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September 2002

Environmental Technology Verification Report

Lead in Dust Wipe Measurement Technology

Palintest
Scanning Analyzer SA-5000 System

Oak Ridge National Laboratory

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV

U.S. Environmental Protection Agency

Oak Ridge National Laboratory

Verification Statement

TECHNOLOGY TYPE:	**ANODIC STRIPPING VOLTAMMETRY**	
APPLICATION:	**MEASUREMENT OF LEAD IN DUST WIPES**	
TECHNOLOGY NAME:	**Scanning Analyzer SA-5000 System**	
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations and stakeholder groups consisting of regulators, buyers, and vendor organizations, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

Oak Ridge National Laboratory (ORNL) is one of the verification organizations operating under the Advanced Monitoring Systems (AMS) Center. AMS, which is administered by EPA's National Exposure Research Laboratory (NERL), is one of six technology areas under ETV. In this verification test, ORNL evaluated the performance of lead in dust wipe measurement technologies. This verification statement provides a summary of the test results for Palintest's Scanning Analyzer SA-5000 system.

VERIFICATION TEST DESCRIPTION

This verification test was designed to evaluate technologies that detect and measure lead in dust wipes. The test was conducted at the Capitol Community Technical College in Hartford, CT, from November 5 through November 9, 2001. The vendors of commercially-available, field portable technologies blindly analyzed 160 dust wipe samples containing known amounts of lead, ranging in concentration from ≤ 2 to 1,500 µg/wipe. The experimental design was particularly focused on important clearance standards, such as those identified in 40 CFR Part 745.227(e)(8)(viii) of 40 µg/ft^2 for floors, 250 µg/ft^2 for window sills, and 400 µg/ft^2 for window troughs. The samples included wipes newly-prepared and archived from the Environmental Lead Proficiency Analytical Testing Program (ELPAT). These samples were prepared from dust collected in households in North Carolina and Wisconsin. Also, newly-prepared samples were acquired from the University of Cincinnati (UC). The UC dust wipe samples were prepared from National Institute of Standards and Technology (NIST) Standard Reference Materials (SRMs). The results of the lead analyses generated by the technology were compared with results from analyses of similar samples by conventional laboratory methodology, in a laboratory that was recognized as proficient by the National Lead Laboratory Accreditation Program (NLLAP) for dust testing. Details of the test, including a data summary and discussion of results, may be found in the report entitled *Environmental Technology Verification Report: Lead in Dust Wipe Detection Technology— Palintest, Scanning Analyzer SA-5000 System,* EPA/600/R-02/057.

TECHNOLOGY DESCRIPTION

The Scanning Analyzer SA-5000 system uses the electrochemical technique of stripping analysis to specifically determine the concentration of lead in a solution. Anodic stripping analysis is a two step process. The first step is called the deposition step and involves the electro-deposition of lead on to a disposable mercury-film electrode. The deposition is achieved by cathodic deposition at a fixed potential and time. Following the fixed deposition time, the system enters the second step, the stripping or measurement step. The stripping step involves scanning the potential anodically using a potential-time waveform. During this anodic scan the deposited lead is reoxidized and stripped out of the electrode. The current and potential are measured during the anodic scan and the resulting voltammogram contains a peak whose potential is specific to lead and whose height is proportional to the concentration of lead in the solution. The peak height is converted from a current to a concentration using one of many calibration curves stored in the instrument. No user calibration is required because each batch of electrodes is checked during manufacture and assigned an eight figure calibration code. The calibration code is used to select the calibration curve which matches the electrode batch. Reporting limits during this verification test were 25 µg/wipe.

VERIFICATION OF PERFORMANCE

The following performance characteristics of the SA-5000 were observed:

Precision: Precision, based on the average percent relative standard deviation (RSD), was 5% for the ELPAT samples and 8% for the UC samples. A technology's performance is considered very precise if the average RSD is less than 10%, but acceptable as long as the average RSD is less than 20%.

Accuracy: Accuracy was assessed using the estimated concentrations of the ELPAT and UC samples. The number of results for the ELPAT samples that were reported within the acceptance ranges that have been established for those samples is one measure of accuracy. The SA-5000 reported results within the acceptance ranges for all 72 ELPAT samples (> 25 µg/wipe). The average percent recovery value (SA-5000 reported result/estimated ELPAT concentration) for all samples reported above 25 µg/wipe was 91%. For the UC samples, the average percent recovery was 80%. This negative bias was statistically significant, but within the acceptable bias range of 100% ± 25%. For the NLLAP laboratory results, the

average percent recovery values were 98% and 88%, respectively, for the ELPAT and UC samples. The negative bias for both the ELPAT and UC samples was statistically significant.

Comparability: A comparison of the SA-5000 results and the NLLAP-recognized laboratory results was performed for all samples (ELPAT and UC) that were reported above 25 µg/wipe. The correlation coefficient (r) for the comparison of UC samples was 1.000 [slope (m) = 0.839, intercept = 5.539], and for the ELPAT samples was 0.995 [m = 0.926, intercept = 6.506]. While the slopes for both the ELPAT and UC samples were statistically different than 1.00, the correlation coefficients show a strong linear agreement (i.e., r values greater than 0.990) with the NLLAP laboratory data.

Detectable blanks: All twenty samples prepared at concentrations < 2 µg/wipe were reported correctly by the SA-5000 as < 25 µg/wipe. Performance was also assessed at concentrations near the reporting limits of the technology. Two sets of four ELPAT samples with estimated concentrations of 16.9 and 17.6 µg/wipe were all reported by the SA-5000 as < 25 µg/wipe. For the set of four ELPAT samples at 29.8 µg/wipe, the SA-5000 reported results between 28 and 32 µg/wipe.

False positive results: A false positive (fp) result is one in which the technology reports a result that is above the clearance level when the true (or estimated) concentration is actually below. For the ELPAT samples, the SA-5000 did not produce any fp results out of a possible12 results. For the UC samples, the SA-5000 did not produce any out of a possible 38 fp results. By comparison, the NLLAP laboratory did not report any fp results on the UC, but had 2 of12 possible fp results on the ELPAT samples.

