

Accelerated GC/MS Analyses of Soil and Sediment Samples for Rapid Brownfields Characterization

David M. Mauro, META Environmental, Inc., Watertown, MA 02472 (www.metaenv.com)

ABSTRACT

This paper presents the results of an interlaboratory study of the performance of a rapid soil extraction method and an accelerated GC/MS analysis method for PAHs and other organic compounds in a field laboratory setting at former MGP sites. The study was conducted in a fixed laboratory under controlled conditions. Six soil samples were extracted by two methods – Soxhlet Extraction and rapid low-pressure liquid extraction (LPLE) - generating 12 soil extracts plus quality control samples. The extracts were split and each was analyzed by EPA Method 8270C, GC/MS, in standard mode and an accelerated mode (12 minute analysis time), generating 24 sets of data. The data were processed using both the instrument manufacturer's software and IST for GC/MS software.

Soil samples, prepared by the LPLE method, were ready for instrumental analysis within about 10 to 15 minutes of initiation of the extraction. Faster average process times were possible by preparing samples in batches. The performance of the LPLE method compared very well to that of the Soxhlet Extraction for all target analytes in all samples, as determined by surrogate spike recovery, PAH recoveries from standard reference materials, and replicate sample precision. Nearly all quality control measures of the LPLE method were well within the typical QC limits for the standard method. The accelerated GC/MS analysis with IST processing of the data was compared to standard EPA Method 8270C analyses of the same sample extracts. Each extract was analyzed and the data processed and reported in about 20 minutes using the accelerated GC/MS conditions and the IST software with results that were indistinguishable from Method 8270C results obtained in one to 1.5 hours per sample; a 4.5-fold decrease in analysis time.

BACKGROUND

The characterization and cleanup of Brownfield sites typically require substantial numbers of chemical analyses of soil, water, and other matrices. These analyses provide essential data for the assessment of environmental impacts and the design and monitoring of restoration activities. Many authors have reported recently that the accuracy of site characterizations and the quality of remediation designs increases dramatically as the amount of data increases. Unfortunately, chemical data can be time consuming and costly to collect, and consequently sufficient amounts of data are collected at only a few sites. Methods are needed to reduce the time needed to characterize a site, to generate more data at less cost, and to rapidly provide remediation-monitoring data, accurately, and with sufficient sensitivity to meet regulatory criteria.

The current analytical methods for generating quantitative data on organic compounds in environmental matrices require two general steps. First, the organic compounds of interest (target analytes) must be extracted from the solid or liquid matrices, concentrated to levels that provide the required detection limits, and separated from large amounts of potentially interfering, non-target substances. This is the sample preparation step. Second, the amount of each target analyte

must be determined using a suitable instrumental method. This is the instrumental analysis step. Both of these steps can be quite time consuming. For example, sample preparation can require from one to 24 hours depending upon the method employed. Then, sample analysis can require several hours for combined data acquisition, quality control checking, and data reporting.

Research by the Electric Power Research Institute has provided some of the tools needed by scientists to generate chemical data quickly and cost-effectively at Brownfield sites. For example, EPA Methods 3511 and 3570, simultaneous determination of volatile and semivolatile organic compounds (VOCs and SVOCs) of concern by gas chromatographic (GC) methods, are based on EPRI research [1,2,3,4].

The Center for Field Analytical Studies and Technology at Tufts University (CFAST) has developed and demonstrated several approaches for rapid data collection during site investigations and remediation [5,6,7,8]. Of particular interest for application at Brownfield sites, are methods developed at CFAST for the rapid analysis of soil samples for SVOCs, particularly polycyclic aromatic hydrocarbons (PAHs), by GC with mass spectrometric detection (GC/MS). The CFAST approach is based on a post-acquisition computer program called IST for GC/MS, which extracts the mass spectrometer responses for target analytes from poor resolution GC/MS data; this allows analyses to be completed quickly since chromatographic resolution of individual compounds is no longer necessary. Using this approach, soil samples can be analyzed at a rate of about three to four per hour, while generating full GC/MS data for the target analytes. The methodology has been demonstrated in the laboratory and in the field by CFAST.

Tests were conducted by META Environmental, Inc. (META) and CFAST to examine the comparability of the fast data acquisition and processing method using IST software (EPA Method 8270 mod.) to standard EPA Method 8270C [9] data acquisition and processing for several soil samples from former manufactured gas plant (MGP) sites and for two certified reference soil samples (CRMs) containing PAHs. In addition, the performance of a rapid extraction procedure was compared to that of the standard Soxhlet method (EPA Method 3540C) for the same soil samples. This paper presents the results of those tests.

