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Project Summary

On-Site Engineering Report for the Low-Temperature Thermal Desorption Pilot-Scale Test on Contaminated Soil

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Performance of the thermal desorption process for removal of organic contaminants, mostly polynuclear aromatic hydrocarbons (PAHs), from soils was evaluated. The Superfund Site soil tested was a fine sandy soil contaminated with creosote. An optimum operating temperature of 550°C and an optimum operating residence time of 10 min, determined from bench studies, were used in the pilot-scale desorber. Contaminants removed from the soil were captured or destroyed in the associated air pollution control equipment. Test results showed that greater than 99% of the PAHs were removed from the soil. The concentration of total PAHs averaged 4629 mg/Kg in the pretreated soils and were below detection in the post-treated soils.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the treatment evaluation study that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study was performed for the U.S. Environmental Protection Agency (EPA) to supply information as part of the data base on best demonstrated available technologies (BDAT) for soil remediation. The data base will be used to develop soil standards for land disposal restrictions.

Thermal desorption has been successfully tested at both the bench and pilot-scale on a wide range of organic contaminants. The process drives volatile and semivolatile organics from the soil by heating the soil to temperatures greater than the boiling point temperature of the contaminants. The contaminants of concern in the test soil were PAHs, semivolatile contaminants that boil at temperatures ranging from approximately 215°C to greater than 525°C. Vapor pressures of these compounds vary depending on whether the contaminant is one compound or a mixture of compounds. Because boiling points of various mixes of contaminants are not known, bench-scale thermal desorption tests were done to determine the optimum temperature and residence time required for their removal. This thermal desorption study was performed in two phases: bench-scale and pilot-scale. Based on the bench test results, the pilot-scale tests were done at an operating temperature of 550°C and a residence time of 10 min.

Treatment Systems and Procedures

For the bench test, a 5-in. diameter by 12-in. long rotating tube unit was used to evaluate the effects of time, temperature, and atmosphere. To eliminate any possibility of explosions from gases in the system, the rotating tube was purged by nitrogen. Treated residues from the tests provided adequate sample for thorough analytical characterization.

A schematic diagram of the thermal desorption pilot plant is shown in Figure 1. The unit consisted of a continuously rotating desorber tube partially enclosed within a gas-fired furnace shell. Small baffles