False negative results: A false negative (fn) result is one in which the technology reports a result that is below the clearance level when the true (or estimated) concentration is actually above. For the ELPAT samples, the SA-5000 reported 17 of a possible 28 fn results. For the UC samples, the SA-5000 reported 22 out of a possible 22 fn results. By comparison, the NLLAP laboratory reported 7 out of a possible 28 fn results for the ELPAT samples, and 16 out of a possible 19 fn results for the UC samples.

Completeness: Completeness is defined as the percentage of measurements that are judged to be usable (i.e., the result is not rejected). An acceptable completeness rate is 95% or greater. The SA-5000 generated results for all 160 dust wipe samples, for a completeness of 100%.

Sample Throughput: Sample throughput is a measure of the number of samples that can be processed and reported by a technology in a given period of time. A single analyst (a Palintest expert) was able to prepare and analyze 80 samples per 12-hour day.

Overall Evaluation: The overall performance was characterized as having an acceptable amount of negative bias, very precise, and in good agreement with an NLLAP-recognized laboratory's results. The verification team found that the SA-5000 was relatively simple for the trained analyst to operate in the field, requiring less than an hour for initial setup. As with any technology selection, the user must determine if this technology is appropriate for the application and the project data quality objectives. Additionally, ORNL and ETV remind the reader that, while the ETV test provides valuable information in the form of a snapshot of performance, state, tribal, or federal requirements regarding the use of the technologies (such as NLLAP recognition for analysis of clearance samples where required) need to be followed. For more information on this and other verified technologies, visit the ETV web site at http://www.epa.gov/etv.

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Lead in Dust Wipe Measurement Technology

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Notice

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Acknowledgments

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Abbreviations and Acronyms

AIHA	American Industrial Hygiene Association
AMS	Advanced Monitoring Systems Center, ETV
ASTM	American Society for Testing and Materials
ASV	Anodic Stripping Voltammetry
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CL	Clearance level for lead (40, 250, or 400 μg/wipe)
ELPAT	Environmental Lead Proficiency Analytical Testing program
EPA	U. S. Environmental Protection Agency
ETV	Environmental Technology Verification Program
ETVR	Environmental Technology Verification Report
fn	false negative result
fp	false positive result
ICP-AES	Inductively coupled plasma-atomic emission spectrometry
NERL	National Exposure Research Laboratory, U.S. EPA
NIOSH	National Institute for Occupational Safety and Health, CDC
NIST	National Institute of Standards & Technology
NLLAP	National Lead Laboratory Accreditation Program
OPPT	Office of Pollution Prevention and Toxics, U.S. EPA
ORNL	Oak Ridge National Laboratory
QA	quality assurance
QC	quality control
RSD	relative standard deviation
RTI	Research Triangle Institute
SD	standard deviation
SRM	Standard Reference Material
UC	University of Cincinnati

Section 1 — Introduction

The U.S. Environmental Protection Agency (EPA) created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations and stakeholder groups consisting of regulators, buyers, and vendor organizations, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing verification test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

ETV is a voluntary program that seeks to provide objective performance information to all of the participants in the environmental marketplace and to assist them in making informed technology decisions. ETV does not rank technologies or compare their performance, label or list technologies as acceptable or unacceptable, seek to determine "best available technology," or approve or disapprove technologies. The program does not evaluate technologies at the bench or pilot scale and does not conduct or support research. Rather, it conducts and reports on testing designed to describe the performance of technologies under a range of environmental conditions and matrices.

The program now operates six centers covering a broad range of environmental areas. ETV began with a 5-year pilot phase (1995–2000) to test a wide range of partner and procedural alternatives in various technology areas, as well as the true market demand for and response to such a program. In these centers, EPA utilizes the expertise of partner "verification organizations" to design efficient processes for conducting performance tests of innovative technologies. These expert partners are both public and private organizations, including federal laboratories, states, industry consortia, and private sector entities. Verification organizations oversee and report verification activities based on testing and QA protocols developed with input from all major stakeholder/customer groups associated with the technology area. The verification described in this report was administered by the Advanced Monitoring Systems (AMS) Center, with Oak Ridge National Laboratory (ORNL) serving as the verification organization. (To learn more about ETV, visit ETV's Web site at http://www.epa.gov/etv.) The AMS Center is administered by EPA's National Exposure Research Laboratory (NERL).

The verification of a field analytical technology for measurement of lead in dust wipe samples is described in this report. The verification test was conducted in Hartford, Connecticut, from November 5 through November 9, 2001. The performance of the Palintest's Scanning Analyzer SA-5000 system was determined under field conditions. The technology was evaluated by comparing its results to estimated concentration values and with results obtained on similar samples using a recognized laboratory analytical method. For background information, reports on performance of this and other anodic stripping voltammetry systems can be found in other published reports (EPA, 1996, Ashley et al., 2001).

Section 2 — Technology Description

In this section, the vendor (with minimal editorial changes by ORNL) provides a description of the technology and the analytical procedure used during the verification testing activities.

General Technology Description

The Scanning Analyzer SA-5000 system (Figure 1) uses the electrochemical technique of anodic stripping analysis to specifically determine the concentration of lead in a solution. Stripping analysis is a two step process. The first step is called the deposition step and involves the electro-deposition of lead on to a disposable mercury-film electrode. The deposition is achieved by cathodic deposition at a fixed potential and for a fixed length of time. Following the fixed deposition time, the system enters the second step, the stripping or measurement step. The stripping step involves scanning the potential anodically using a potential-time waveform. During this anodic scan, the deposited lead is reoxidized and stripped off of the electrode. The current and potential are measured during the anodic scan and the resulting voltammogram contains a peak whose potential is specific to lead and whose height is proportional to the concentration of lead in the solution. The peak height is converted from a current to a concentration using one of many calibration curves stored in the instrument. No user calibration is required because each batch of electrodes is checked during manufacturing and assigned an eight figure calibration code. The calibration code is used to select the calibration curve which matches the electrode batch.

Figure 1. Palintest's Scanning Analyzer SA-5000 System.

Analytical Procedure

The following is the procedure that was followed by Palintest during the verification test.