METHODS AND MATERIALS

Standards

Initial and continuing calibration standards, matrix spiking solutions, and surrogate spiking solutions were made by META from commercial mixes (Ultra Scientific, North Kingstown, RI). Sufficient quantities of each standard solution were generated so that the solutions could be split between META and CFAST, and so that one batch of standards was used for all analyses.

Samples

Four soil samples were collected from former MGP sites and shipped to META by overnight carrier. The laboratory identification numbers for those samples were:

PS990427-01

PS990427-02

PS990427-03

GK980417-09

In addition two CRMs were purchased from Resource Technology Corporation of Laramie, Wyoming. The sample identification numbers and total PAH concentrations for those samples were:

CRM104-100	97 mg/kg
CRM103-100	7,200 mg/kg

All samples were stored at 4 °C, in the dark prior to sample extraction.

Sample Preparation

Prior to extraction, the soil samples were gently mixed with a stainless steel spatula until visibly homogeneous. The CRMs were homogeneous as supplied and thus were not mixed further.

Soxhlet Extraction

The Soxhlet extractions were conducted by META following EPA Method 3540C. Generally, 10 grams of soil were gently mixed with anhydrous sodium sulfate and placed in a Soxhlet extraction vessel. Surrogate compounds were added to every sample, blank, and quality control sample. Also, one blank sample was spiked with all the target analytes (blank spike). Then, the samples were extracted for 16 hours using 1:1 methylene chloride:acetone. Following extraction, the extracts were concentrated to 10mL and split for analysis by META and CFAST.

Low Pressure Liquid Extraction

A second portion of each soil sample was extracted at META using a rapid LPLE method, as follows. Approximately 2 grams of soil were placed in a 30 mL Teflon® centrifuge tube with a Teflon® screw cap. Then, 5.0 mL of methylene chloride containing surrogate compounds, and about 2 grams of anhydrous sodium sulfate were added to the sample. The soil/sodium sulfate was ground until free-flowing using a clean, stainless steel spatula. Once ground, each sample was sealed and placed in a water bath at 80 °C for 5 minutes, followed by a vigorous 2 minute hand shake while still hot. Next, each sample was chilled in a cold water bath for about 2 minutes, then centrifuged for about 2 minutes. A 1.0 mL aliquot of the solvent was removed with a syringe and split between META and CFAST for analysis.

Quality Control (QC) Samples

Several QC samples were prepared and analyzed with the samples. First, two of the soil samples were CRMs that were supplied with Certificates of Analysis, providing reference values and prediction intervals for PAHs.

Second, each extraction batch included a method blank sample and a method blank spike. These QC measures were used as an indication of the precision, accuracy, and comparability of the methods in the absence or presence of matrix effects.

Analysis by EPA Method 8270C

All extracts were spiked with internal standard compounds prior to analysis. The extracts were analyzed using a Hewlett Packard (HP) 5890 Series II gas chromatograph (GC) with a 5971A mass selective detector (MSD), a HP 7673 autosampler, and HP Chemstation software. The instrument was operated in the splitless mode with 1 μ L injections onto a 30 m x 0.25 mm x 0.25 μ m RTX-5 (5% phenylmethylsiloxane) capillary column. The run time to elute all the target compounds was about 35 minutes, but the full cycle time was about 60 minutes.

Eighty (80) compounds were included in the calibration standards and were determined in the samples for the EPA Method 8270C analyses. However, the comparison between the standard Method 8270C and accelerated GC/MS (Method 8270 mod.) analyses focused only on the PAHs.

Analysis by EPA Method 8270 mod.