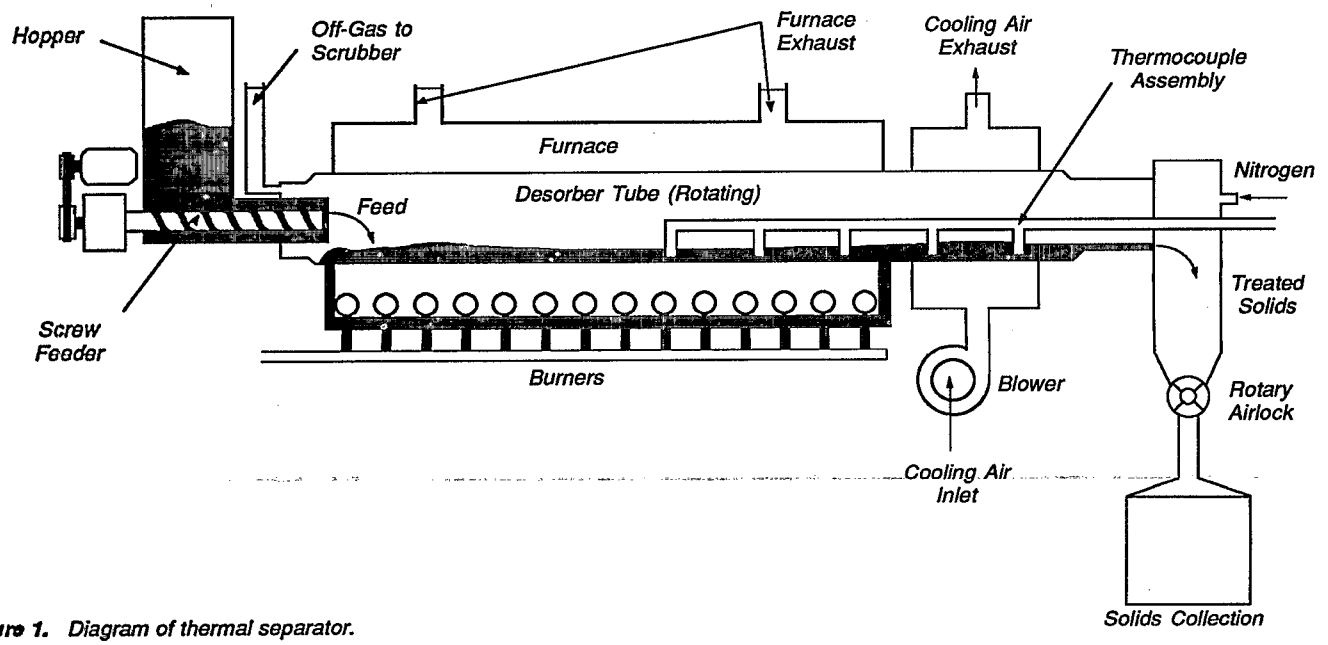

Figure 1. *Diagram of thermal separator.*

were located at intervals within the tube to provide soil mixing. A stationary thermowell was extended from the discharge end into the tube with six thermocouples to monitor the soil temperature and three to monitor the gas temperature along the tube length. The furnace was a refractory-lined chamber. The 14 equally spaced burners were controlled by a standard burner control system with appropriate safety features. Temperature measurements for furnace burner control or monitoring were taken by four thermocouples that contact at various locations on the outer metal wall of the rotating tube beneath the furnace refractor. The furnace flue gas was discharged directly to the atmosphere through a remotely positioned exhaust duct. The desorber was rated at 320,000 Btu maximum heat duty. A nitrogen purge was introduced continuously at a low rate of 2 ft^3/min to the desorber to help flush contaminants and to maintain an atmosphere that does not support combustion (i.e., <6% oxygen). To measure residence time, before the study colored aquarium gravel was placed into the feed hopper and its discharge was visually observed from the desorber. The average retention or residence time in the tube was calculated as the difference between the time that the colored gravel was placed in the screw feeder and the time it was discharged. Solids discharged from the desorber while it was operating at steady-state were weighed on a digital electronic scale to determine the soil feed rate.

The Superfund soil was a fine, sandy soil with 75% of its particles having a grain diameter between 0.1 and 0.4 mm. The soil had a relatively low moisture content of 10% and a Btu value below 500 Btu/lb.

Various temperatures and soil residence times were evaluated throughout the bench-scale testing program. The following information summarizes the removal of semivolatile organics during the bench-scale tests:

Run #1 (300°C at 10 min) removed 96.4%
Run #2 (425°C at 10 min) removed 99.97%
Run #3 (550°C at 10 min) removed 99.995%
Run #4 (300°C at 20 min) removed 97.4%
Run #5 (550°C at 5 min) removed >99.9999%

Based on the bench-scale study results, temperature and residence time operating conditions of 550°C and 10 min were selected for the pilot-scale testing program. Though the above results indicate the run at 550°C and a 5-min residence time provided the highest removal efficiencies for the semivolatile contaminants, it was anticipated that larger particles would be introduced into the pilot-scale unit and the feed streams might not be totally uniform and could contain "hot spots." Therefore, a temperature of 550°C and a residence time of 10 min were chosen to allow for better treatment of the contaminated soil.

Six sets of temporally related soil samples (waste feed and treated residual) were collected during the thermal desorption pilot test to evaluate the performance of the technology for treating creosote-contaminated soil. Additional samples of the off-gases were collected to characterize the emissions from the unit. Off-gases were sampled before the air pollution control equipment to determine if any degradation products were being formed. The air samples were analyzed for volatile and semivolatile organics. Detailed analytical procedures are included in the On-Site Engineering Report (OER) for these Thermal Desorption Studies.

Results

Tables 1 and 2 give the concentrations of the organic contaminants in the soil before and after treatment on a dry weight basis. Individual contaminants in the pretreatment soil ranged as high as 1200 mg/kg for phenanthrene to less than the detection limit for some of the other contaminants. All contaminants analyzed in the post-treatment samples were below the detection limits. On the average, total semivolatile organic contaminants were reduced from 4629 mg/kg to less than the detection limit. Hence average removal for total semivolatile organics was greater than 99.9%.

No appreciable reduction in lead or arsenic was observed during the study because of the low operating temperature in relation to the boiling points of lead and arsenic. Mercury, however, with a boiling point of 356°C, showed greater than a 90% reduction in soil levels after treatment.

Air sampling was done to characterize the gases coming off the treatment sys-

Table 1. *Concentrations of Critical Semivolatile Organic Contaminants in Pretreatment Soil Samples on a Dry Weight Basis (mg/kg)*

Contaminant	MDLs*	PQLs*	Test number 1	2	3	4	5	6
Phenol	2.5	20	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
2-Methylphenol	1.4	20	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4
4-Methylphenol	2.0	20	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
2,4-Dimethylphenol	7.0	20	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0
Napthalene	0.96	20	130	130	170	130	150	150
2-Methylnapthalene	11.0	20	190	170	180	170	170	200
Acenapthylene	0.41	20	38	32	46	34	35	42
Acenapthene	12.0	20	330	310	390	310	320	390
Dibenzofuran	4.8	20	240	210	290	210	220	250
Flourene	1.2	20	360	330	500	340	340	460
Phenanthrene	2.0	20	900	980	990	1100	1000	1200
Anthracene	4.3	20	360	440	400	460	430	400
Flouranthene	0.61	20	610	640	690	670	590	810
Pyrene	3.1	20	460	540	640	620	580	640
Benzo(a)anthracene	1.4	20	160	150	210	160	160	190
Chrysene	7.0	20	150	140	200	140	150	170
Benzo(b)flouranthene	1.4	20	180 †	130	220	130	130	160
Benzo(k)flouranthene	1.4	20	—	—	—	—	—	—
Benzo(a)pyrene	6.6	20	73	62	120	64	65	76
Indeno(1,2,3-cd)pyrene	2.1	20	26	33	31	<2.1	28	30
Dibenzo(a,h)anthracene	0.97	20	<0.97	19	<0.97	<0.97	<0.97	<0.97
Benzo(g,h,i)perylene	19.0	20	45	<19	32	<19	<19	20
Total concentration critical contaminants			4252	4316	5109	4538	4368	5188