1. Place the dust wipe into a 50 mL sonicator tube. Using a pipettor add 15 mL (3 x 5 mL) of 25% nitric acid to the sonicator tube. Use a new crushing rod to push the wipe down into the tube ensuring it is covered by the acid. Continue to push the wipe into the acid solution until trapped air bubbles in the wipe have been released.

2. Place the tube in the ultrasonicator. Fill the ultrasonicator with warm water (45 - 50 °C) so that the level of water in the sonicator is at least 1 cm above the level of liquid in the tube.

3. Sonicate the tube for 30 minutes then remove the tube and place in a rack.

4. Take the same crushing rod as previously used and repeat the mixing of the wipe in the tube. Replace the tube in the ultrasonicator and sonicate for an additional 15 minutes.

5. Remove the cap and carefully add deionized or distilled water to the 50 mL mark. Using the same crushing rod as previously used, mix the wipe and solution to ensure complete distribution of the extract. Replace the cap and mix well by shaking.

6. Take a 5 mL screw capped test tube and pour a portion of the solution into the tube filling to the 5 mL mark.

7. Add one SoluPrep SP-B tablet, crush and mix until completely dissolved.

8. Test the sample with the scanning analyzer. Switch on the instrument. Select Dust from the menu. Key in the correct calibration code shown on the electrode pack. Open the foil strip containing an electrode and insert into the connector. Insert the electrode into the sample. The instrument automatically starts the test and the result is displayed after 45 seconds.

Section 3 — Verification Test Design

Objective

The purpose of this section is to describe the verification test design. It is a summary of the test plan (ORNL, 2001).

Testing Location and Conditions

The verification of field analytical technologies for lead in dust wipes was conducted at the Capitol Community Technical College in Hartford, Connecticut. The test was conducted in the basement of a classroom building. The temperature and relative humidity were monitored during field testing, but remained fairly constant. The average temperature and relative humidity over the four days of testing were 68 °F and 32%, respectively.

Drivers and Objectives for the Test

The purpose of this test was to evaluate the performance of field analytical technologies that are capable of analyzing dust wipe samples for lead contamination. This test provides information on the potential applicability of field technologies to EPA standards for dust clearance testing. The experimental design was designed around the three clearance standards of 40 $\mu g/ft^2$ for floors, 250 $\mu g/ft^2$ for window sills, and 400 $\mu g/ft^2$ for window troughs that are outlined in 40 CFR Part 745.227(e)(8)(viii) (CFR, 2001).

The primary objectives of this verification were to evaluate the field analytical technologies in the following areas: (1) how well each performs relative to a conventional, fixed-site analytical method for the analysis of dust wipe samples for lead; (2) how well each performs relative to results generated in previously rounds of ELPAT testing (described in the next section), and (3) the logistical and economic resources necessary to operate the technology. Secondary objectives for this verification were to evaluate the field analytical technology in terms of its reliability, ruggedness, cost, range of usefulness, sample throughput, data quality, and ease of use. Note that this verification test does not provide an assessment of the selection of locations for dust samples in a facility or an assessment of the way that dust samples are collected. The planning for this verification test follows the guidelines established in the data quality objectives process.

Summary of the Experimental Design

All of the samples analyzed in this verification test were prepared gravimetrically. At the time of the test, both of the wipes utilized in the test (PaceWipe™ and Palintest Dust Wipe™) were on the list of wipes recommended for lead testing by the American Society for Testing and Materials (ASTM, 1996). Initial consideration was given to conducting the test in a real-world situation, where the technologies would have been deployed in a housing unit that had been evacuated due to high levels of lead contamination. In addition to the safety concern of potentially subjecting participants to lead exposure, the spatial variability of adjacent samples would have been expected to be so great that it would be much larger than the anticipated variability of these types of technologies, thereby making it difficult to separate instrument/method variability and sampling variability. The availability of well-characterized samples derived from "real-world" environments made the use of proficiency testing samples (so-called "ELPAT" samples) and other prepared samples an attractive alternative.

ELPAT and Blank Sample Description

In 1992, the American Industrial Hygiene Association (AIHA) established the Environmental Lead Proficiency Analytical Testing (ELPAT) program. The ELPAT Program is a cooperative effort of the American Industrial Hygiene Association (AIHA), and researchers at the Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), and the EPA Office of Pollution Prevention and Toxics (OPPT). The ELPAT program is designed to assist laboratories in improving their analytical performance, and therefore, does not specify use of a particular analytical method. Participating laboratories are sent samples to analyze on a quarterly basis. The reported values must fall within a range of acceptable values in order for the laboratory to be deemed proficient for that quarter.

Research Triangle Institute (RTI) in Research Triangle Park, NC, is contracted to prepare and distribute the lead-containing paint, soil, and dust

wipe ELPAT samples. For the rounds of testing which have occurred since 1992, archived samples are available for purchase. Some of these samples were used in this verification test. Because the samples have already been tested by over one-hundred laboratories, a certified concentration value is supplied with each sample. This certified value represents a pooled measurement of all of the results submitted, with outliers excluded from the calculation.

The following description, taken from an internal RTI report, briefly outlines how the samples were prepared. RTI developed a repository of real-world housedust, collected from multiple homes in the Raleigh/Durham/Chapel Hill area, as well as from an intervention project in Wisconsin. After collection, the dust was sterilized by gamma irradiation, and sieved to 150 μm. A PaceWipe™ was prepared for receiving the dust by opening the foil pouch, removing the wet folded wipe and squeezing the excess moisture out by hand over a trash can. The wipe was then unfolded and briefly set on a Kimwipe™ to soak up excess moisture. The PaceWipe was then transferred to a flat plastic board to await the dust. After weighing a 0.1000 ± 0.0005 g portion of dust on weighing paper, the pre-weighed dust was gently tapped out onto the PaceWipe. The wipe was then folded and placed in a plastic vial, which was then capped. All vials containing the spiked wipes were stored in a cold room as a secondary means of retarding mold growth until shipment.