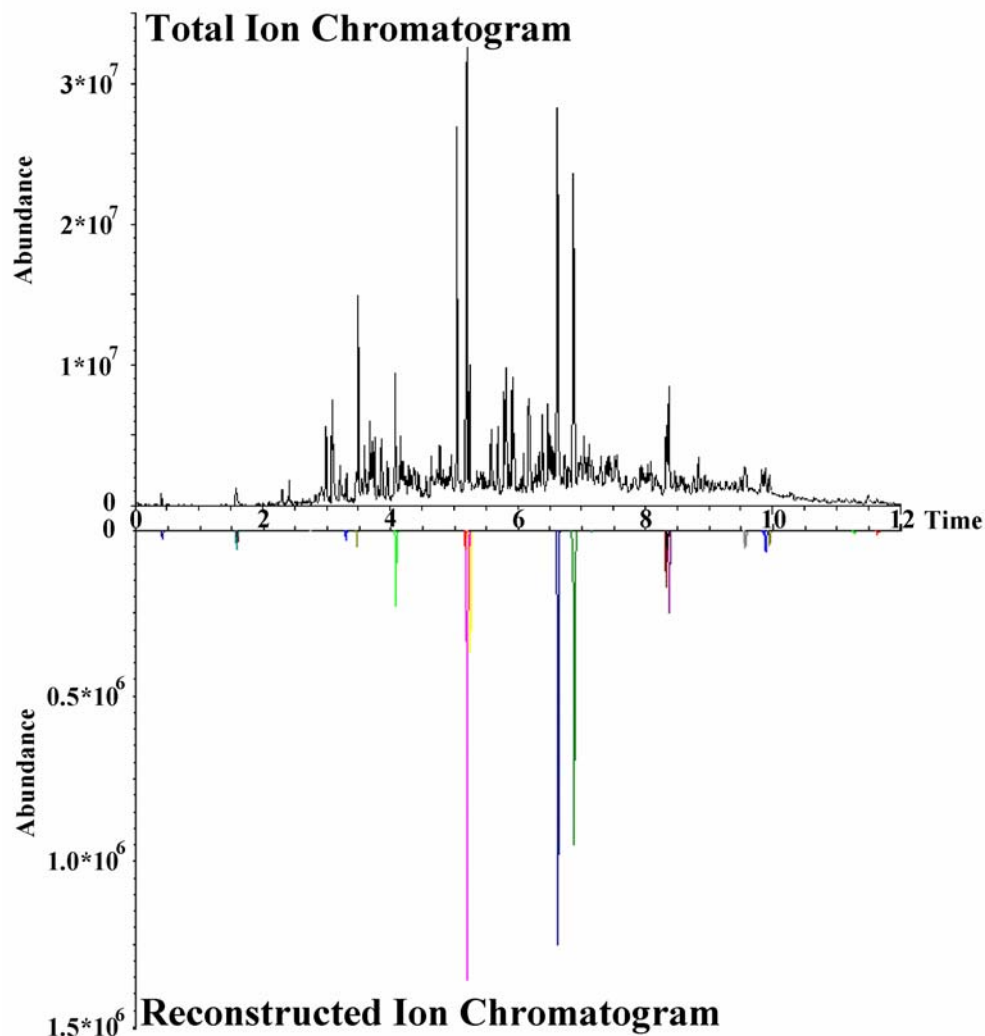
All extracts were spiked with internal standard compounds prior to analysis. The extracts were analyzed using a CFAST-modified HP 5890 Series II GC with a 5971A MSD, a CFAST-built large volume injector. Data analysis was performed using IST for GC/MS software. The instrument was operated in the splitless mode with 1 to 4 μ L injections onto a 30m x 0.32 mm x 0.25 μ m HP-5MS (5% phenylmethylsiloxane) capillary column. The run-time to elute all the target compounds was approximately 12 minutes. Sixteen (16) PAHs were determined for the EPA 8270mod. analyses.

RESULTS AND DISCUSSION

Extraction and Analysis Times

The total analysis time for a sample was greatly reduced using the combination of LPLE and accelerated GC/MS. For example, extraction of the soil by LPLE took about 10 to 15 minutes per sample. Additional timesavings were realized by preparing samples in batches. Further, the GC/MS run time was reduced from about 50 minutes (35 minutes for analyte elution and a 15 minute bake period) to 12 minutes using the accelerated GC/MS conditions. Figure 1 shows a 12 minutes analysis of sample CRM103-100 along with the IST-isolated PAHs. Using a 12-minute run time, the individual PAHs are clearly extracted from the complex sample matrix. The full instrument cycle time (the time elapsed between each injection) was reduced from about 60 minutes to about 20 minutes. Also, data processing time was reduced by about 60% using the IST software.

Figure 1. LPLE/Accelerated GC/MS Analysis of CRM103-100



Detection Limits

One objective was to assess whether the LPLE/accelerated GC/MS approach could generate quantitative, compound-specific data at quantitation limits (QLs) sufficiently low for regulatory purposes. For this study, QLs were calculated by adjusting the concentration of the lowest calibration standard within the linear range for sample size, extract volume, and percent solids. The detection limits (DLs) were estimates of the lowest concentration of a particular compound that still gave a measurable GC peak and mass spectrum.

