil transfer is done one conveyor belt, microwave is projected during transfer.

Electric power can be adjusted between 1 and 6 kW, and stay over time can be adjusted through rpm.

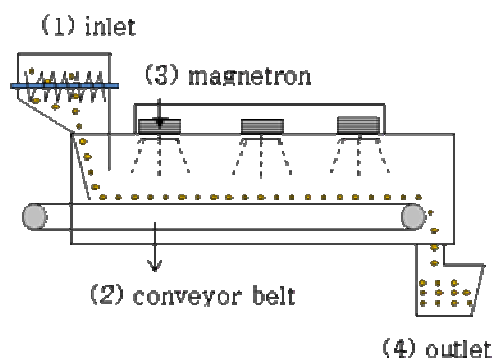


Figure 1: Schematic of microwave process used in this study.

Figure 1 shows schematic of the device, where (1) is the inlet port of screw type through which polluted soils enter microwave device; (2) is the conveyor belt through which microwave is penetrated while polluted soils are transferred; and (3) is magnetron which microwave generated; (4) is outlet port.

3. RESULT

3.1 Variation of TPH concentration according to heating time

Since conditions for basic experiment on polluted soil characteristics and the optimum operation deduced the experiment conditions in microwave device, this research experimented the optimum height of the polluted soil on the conveyor belt of continuous microwave. Polluted soil heights were 1cm, 2cm and 3cm for the experiment, and were adjusted

through conveyor belt inlet port. As for analysis item, through experiment of TPH removal rate, optimum height was determined. As shown in Figure 2 in case where electric power is 2kW, TPH was removed up to 60% or so, and with 3cm the lowest efficiency, the efficiency did not show significant difference with height.

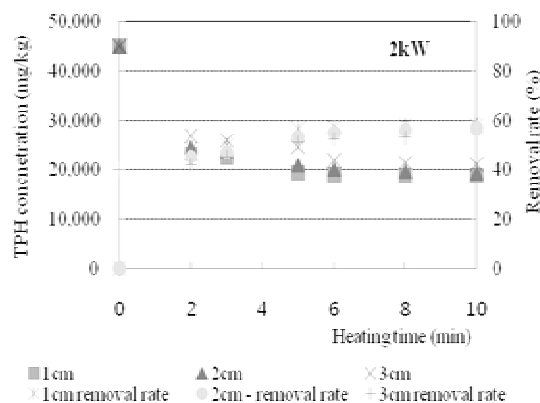


Figure 2: Variation of TPH concentration and removal rate on the height of soil on conveyor belt at 2 kW.

Figure 3 showed that 3cm removal rate was notably low when microwave electric power was 4kW, and it is determined that that is because heat transfer changes with electric power.

Figure 4 shows that the removal rate in case of 4kW operation is about 10% more efficient than 6kW, which indicates that removal rate changes with treatment time.

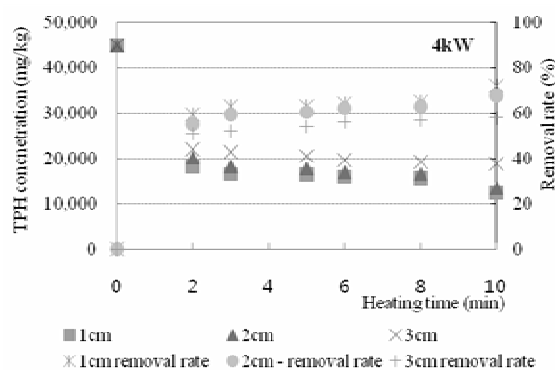


Figure 3: Variation of TPH concentration and removal rate on the height of soil on conveyor belt at 4 kW.

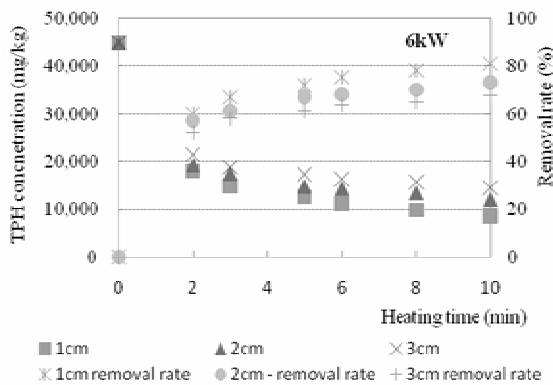


Figure 4: Variation of TPH concentration and removal rate on the height of soil on conveyor belt at 6 kW.

The polluted soil height 1cm showed about 80% removal rate, and both 2cm and 3cm removal rates were similarly about 70%. Judging from the difference of removal rates depending on the height of polluted soil on conveyor belt during 6kW treatment, it is determined that heights are significantly affected by electric power, causing difference in removal rates.

This presumably is because polluted soil thicknesses are significantly affected since the higher electric power increases, the greater heat transfer power rises, vibrating the water content within the polluted soil, which in turn increases the generated energy.

However, according to Mon¹²⁾, as a result of research on the removal rates respectively for soil layer thickness of 6mm, 12mm and 18mm, the thicker the soil layer is, the more the removal effect was, and that is because the thicker the layer is, the more polluted materials the vapor generated within the layer removed.

However, this research used 1cm, 2cm and 3cm, and the thicker the soils were, the lower removal rates were. That is

because the more the electric power increases, the more the accumulated energy increases with time, and even though the polluted soil thickness varies among 1cm, 2cm and 3cm, the amount of the transferred electric power increases, raising TPH removal rates beyond 4kW with penetration time.