Before use in the ELPAT program, RTI performed a series of analyses to confirm that the samples were prepared within the quality guidelines established for the program. The data quality requirements for the ELPAT samples were: 1) the relative standard deviation of the samples analyzed by RTI must be 10% or less; 2) the measured concentrations must be within 20% of the target value that RTI was intending to prepare; and 3) analysis by an accredited laboratory must yield results within ± 20% of the RTI result. Ten samples were analyzed by RTI and nine samples were sent to the Wisconsin Occupational Health Laboratory for independent, confirmatory analysis. All ELPAT samples used in this test met the data quality requirements described above. The estimated concentration for an ELPAT sample used in this evaluation was the certified ("consensus") value (i.e., an analytically derived result).

RTI prepared the blank samples using the same preparation method as the ELPAT samples, but the concentration of lead was less than 2 μg/wipe, well below the expected reporting limits of the participant technologies.

University of Cincinnati Sample Description

The ELPAT samples consisted of dust mounded in the center of a PaceWipe. The University of Cincinnati (UC) prepared "field QC samples" where the dust was sprinkled over the wipe, more similar to how a wipe would look when a dust wipe sample is collected in the field. The sample was prepared by weighing, so the concentrations can be estimated. In a typical scenario, UC sends these control samples to a laboratory along with actual field-collected samples as a quality check of the laboratory operations. Because the samples are visually indistinguishable from an actual field sample, are prepared on the same wipe, and are shipped in the same packaging, the laboratory blindly analyzes the control samples. This provides the user with an independent assessment of the quality of the laboratory's data.

A cluster of twenty UC samples prepared at the key clearance levels were added to the experimental design, primarily so that an abundance of data would exist near the clearance levels, in order to assess false positive and false negative error rates. For Palintest, the UC samples were prepared on their own Palintest DustWipes™. The UC wipe samples were prepared using National Institute of Standards & Technology (NIST) Standard Reference Materials (SRMs). NIST SRM 2711 was used to prepare the 40 μg/wipe samples, and NIST SRM 2710 was used to prepare the 250 and 400 μg/wipe samples. Both SRM 2711 and SRM 2710 are Montana Soil containing trace concentrations of multiple elements, including lead. Some NIST SRM materials that are spiked on dust wipes are known to have low extraction recoveries when prepared by standard analytical methods (e.g., lead silicates cannot be extracted unless hydrofluoric acid is used) (Ashley et al., 1998). These particular SRMs are not known to contain lead silicates or to give lower lead recoveries. However, it is important to note the

possibility of such when using NIST SRMs for lead dust wipe analysis, since similar SRMs (e.g., Buffalo river sediment from Wyoming) do show recoveries in the low 90% range (Ashley et al., 1998).

Because accurate and precise estimated concentrations for the UC samples were imperative, ORNL imposed the following data quality requirements for the UC-prepared wipe samples: 1) each estimated concentration had to be within a ± 10% interval of the target clearance level; 2) additional quality control (QC) samples (at least 5% of the total samples ordered) were to be prepared and analyzed by UC as a quality check prior to shipment of the samples; and 3) the relative standard deviation of the QC samples had to be $\leq$ 10%. It is important to note here the reason why the data quality requirements between the UC and ELPAT samples were different. The data quality requirements for the ELPAT samples (i.e., ± 20% of the target value) were established by the ELPAT program. Since archived samples were being used, those data quality requirements could not be changed.

As a quality check of the sample preparation process, UC prepared an additional nine samples (5% of the total number ordered). UC extracted and analyzed the samples following internal procedures (nitric/hydrochloric acid extraction, followed by atomic absorption spectrometry - see EPA, 1996 for Methods 3050B and 6010B) and provided those results to ORNL. For the nine samples (three at each of the three clearance levels), the average percent recovery (i.e., UC measured concentration/UC estimated concentration x 100%) was 97% (median value = 96%, standard deviation = 3%, range = 94% to 103%). Additionally, 18 randomly-selected samples (six at each of the three clearance levels) were analyzed by the EPA Region 1 laboratory in North Chelmsford, MA, as an independent quality control check of the accuracy and precision of UC's sample preparation procedure (nitric acid digestion followed by ICP/AES analysis - EPA 1996). The average percent recovery (EPA Region 1 reported concentration/UC estimated concentration x 100%) was 91% (median 90%, standard deviation = 3%), with a range of values from 86% to 97%. The average recovery determined from the EPA Region 1 analyses (91%) was lower than that which was determined by UC (97%), but both values were within the data quality requirement of 100 ± 10%. Based on these data, ORNL determined that the UC sample preparation process met the established data quality criteria and was deemed acceptable for use in the determination of false positive/false negative error rates.

Distribution and Number of Samples

A total of 160 samples were analyzed in the verification test. Figure 2 is a plot containing the distribution of the sample concentrations that were analyzed in this study. Twenty samples were prepared by the University of Cincinnati at +/- 10% of each of the three clearance levels (3 test levels x 20 samples = 60 samples total). Research Triangle Institute prepared 20 "blanks" at lead concentrations < 2 μg/wipe. These samples are noted as such in Figure 2. The remaining samples in Figure 2 are ELPAT samples. For most of the ELPAT samples, four samples were analyzed at each concentration level (16 test levels x 4 samples each = 64 samples total). There were two concentration levels (at 49 and 565 μg/wipe) where eight samples were analyzed. While the set of samples at each concentration level were prepared using homogeneous source materials and an identical preparation procedure, ELPAT samples cannot be considered true "replicates" because each sample was prepared individually. However, these samples represent four samples prepared similarly at a specified target concentration, with an estimated value calculated from more than 100 analyses of similarly prepared samples.

Sample Randomization

The samples were packaged in 20-mL plastic scintillation vials and labeled with a sample identifier. Each participant received the same suite of samples, but in a randomized order. The samples were distributed in batches of 16. Completion of chain-of-custody forms documented sample transfer.