Table 1 shows that the QLs for the LPLE-based analyses were about 25-times higher than those for the Soxhlet extracts when analyzed by EPA Method 8270C. This difference was directly related to differences in sample size and extract concentration factors. For a clean sample, the QLs for LPLE/8270C were 0.25 mg/kg in soil for most compounds. This QL is well below the

Estimated Quantitation Limits of 0.66 mg/kg given in Method 8270C. The QL for MSE/8270mod. were 2.0 mg/kg in soil for most compounds. This higher QL resulted because the CFAST instrument was somewhat less sensitive than META's instrument, and because the lowest initial calibration standard in the CFAST data was higher than META's lowest calibration standard.

Table 1. Target Compounds and Estimated Quantitation Limits (mg/kg)* for This Study

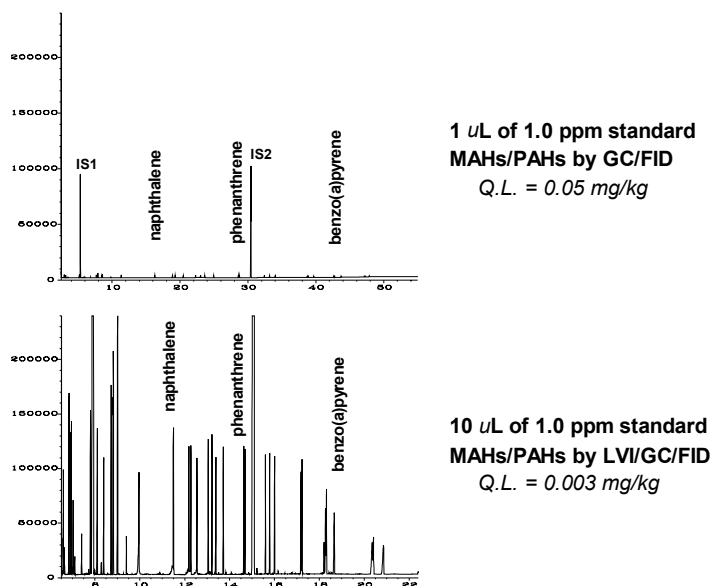
Parameter	Soxhlet Extraction and Method 8270C	LPLE and Method 8270C	Soxhlet Extraction and Method 8270mod.**	LPLE and Method 8270mod.**
naphthalene	0.01	0.25	2.0	2.0
acenaphthylene	0.01	0.25	2.0	2.0
acenaphthene	0.01	0.25	2.0	2.0
fluorene	0.01	0.25	2.0	2.0
phenanthrene	0.01	0.25	2.0	2.0
anthracene	0.01	0.25	2.0	2.0
fluoranthene	0.02	0.5	2.0	2.0
pyrene	0.01	0.25	2.0	2.0
benz(a)anthracene	0.02	0.5	2.0	2.0
chrysene	0.01	0.25	2.0	2.0
benzo(b)fluoranthene	0.04	1.0	2.0	2.0
benzo(k)fluoranthene	0.01	0.25	2.0	2.0
benzo(a)pyrene	0.02	0.5	2.0	2.0
indeno(1,2,3-cd)pyrene	0.08	2.0	2.0	2.0
dibenz(a,h)anthracene	0.08	2.0	2.0	2.0
benzo(g,h,i)perylene	0.02	0.5	2.0	2.0

* The quantitation limits are those for method blank samples; the actual QLs varied depending upon the linearity of the instrument at low calibration levels, the sample size, dilution factors, and sample moisture content. In addition, the QLs are for nonconcentrated extracts; however, the extracts could be concentrated up to ten-fold using standard techniques such as Kuderna-Danish, rotoevaporation, or nitrogen blowdown giving QLs 5 to 10 times lower.

** One purpose of this study was to show that the IST software was capable of identifying target compounds under fast GC/MS conditions. To minimize sources of variability, META and CFAST used the same standards and same injection volumes (1 uL). However, CFAST used a large volume GC injection port that can accommodate injection volumes up to 200 uL. With this hardware, quantitation limits as low as 0.01 to 0.02 mg/kg have been demonstrated.

Because QLs and DLs are dependent on several factors including instrument sensitivity, calibration range, sample size, concentration or dilution factors, and GC injection volumes, changes in QLs can be achieved by changing one or more of these operational parameters without affecting the performance of the extraction method (LPLE) or the quantitation method (IST). For example, large volume injection (LVI) devices for gas chromatographs have become commonplace in environmental laboratories. Using these devices, the QLs of semivolatile compounds, such as PAHs, have been lowered by as much as ten to fifty times (Figure 2).