3.2. Comparison of Treatment Amount by Polluted Soil Thickness and Microwave Electric Power

To deduce optimal condition of continuous type microwave, the research calculated the treatment amounts by electric power and polluted soil thickness changes in the same removed TPH concentration.

The electric power at which the TPH concentration remaining after 25 minutes treatment of continuous type microwave is highest is 2kW, and at this time, the TPH concentration is 18,770mg/kg. Upon treatment at 6kW, where TPH removal efficiency is highest, the TPH concentration was 8,462mg/kg, so the research calculated the treatment amount based on the TPH concentration range 18,000 through 19,000 mg/kg to select concentration similar to the TPH remaining at 2kW treatment. The TPH concentrations that fall in this range were 18,770mg/kg for 2kW, 18,365mg/kg for 4kW and 18,005mg/kg for 6kW.

Table 1 shows the treatment amount by the electric power, and as for the time to reach each reference concentration, 2kW took 10 minutes, 4kW and 6kW in 2 minutes.

Therefore, as shown in (C) since the treatment time for 6kW is reduced to 1/5 compared to 2kW, the treatment amount for 6kW become 5 times. In addition, as for the value of (D) of Table 1, the electric powers of 4kW and 6kW are respectively double and triple the 2kW, however in

view of treatment amounts, they are in reverse proportional relations, so the values were multiplied with the treatment amount by the unit time by taking reciprocal number.

As for the amount that can be treated during the same length of time by calibrating electric power, 4kW was shown the most efficient as in (E) of Table 1, so the treatment amount by the polluted soil thickness was calculated based on 4kW.

Table 1: Comparison of entire treatment as particle size of soils at 4 kW

(A)	(B)	(C)	(D)	(E)
1 [18,365 mg/kg]	2	5	1	5
2 [18,230 mg/kg]	3	3.3	2	6.6
3 [18,860 mg/kg]	10	1	3	3

Note

A: Thickness of soil sample (cm)

[Concentration]

B: Heating time (min)

C: Unit treatment capacity based

D: Unit thickness for treatment on heating time

E: Overall thickness required for treatment

E: $C * D$

Table 1 shows the treatment amount based on 4kW, and the TPH removal concentrations by polluted soil height upon 4kW treatment were set up 18,200 through 18,900mg/kg range. The times to reach the same TPH concentration upon 1cm, 2cm and 3cm treatments at 4kW were 2 minutes for 1cm, 3 minutes for 2cm and 10 minutes for 3cm. Therefore, according (C) of Table 17, 3 minutes can

treat 3.3 times the treatment of 10 minutes and 2 minutes 5 times. According to Table 1 (D), treatment amount increases in proportion to soil thickness, so 2cm can treat double 1cm, and 3cm triple 1cm. As for entire treatment amount, if treatment amount is calculated as (E) which resulted by multiplying polluted soil thickness and treatment time, polluted soil thickness 2cm was shown most efficient.

5. CONCLUSION

The polluted soil height 1cm showed about 80% removal rate, and both 2cm and 3cm removal rates were similarly about 70%.

But soil thickness 2cm was shown most efficient from view point of economic.

REFERENCES

- [1] Website Korea energy economics institute , <http://www.keei.re.kr/>, Korea
- [2] Webstie, <http://www.petrinet.co.kr>, Korea
- [3] Jennam Regional Environmental Technology Development Center Report. 2003. Remediation Technology development of oil-contaminated soil by oil-chemistry industry, Korea.
- [4] David, J., Wilson, Ann, N.C., Marcle Dekker. 1994. Journal of Hazardous Materials. Vol 42. pp. 265-308. USA
- [5] Chang, R.C. Yen, J.H. 2006. On-site mercury-contaminated soils remediation by using thermal desorption technology. Journal of hazardous materials B128. pp. 208-217. Taiwan
- [6] Robinson, J.P., Snape, C.E., Kingman, S.W., Shang, H. 2007. Thermal desorption and pyrolysis of oil contaminated drill cutting by microwave heating. Journal of analytical and applied pyrolysis, pp.1-6. UK

- [7] LaGrega, M.D., Buckingham, P.L. Evans, J.C. 1994. Hazardous waste management. New York, McGraw-Hill, USA
- [8] Shang, H., Snape, C.E. 2005. Kingman, S.W., Robinson, J.P., Industrial Engineering Chemistry Research. pp. 6837. UK
- [9] Shang, H., Snape, C.E., Kingman, S.W., Robinson, J.P. 2006. Microwave treatment of oil-contaminated North Sea drill cuttings in a high power multimode cavity, Separation and Purification Technology, 49, pp. 84-90. UK
- [10] Rozainee, M., Khairuddin, W., Ali, W., Tan, K.G., Tan, C.H., Kumoro, A.C. 2001. Comparison of sludge drying performance between microwave and convective drying. Proceeding of the 5th symposium of Malaysian Chemical Engineers, pp. 361-367. Malaysian
- [11] Hong, S.M., Lee, Y.S., Shin, Y. H., Lee, E. S., 2005. Optimizing Lab Scale Sewage Sludge Reduction Process Using Microwave and Hot Air System. Daewoo construction technology research report. Vol 27. pp.67-74. Korea
- [12] Moon, K.W., Kim, Y.H., Lee, B. C. 1996. Microwave Remediation of soil Contaminated by Volatile Organic Chemical. Korea Journal of Environmental Health Social. Vol 22. pp.116-122. Korea