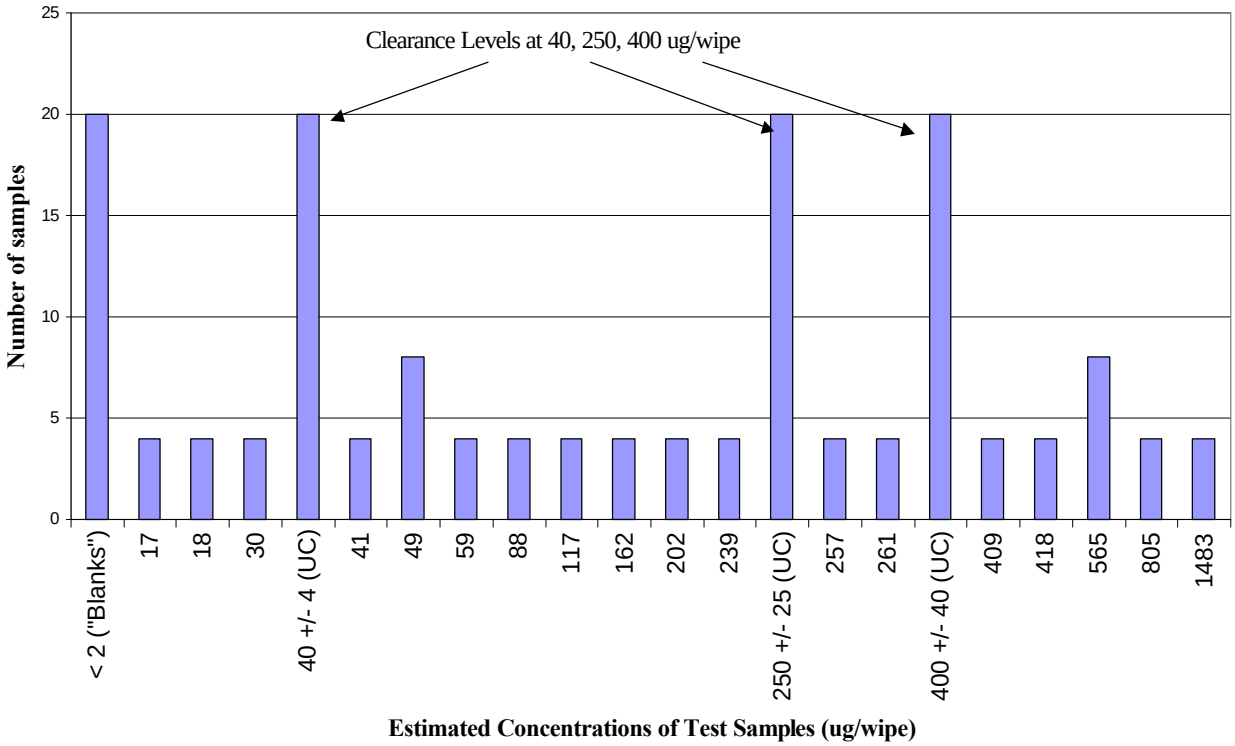

Figure 2. Distribution of sample concentrations.

Description of Performance Factors

In Section 5, technology performance is described in terms of precision, accuracy, completeness, and comparability, which are indicators of data quality (EPA, 1996). False positive and negative results, sample throughput, and ease of use are also described. Each of these performance characteristics is defined in this section.

Precision

Precision is the reproducibility of measurements under a given set of conditions. Standard deviations estimated at each concentration level can be used to establish the relationship between the uncertainty and the average lead concentration. Standard deviation (SD) and relative standard deviation (RSD) for "replicate" results are used to assess precision, using the following equation:

$$RSD = (SD/\text{average concentration}) \times 100\% \,. \quad \text{(Eq. 1)}$$

The overall RSD is characterized by two summary values:

- mean — i.e., average;
- range — i.e., the highest and lowest RSD values that were reported.

The average RSD may not be the best representation of precision, but it is reported for convenient reference. An average RSD value less than 10% indicates that the measurements are very precise. RSDs greater than 20% should be viewed as indicators of larger variability and possibly non-normal distributions. The uncertainty in the analytical measurements will include influences from both the preparation (i.e., extraction) and measurement steps.

Accuracy

Accuracy is a measure of how close the measured lead concentrations are to estimated values of the true concentration. The estimated values for the ELPAT samples are the certificate values that are reported on the certificate of analysis sheet provided with the samples. The ELPAT certified values represent an average concentration determined by more than 100 accredited laboratories that participated in previous rounds of ELPAT testing. The UC estimated value is the concentration reported by UC for individual samples, calculated by the amount of NIST-traceable material loaded on the dust wipes. The accuracy and precision of the UC value was assessed by an independent laboratory analyzing randomly selected QC samples. An EPA laboratory in Region 1 analyzed 10% of the total number of samples prepared by UC at each of

the three concentration levels and confirmed that the process used to prepare the samples met the pre-determined data quality objective of accuracy within a ± 10% interval of the estimated value.

Accuracy of the field technology measurements was statistically tested using t-tests or non-parametric tests at the 5% significance level. These statistical tests compared the average results with the overall estimated values using the precision of the sample measurements. Bias was quantified by computing the percent recovery for four similar samples or a single sample using the equation:

$$\textit{percent recovery} = [\textit{measured amount(s)/estimated value}] \times 100\% \quad \text{(Eq. 2)}$$

Accuracy was assessed using both the ELPAT and UC estimated concentrations. The comparison to the ELPAT value represents how close the technology reported results to the consensus value, which represents the amount of "recoverable" lead in the sample. Because the UC samples were prepared gravimetrically from samples of known lead content, the comparison to the UC samples represents how close the technology reported results to an absolute lead value. Comparison to the gravimetric values reveals any bias imposed by the tested sampling and analytical method.

The optimum percent recovery value is 100%. Percent recovery values greater than 125% indicate results that are biased high, and values less than 75% indicate results that are biased low. A small but statistically significant bias may be detectable for a field technology if precision is high (i.e., low standard deviation). The field technology can still have acceptable bias with an average percent recovery in the interval of 75% to 125%. Bias within the acceptable range can usually be corrected to 100% by modification of calibration methods.