Figure 2. 20-Fold Decrease in Detection Limit using Large Volume Injection



Quality Control Measures

Surrogate Compounds

The recoveries of surrogate compounds are summarized in Table 2. The following aspects of the data were noted:

- All surrogate recoveries were within the EPA Contract Laboratory Program (CLP) soil limits for all samples prepared by LPLE. However, 17 surrogates were above those limits in the samples prepared by Soxhlet extraction. Most of the high recoveries were for acid compounds (2-fluorophenol and phenol-d5) analyzed by 8270C at META, and appeared to be due to an increase in response factors for acidic compounds as the instrument stabilized over time.
- The surrogate recoveries appeared to be artificially low in two of the LPLE samples because dilution of those samples reduced the mass loading of surrogate compounds on-column to low levels.
- In general, surrogate recoveries were higher in the Soxhlet-prepared samples than in the LPLE samples, especially for acidic compounds. This was the case for both the 8270C and 8270mod. analyses. Also, the trend of Soxhlet recoveries being higher than LPLE recoveries was observed in the soil blank samples, which should provide the best indication of expected analyte recovery in the absence of matrix effects. However, the differences were small.
- The surrogate recoveries for samples prepared by LPLE and analyzed by both 8270C and 8270mod. compared well, particularly for the neutral compounds (2-fluorobiphenyl and

p-terphenyl-d5). Also, the surrogate recoveries for the samples prepared by Soxhlet extraction compared well, except for phenol-d5 and p-terphenyl-d5. For example, the average recovery of phenol-d5 by 8270C was 126% as compared to an average recovery of 75% for the 8270mod. method. As indicated in item 1 above, this difference was likely due to instrument response factor drift for the 8270C analyses that resulted in over-determined phenol-d5 concentrations.

- The average recovery of p-terphenyl-d5 (144%) in the 8270mod. analyses was somewhat higher than that for 8270C (104%). The exact cause of this systematic difference could not be identified, however one exceptionally high recovery (218%) by 8270 mod. greatly influenced the surrogate recovery average.

Table 2. Comparison of Surrogate Recoveries (%) in All Samples

	LPLE/8270C		LPLE/8270mod.		Soxhlet/8270C		Soxhlet/8270mod.	
	mean±s	range	mean±s	range	mean±s	range	mean±s	range
2-fluorophenol	87 ± 18	56 -104	na		117 ± 7.6	107 - 129	na	
phenol-d5	89 ± 18	60 -1 05	66 ± 14	45 - 84	126 ± 6.2	116 - 137	75 ± 23	43 - 100
nitrobenzene-d5	84 ± 16	53 - 98	na		103 ± 9.0	93 - 117	na	
2-fluorobiphenyl	94 ± 8.7	78 - 103	90 ± 5.6	80 - 98	105 ± 5.4	97 - 113	107 ± 12	85 - 127
2,4,6-tribromophenol	72 ± 15	43 - 85	78 ± 14	47 - 91	104 ± 15	82 - 130	99 ± 26	67 - 135
p-terphenyl-d5	89 ± 4.5	81 - 94	105 ± 12	85 - 120	104 ± 19	73 - 126	144 ± 35	107 - 218

mean - mean of 8 samples

s - standard deviation

na - not analyzed

Certified Reference Materials

Preparing and analyzing two certified reference soils known to contain PAHs tested the comparability of the LPLE sample preparation method and the rapid Method 8270 GC/MS analysis using the IST software. One CRM, CRM104-100, contained relatively low concentrations of PAHs (97 mg/kg), while the other CRM, CRM103-100, contained relatively high concentrations of PAHs (7,200 mg/kg).

Figures 3 and 4 show the results obtained for both sample preparation and analysis methods as compared to the reference values and prediction intervals for the PAH compounds. The reference values and prediction intervals were listed on the Certificate of Analysis for each CRM. Prediction intervals were chosen over confidence intervals because they provide a better indication of the range that one expects to contain a single future value of each particular compound based on the variability observed in the original interlaboratory testing of the CRM. It

is clear that both extraction procedures and both instrumental methods generated results that were comparable to the reference values and well within the prediction intervals. In general, the LPLE method under-recovered PAHs slightly, while the Soxhlet method over-recovered PAHs slightly, when compared to the reference values. However, this trend was not consistent for all compounds.

The deviations from the reference values were generally small. Nearly all deviations from true values were less than 50%, and most % differences were less than 25%. Of the 91 % differences calculated, 45 were positive, indicating that the measured value was greater than the reference value, and 46 were negative, indicating that the measured value was less than the reference value. The fact that the results were split evenly suggests no bias in the data.