† *Benzo(b) - and benzo(k)flouranthene were found to co-elute; therefore a total amount is given.*
* *MDL = method detection limit; PQL = practical quantitation limit.*

Table 2. *Concentrations of Critical Semivolatile Organic Contaminants in Post-treatment Soil Samples (mg/kg)*

Contaminant	MDLs*	PQLs*	Test Number 1	2	3	4	5	6
Phenol	0.043	0.34	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043
2-Methylphenol	0.023	0.34	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023
4-Methylphenol	0.033	0.34	<0.033	<0.033	<0.033	<0.033	<0.033	<0.033
2,4-Dimethylphenol	0.120	0.34	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120
Napthalene	0.016	0.34	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016
2-Methylnapthalene	0.190	0.34	<0.190	<0.190	<0.190	<0.190	<0.190	<0.190
Acenapthylene	0.007	0.34	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Acenapthene	0.210	0.34	<0.210	<0.210	<0.210	<0.210	<0.210	<0.210
Dibenzofuran	0.081	0.34	<0.081	<0.081	<0.081	<0.081	<0.081	<0.081
Flourene	0.020	0.34	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Phenanthrene	0.034	0.34	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034
Anthracene	0.073	0.34	<0.073	<0.073	<0.073	<0.073	<0.073	<0.073
Flouranthene	0.010	0.34	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Pyrene	0.052	0.34	<0.052	<0.052	<0.052	<0.052	<0.052	<0.052
Benzo(a)anthracene	0.023	0.34	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023
Chrysene	0.120	0.34	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120
Benzo(b)flouranthene	0.024	0.34	<0.047†	<0.047	<0.047	<0.047	<0.047	<0.047
Benzo(k)flouranthene	0.023	0.34	—	—	—	—	—	—
Benzo(a)pyrene	0.110	0.34	<0.110	<0.110	<0.110	<0.110	<0.110	<0.110
Indeno(1,2,3-cd)pyrene	0.035	0.34	<0.035	<0.035	<0.035	<0.035	<0.035	<0.035
Dibenzo(a,h)anthracene	0.016	0.34	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016
Benzo(g,h,i)perylene	0.320	0.34	<0.320	<0.320	<0.320	<0.320	<0.320	<0.320
Total concentration critical contaminants			<1.58	<1.58	<1.58	<1.58	<1.58	<1.58

† *Benzo(b) - and benzo(k)flouranthene were found to co-elute; therefore a total amount is given.*
* *MDL = method detection limit; PQL = practical quantitation limit.*

tem before they reached any air pollution control equipment. Results of off-gas analyses show a predominance of aromatic compounds. Phenolic compounds, as well as volatile aromatic compounds such as benzene, toluene, and xylene, that were not detected in the pretreatment soil samples were detected in the off-gas samples. This indicates the possible masking of these compounds by the more concentrated contaminants in the soil samples or the possible degradation of the more complex PAHs and subsequent oxidation to form the phenolic compounds. All the more complex aromatics detected in the pre-treatment soil were also detected in the off-gas.

Conclusions

Bench tests should be performed first to determine the operating temperature and residence time for the pilot-scale desorber with specific soils. For this study, a residence time of 10 min at a temperature of 550°C was selected from bench results for optimum operation of the pilot scale desorber.

On the average, the pilot-scale desorber reduced total semivolatile organic contaminants from 4629 mg/kg to less than the method detection limit, greater than 99.9% removal. All of the individual semivolatile organics were reduced to concentrations below the method detection limits. The highest average individual contaminant concentration in the pretreatment soil was 1028 mg/kg for phenanthrene, and this was reduced to less than the method detection limit of 0.034 mg/kg in the post-treatment soil. Volatile organic contaminants were below the detection limit in the pretreatment soil, and therefore, they were not analyzed in the post-treatment soil.

The off-gas from the pilot desorber contained all of the semivolatile organics in approximately the same proportions that were present in the pre-treatment soil. Some phenols and volatile organic compounds, such as benzene, toluene, and xylene, were detected in the off-gas. This indicates that some degradation of the higher ring compounds to lower ring compounds was taking place.

No appreciable volatilization of lead or arsenic occurred in the pilot desorber. Mercury, which has a boiling point of 356°C, was 90% vaporized from the soil in the pilot desorber.

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The complete report, entitled "On-Site Engineering Report for the Low-Temperature Thermal Desorption Pilot-Scale Test on Contaminated Soil," (Order No. PB92- 216936/AS; Cost: $26.00, subject to change) will be available only from:
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