Comparability

Comparability refers to how well the field technology and conventional laboratory data agree. The difference between accuracy and comparability is that accuracy is judged relative to a known value, comparability is judged relative to the results of a laboratory procedure, which may or may not report the results accurately. Because true "replicates" were not available for use in this study, the averages from similar samples measured by the technology were compared with corresponding averages measured by the laboratory for all target concentration levels. A correlation coefficient quantifies the linear relationship between two measurements (Draper and Smith, 1981). The correlation coefficient is denoted by the letter r; its value ranges from –1 to +1, where 0 indicates the absence of any linear relationship. The value r = –1 indicates a perfect negative linear relation (one measurement decreases as the second measurement increases); the value r = +1 indicates a perfect positive linear relation (one measurement increases as the second measurement increases). Acceptable r values are 0.990 or greater. The slope of the linear regression line, denoted by the letter m, is related to r. Whereas r represents the linear association between the vendor and laboratory concentrations, m quantifies the amount of change in the vendor's measurements relative to the laboratory's measurements. A value of +1 for the slope indicates perfect agreement. Values greater than 1 indicate that the vendor results are generally higher than the laboratory, while values less than 1 indicate that the vendor results are usually lower than the laboratory.

Detectable Blanks

Twenty samples in the test were prepared at < 2 µg/wipe, below the anticipated reporting limits of both the field technologies and the laboratory. Any reported lead for these samples is considered a "detectable blank". Performance was also assessed at concentrations near the reporting limits of the technology.

False Positive/Negative Results

A false positive (fp) result is one in which the technology detects lead in the sample above a clearance level when the sample actually contains lead below the clearance level (Keith et al., 1996). A false negative (fn) result is one in which the technology indicates that lead concentrations are less than the clearance level when the sample actually contains lead above the clearance level. For example, if the technology reports the sample concentration to be 35 µg/wipe, and the true concentration of the sample is 45 µg/wipe, the technology's result would be considered a fn at the 40 µg/wipe clearance level. Accordingly, if the technology reports the result as 45 µg/wipe and the true concentration is 35 µg/wipe, the technology's result would be a fp at the 40 µg/wipe clearance level.

A primary objective for this verification test was to assess the performance of the technology at each of the three clearance levels of 40, 250, and 400 µg/wipe, and estimate the probability of the field technology reporting a fp or fn result. For each clearance level, the probabilities of fn were estimated as curves that depend on a range of concentrations reported about the clearance level. These error probability curves were calculated from the results on the 60 UC samples at concentrations ± 10% of each clearance level. In order to generate probability curves to model the likelihood of false negative results, it was assumed that the estimated concentration provided by UC was the true concentration. However, this evaluation did not include the gravimetric preparation uncertainty in the UC estimated concentration. This error is likely to be much smaller than other sources of measurement error (e.g., extraction efficiency and analytical).

The fp/fn evaluation also included a comparison to the ELPAT sample results. The "estimated" value for the UC and ELPAT samples are defined differently. The UC value is based on weight of the NIST-traceable material, while the ELPAT estimated value is the average analytical reported value from more than 100 accredited laboratories. The UC sample estimated lead content is determined gravimetrically, which should be closer to the "true" concentration than an analytical measurement that includes preparation and instrumental errors. In contrast, determining the technology's fp/fn error rates relative to the ELPAT estimated concentrations represents a comparison to typical laboratory values. One limitation of using the ELPAT sample is that concentrations covered a wider overall distribution of lead levels. Thus, the availability of sample concentrations that were tightly (i.e., +/- 10%) clustered about the clearance levels was limited. In order to perform a broader fp/fn analysis, the range of lead levels in the ELPAT samples that bracketed the pertinent clearance levels was extended to ± 25% of the target concentration.

Completeness

Completeness is defined as the percentage of measurements that are judged to be usable (i.e., the result is not rejected). An acceptable completeness rate is 95% or greater.

Sample Throughput

Sample throughput is a measure of the number of samples that can be processed and reported by a technology in a given period of time. Sample throughput is reported in Section 5 as number of samples per day per number of analysts.

Ease of Use

A significant decision factor in purchasing an instrument is how easy the technology is to use. Several factors are evaluated and reported on in Section 5:

- What is the required operator skill level (e.g., technician or advanced degree)?
- How many operators were used during the test?
- Could the technology be run by a single person?
- How much training would be required in order to run this technology?
- How much subjective decision-making is required?

Cost

An important factor in the consideration of whether to purchase a technology is cost. Costs involved with operating the technology and a typical laboratory analyses are estimated in Section 5. To account for the variability in cost data and assumptions, the economic analysis is presented as a list of cost elements and a range of costs for sample analysis. Several factors affect the cost of analysis. Where possible, these factors are addressed so that decision makers can independently complete a site-specific economic analysis to suit their needs.

Miscellaneous Factors

Any other information that might be useful to a person who is considering purchasing the technology is documented in Section 5 under "Observations". Examples of information that might be useful to a prospective purchaser are the amount of hazardous waste generated during the analyses, the ruggedness of the technology, the amount of electrical or battery power necessary to operate the technology, and aspects of the technology or method that make it user-friendly or user-unfriendly.

Section 4 — Laboratory Analyses

Background

EPA regulations (40 CFR Part 745.227(e)(8)(vii)) specify that residences and child occupied facilities built before 1978 that have undergone an abatement must pass clearance testing (CFR 2001). These EPA regulations also state in 40 CFR Part 745.227(f)(2) that dust samples for clearance must be analyzed by a laboratory recognized by EPA (CFR 2001). Many EPA-authorized state and tribal lead programs have the same or similar requirements. EPA's vehicle for recognizing laboratory proficiency is the National Lead Laboratory Accreditation Program (NLLAP). Although the NLLAP was initially designed to accredit fixed site laboratories, in August 1996 the NLLAP was modified so that mobile laboratory facilities and testing firms operating portable testing technologies could also apply for accreditation. Despite this modification, the NLLAP list of accredited laboratories has almost exclusively consisted of fixed site laboratories. One possible outcome of this ETV test is that more mobile laboratory facilities and testing firms operating portable testing technologies will apply for NLLAP accreditation. In order to assess whether the field portable technologies participating in this verification test produce results that are comparable to NLLAP-recognized data, an NLLAP-recognized laboratory was selected to analyze samples concurrently with the field testing.