The CRMs were considered to be good tests of the extraction performance of the LPLE method because they represented aged samples in which the PAHs have sequestered. It is known that recovery of organic compounds from aged soils can be difficult [10]. The CRM data clearly indicate that the LPLE method used in this study will quantitatively extract PAHs from aged soil in a very short period of time.

Figure 3. Results of Analysis of CRM104-100

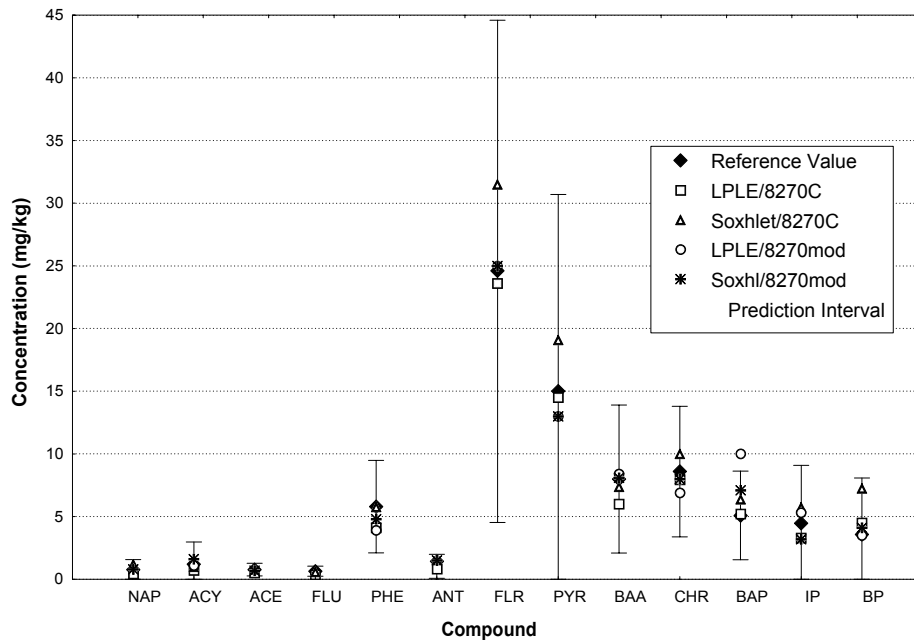
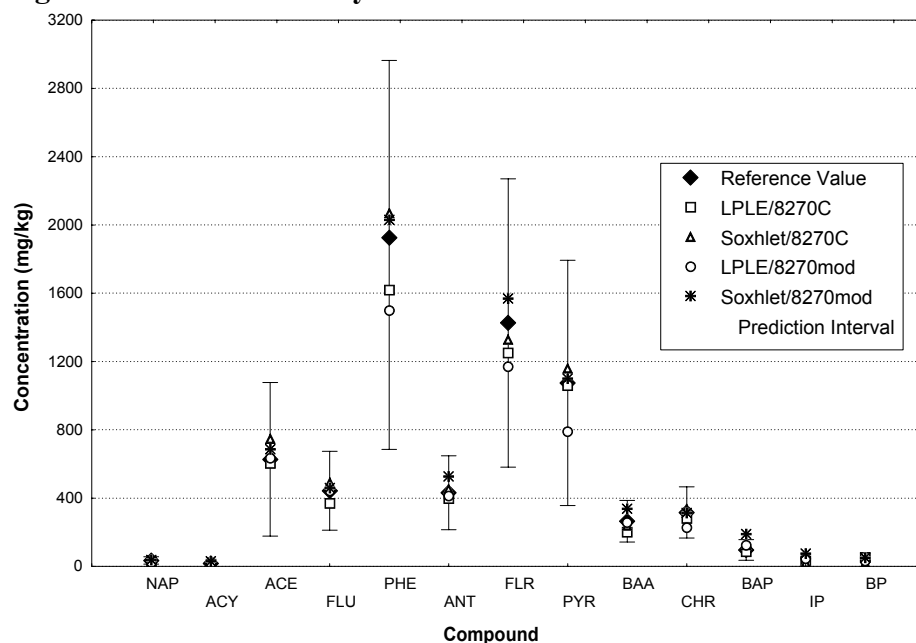


Figure 4. Results of Analysis of CRM103-100



Also, both CRMs were considered to be good tests of the ability of the IST software to accurately quantify PAHs in a soil extract because they contained relatively large amounts of potentially interfering, extractable matter. Clearly, the results obtained using the accelerated GC time and the IST software were indistinguishable to the standard method, even in the presence of large quantities of potential interferences.