NLLAP Laboratory Selection

NLLAP was established by the EPA Office of Pollution Prevention and Toxics under the legislative directive of Title X, the Lead-Based Paint Hazard Reduction Act of 1992. In order for laboratories to be recognized under the NLLAP, they must successfully participate in the ELPAT Program and undergo a systems audit. The acceptable range for the ELPAT test samples is based upon the reported values from participating laboratories. Acceptable results are within three standard deviations from the consensus value. A laboratory's performance is rated as proficient if either of the following criteria are met: (1) in the last two rounds, all samples are analyzed and the results are 100% acceptable; or (2) three-fourths (75%) or more of the accumulated results over four rounds are acceptable.

The NLLAP required systems audit must include an on-site evaluation by a private or public laboratory accreditation organization recognized by NLLAP. Some of the areas evaluated in the systems audit include laboratory personnel qualifications and training, analytical instrumentation, analytical methods, quality assurance procedures, and record keeping procedures.

The list of recognized laboratories is updated monthly. ORNL obtained the list of accredited laboratories in July 2001. The list consisted of approximately130 laboratories. Those laboratories which did not accept commercial samples and those located on the U.S. west coast were automatically eliminated as potential candidates. ORNL interviewed at random approximately ten laboratories and solicited information regarding cost, typical turnaround time, and data packaging. Based on these interviews and discussions with technical panel members who had personal experience with the potential laboratories, ORNL selected DataChem (Cincinnati, OH) as the fixed-site laboratory. As a final qualifying step, DataChem blindly analyzed 16 samples (8 ELPAT and 8 prepared by UC) in a pre-test study. As shown in Table 1 below, DataChem passed the pre-test by reporting concentrations that were within 25% of the estimated concentration for samples above the reporting limit.

Laboratory Method

The laboratory method used by DataChem was hot plate/nitric acid digestion, followed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) analysis. The preparation and analytical procedures, as supplied by DataChem, can be found in the test plan (ORNL, 2001). To summarize the procedure, the wipe was digested in 2 mL of nitric acid, heated in a hotblock for 1 hour at 95 °C, diluted to 20 mL with distilled water, and analyzed by ICP-AES. DataChem's procedures are modifications of Methods 3050B and 6010B of EPA SW-846 Method Compendium for the preparation and analysis of metals in environmental matrices (EPA, 1996). Other specific references for the preparation and analysis of dust wipes are available from the American Society for Testing and Materials (ASTM, 1998).

Table 1. Summary of DataChem Pre-Test Results

Sample Type	DataChem Reported Conc (µg/wipe)	Estimated Conc (µg/wipe)	Percent Recovery	Analysis Order
ELPAT	<20	2.12	n/a	16
ELPAT	<20	2.12	n/a	12
ELPAT	41	41.3	99%	6
ELPAT	44	41.3	107%	3
ELPAT	190	201.6	94%	15
ELPAT	210	201.6	104%	9
ELPAT	440	408.7	108%	2
ELPAT	450	408.7	110%	13
UC	<20	10.3	n/a	4
UC	<20	5.9	n/a	1
UC	25	29.9	84%	14
UC	38	44	86%	10
UC	150	172.4	87%	11
UC	200	237.5	84%	7
UC	250	327.3	76%	5
UC	310	379	82%	8

Laboratory Performance

ORNL validated all of the laboratory data according to the procedure described in the verification test plan (ORNL, 2001). During the validation, the following aspects of the data were reviewed: completeness of the data package, correctness of the data, correlation between "replicate" sample results, and evaluation of QC sample results. Each of these categories is described in detail in the verification test plan. An evaluation of the performance of the laboratory results through statistical analysis of the data was performed and is summarized below. (See Section 3 for a detailed description of how the performance factors are defined and the calculations that are involved.)

In Table 2, DataChem's reported values are compared to the estimated values to determine percent recovery (i.e., accuracy of the DataChem results) for both the ELPAT and the UC samples. The results are also shown graphically in Figure 3. The average percent recovery for the ELPAT samples was 98%, while the average for the UC samples was 88%. Both Table 2 and Figure 3 indicate that the analytical results from the University of Cincinnati wipe samples were generally reported lower than the estimated value, while the results for the ELPAT samples were closer to the estimated value. The better agreement with the ELPAT samples is not unexpected, given that the ELPAT estimated concentrations represent analytical consensus values that include typical extraction inefficiencies and instrumental error. The negative bias observed with the UC and the ELPAT samples was statistically significant. The cause of the negative bias for the UC samples could be related to: 1) extraction inefficiencies (due to the use of NIST SRMs that contain lead that is unrecoverable with the extraction procedure which was used) and/or, 2) typical analytical variation due to preparation and measurement errors. Another indication of accuracy is the number of individual ELPAT results which were reported within the acceptance ranges that have been established for those samples. For the 72 ELPAT samples (> 20 µg/wipe), DataChem reported 71 (99%) within the acceptable ranges of values.

The precision assessment presented in Table 3 indicates that the analyses were very precise. The average RSD for the ELPAT samples was 7%, while the average RSD for the UC samples was 8%. The variability of the UC sample preparation process, provided for reference of the minimal achievable RSD for the UC samples, was 6%. A single estimate of the ELPAT variability was not determined, since the ELPAT samples were comprised of 20 different batches of samples. DataChem reported all 20 detectable blank samples correctly as < 20 µg/wipe. In addition, DataChem reported seven of the eight samples with estimated concentrations of either 16.9 µg/wipe or 17.6 µg/wipe as less than their reporting limit of 20 µg/wipe and only one was incorrectly reported as 30 µg/wipe.