MGP Site Samples

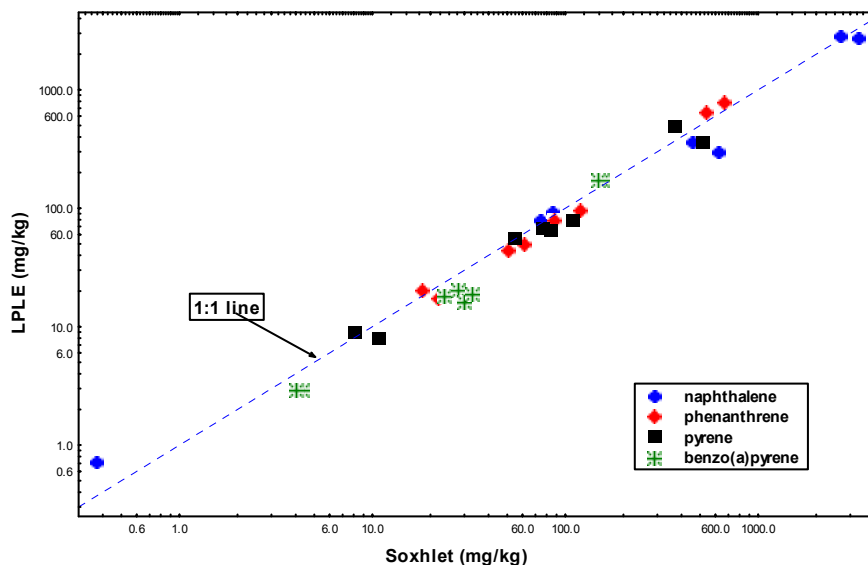
Four soil samples from former MGP sites in New Jersey were included in this study. The samples ranged from fine sand to medium sand, silt, and gravel. Some samples contained visible dark organic liquid. Also, one sample contained a substantial amount of diesel-range petroleum hydrocarbons in addition to PAHs.

Figure 5 shows a comparison of the results for four PAHs that spanned the molecular weight range of the analysis, including naphthalene, phenanthrene, pyrene, and benzo(a)pyrene. The data from all four MGP site samples are included in Figure 5. In addition, the data from both instrumental methods, 8270C and 8270 mod., are included. Thus, the combination of four compounds in four samples compared pair wise for two methods gives a total of 32 data points on Figure 5 (note that naphthalene was not detected by 8270mod. in one sample, and therefore the total number of data points is 31). By pooling the data in this way and drawing a 1:1 line that represents perfect correlation, any combination of extraction and analysis method that produces consistently different results will be apparent visually. Figure 5 shows that the comparability of the two methods was very good, as indicated by a pooled correlation coefficient of 0.985 for all four samples and all four analytes.

Expanded Compound Lists

As discussed previously, EPA Method 3570, and therefore LPLE, were designed to recover a wide range of both volatile and semivolatile organic compounds from solid matrices. To demonstrate the performance, several spiking tests of EPA Method 3570 were conducted with a mixture of 116 volatile and semivolatile compounds spiked into clean sand. The compound mixture included all CLP SVOCs plus most of the CLP VOC compounds. Three replicate spikes were prepared. The recoveries ranged from 24 percent for cis-1,2-dichloroethene to 120 percent

Figure 5. Comparison of Analyses of MGP Samples



for 4-nitroaniline. The average recovery for all compounds was 92 percent; the median recovery was 98 percent; and the %RSD was 0.2 percent, indicating very good recovery over a wide range of compounds.

The recovery of VOCs and SVOCs from environmental samples containing various amounts of natural organic matter, clay, moisture, and other chemicals, may not be as complete as indicated by these data. However, our analyses of certified reference soils and actual site samples showed that Method 3570 performed as well as other preparation methods for a wide range of environmental samples.

Comparison of LPLE/Accelerated GC/MS to Soxhlet/GC/MS

This paper shows that the LPLE method extracts PAHs from several soil types in 10 to 15 minutes with the precision and accuracy of Soxhlet extraction. Samples were prepared in batches of six to 10 giving an average sample extraction time of about 4 minutes. In addition, data were collected (not reported) that indicate that the method reliably extracts most of the semivolatile organic compounds of concern (EPA Method 8270 list), and can even be extended to recover many of the EPA Method 8260 volatile organic compounds. It is clear from the estimates shown in Table 3 that this approach results in substantial timesavings with the added benefit of using less solvent and generating less waste.

A potential disadvantage of the LPLE method is the low sample to solvent concentration ratio and the resulting higher detection limits. However, this limitation is correctable with small changes in the method. For example, an extract concentration step could be added to the method utilizing the nitrogen blow-down technique that could effectively lower the detection limits by a factor of 5 to 10. The concentration step would add several minutes to the overall sample preparation time, but also could be done in batches of five to 20 samples. Thus, the average sample preparation time would remain at a few minutes per sample. Other techniques are available to lower detection limits. For example, LVIs for GCs can be used to realize one to two orders of magnitude decreases in detection limits. Therefore, LVIs would eliminate the sensitivity limitation of the LPLE method.

The LPLE method is a modification of EPA Method 3570, Microextraction Technique for Soil and Solid Matrices. Presently, it can be used for projects after site-specific regulatory approval.

As stated earlier in this paper, the application of accelerated GC/MS conditions and the IST software to LPLE extracts reduces analysis time over EPA Method 8270 and commercial data processing software. There are no disadvantages to running EPA Method 8270 in accelerated mode with the IST software equivalent to the LPLE disadvantages. The changes in GC operating conditions and the use of the IST software would not be considered major modifications of Method 8270, since all of the Method 8270 quality control requirements, such as, mass spectrometer tuning, initial and continuing calibrations, and internal standard quantitation are part of the method. One potential disadvantage is the inability to separate benzo(b)fluoranthene and benzo(k)fluoranthene at some accelerated GC operating conditions. When this occurs, the results are reported as the sum of the two compounds.

Table 3. Comparison of LPLE/accelerated 8270 to Soxhlet/8270

	LPLE/accelerated 8270/IST	Soxhlet/8270	Savings or Reduction
Estimated per sample extraction and analysis time	20 to 30 minutes	6 to 24 hours	> 90%
Target analytes	16 PAHs (expandable to 8270 full list)	acidic, basic, and neutral organic compounds	NA
Quantitation Limits*	0.25 to 2 mg/kg	0.01 to 0.6 mg/kg	NA
Analyte Recovery	equivalent to Soxhlet/8270	benchmark	NA
Precision	equivalent to Soxhlet/8270	benchmark	NA
Solvent used per sample	5 mL	300 mL	98%
Total solvent used**	0.5 L	30 L	98%
Waste generated**	1 L waste solvent, 5 kg used and unused soil, small amounts of laboratory trash	60 L waste solvent, 25 kg used and unused soil, moderate amounts of laboratory trash	98%

* based on the extraction method and instruments used in this report; lower QLs are possible as discussed in the text

** assumes 100 samples analyzed

NA - not applicable

CONCLUSIONS

A method for the rapid analysis of soil samples for PAHs was tested in an interlaboratory study. The method consisted of two innovative steps: first, soil samples were extracted using a rapid extraction technique at elevated temperature and pressure, and second, the soil extracts were analyzed using a short GC/MS run-time and the IST software.

- The LPLE sample preparation method recovered native and spiked PAHs quantitatively at a preparation time of 10 to 15 minutes for a single sample. The method was simple to perform, used inexpensive and readily available labware, generated little soil or solvent waste, and could be done in a field laboratory. The recovery of native compounds by LPLE was comparable to the reference values of the CRMs and to Soxhlet extraction of site samples for most analytes in the samples. The LPLE results were well within the QC criteria established for EPA CLP methods.
- Because of the smaller sample size and the elimination of extract concentration, the detection limits of the LPLE method are higher than those of the standard methods. However, either maximizing the mass spectrometer sensitivity or using a large volume injector overcame this limitation. Additional reductions in the detection limits could be achieved by adding an extract concentration step or by increasing the injection volume, or both.
- The accelerated GC/MS results using the IST software were the same as the standard EPA Method 8270C conditions and data processing procedures. The analysis time (as estimated using the instrument cycle time and data processing time estimates) was reduced from about 90 minutes to about 20 minutes per sample. IST for GC/MS software is available from Ion Signature Technology at www.ionsigtech.com.
- The study has demonstrated that the LPLE plus accelerated GC/MS/IST approach can generate regulatory or litigation quality PAH data at turnaround times of three to four samples per hour. However, elevated detection limits and the lack of agency approval of the method for routine use presently limit its application.
- The cost of analyses using LPLE/accelerated GC/MS on-site are typically much higher than fixed laboratory costs for small projects, but become competitive with and eventually significantly less than fixed laboratory costs as the number of sample analyses increase.
- The combination of EPA Method 3570 or LPLE and GC/MS either in standard or accelerated run mode can be used for site characterization, risk assessment, design, monitoring, and forensic studies. META has used these methods at more than 100 sites for a diverse list of clients in fixed and field laboratory operations. The performance has been demonstrated by inter and intra-laboratory studies and third party data validation.

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