Table 2. Summary of DataChem percent recovery values by sample source

Statistic	ELPAT	UC
n [a]	72	60
average % recovery	98	88
std dev	9	5
minimum % recovery	81	74
maximum % recovery	143	96

[a] excludes estimated values <20 µg/wipe(n=28)

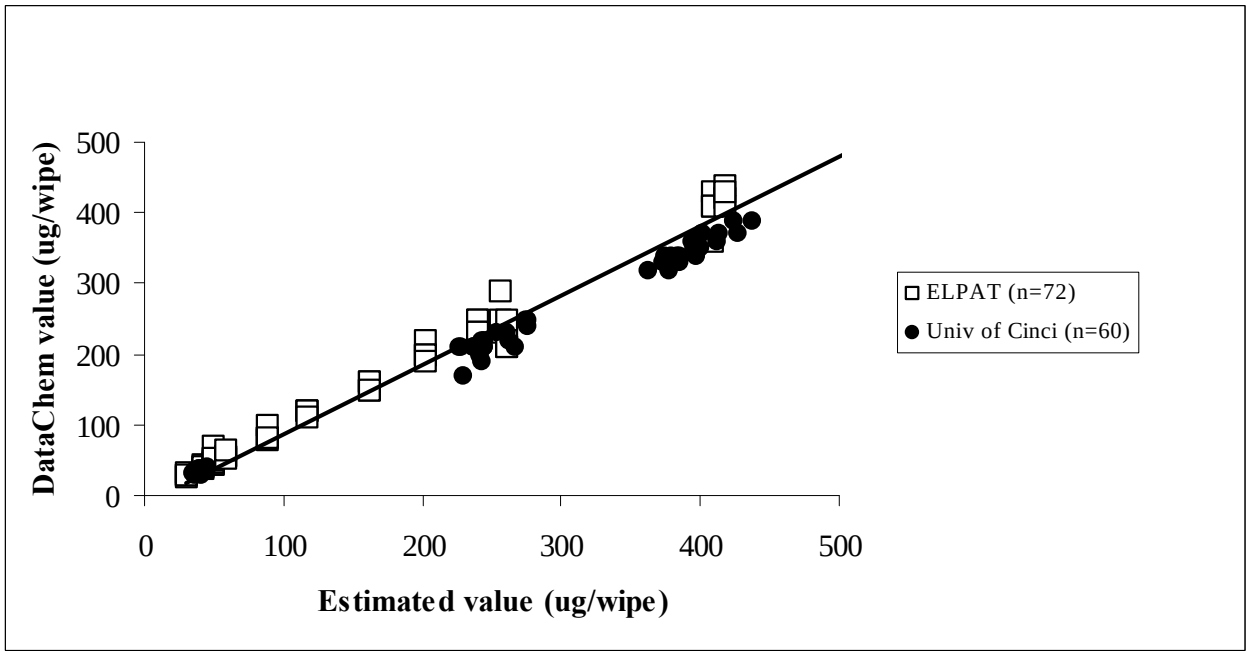

Figure 3. Plot of DataChem reported values versus estimated values, shown for concentrations < 500 µg/wipe.

Table 3. Summary of DataChem precision estimates by sample source

Sample Source	Number of sample sets	average RSD	Min RSD	Max RSD
ELPAT	18 [a]	7	2	21
UC	3 [b]	8	6	9
UC preparation [a]	3 [c]	6	5	7

[a] 4 replicates in each sample set
[b] 20 replicates in each sample set
[c] The value represents the variability in the sample preparation process.

An important evaluation parameter for the analysis of dust wipe samples is how the method performs at the clearance levels and the method's likelihood of reporting false positive (fp) and false negative (fn) results. Recall from the experimental design that 20 UC samples were prepared at ± 10% of each clearance level of 40, 250, and 400 µg/wipe, for a total of 60 UC samples. The ELPAT samples covered a wider range of concentrations. There was a total of 40 ELPAT samples that fell within a ±25% interval of the target values that could be used for the fp/fn assessment. The number of false negative and false positive results reported by DataChem relative to the UC and ELPAT estimated concentrations is summarized in Table 4. There are a specific number of possible fp and fn results. For example, if the estimated lead level on the wipe is less than the clearance level (CL), then it is not possible to produce a false negative result; only a false positive (i.e., > 40) result is possible. For the UC samples, in every case where the estimated concentration was less than the CL, DataChem reported a result for that was also less than the CL, indicating no fp results at any of the three CL. DataChem reported two fp results for the ELPAT samples out of a possible 12.

When the estimated concentration was above the clearance level, however, DataChem sometimes reported results as less than the clearance level. DataChem reported a higher rate of fn results for the UC samples than the ELPAT samples (16 of 19 vs 7 of 28 possible fn results, respectively). This finding is not surprising, since the results reported above indicated that DataChem's results were negatively biased, or reported lower than the estimated values for the UC samples. As stated in Section 3, it is important to note that in this evaluation, the estimated concentration of the UC samples is assumed to be the "true"concentration, and the uncertainty in gravimetric preparation for the UC estimated concentration is not considered in the evaluation.

Figures 4, 5, and 6 show models of the likelihood of DataChem reporting a false negative result at each of the clearance levels versus the true concentrations of the UC samples. (Note that only the UC samples must be used in generation of probability curves because these estimated values are a closer representation of the true lead concentration than the ELPAT estimated concentration. See Song et al., 2001.) These figures indicate that the likelihood of DataChem reporting false negative results for the UC samples at the exact clearance level is high, near 100% in all three cases. This means, for example, that if DataChem reported a value as exactly 250 µg/wipe, the probability that the true concentration is >250 is essentially 100%. Again, this is due to the negative bias that was observed in the measurement of the UC samples. The plots also demonstrate that, due to the relatively high level of precision of results reported by DataChem, the performance is very minimally impacted by performing replicate analyses, as the distribution of false negative probabilities is very similar whether 1 or 5 measurements (in Figures 4, 5, and 6, delineated as N = 1, N = 2, etc.) are performed. The interpretation of these curves for use in a "real-world" situation can be demonstrated by the following example. Suppose that a user decides that an acceptable level of risk for having false negative results is 5%. Using Figure 4, 5% FN probability (y = 0.05) corresponds to a "true" lead concentration of 54 µg/wipe (meaning if the true concentration of the sample is 54 µg/wipe, there is only a 5% chance/risk that DataChem will report the value as < 40 µg/wipe.)

By plotting DataChem's measured values versus the estimated concentrations, the equations of the linear regression lines can be calculated for each of the three CL. The slope, intercept, and correlation coefficient for the ELPAT and UC samples are presented in Table 5. The user might like to know at what reported value (and at what associated probability) will DataChem be likely to report a "clean" sample (i.e., there is a high probability that the true concentration is < CL). For example, for the UC samples, we know that a value reported by DataChem as 39 µg/wipe is biased low and will have a true concentration of > 40 (44.7 µg/wipe, using the linear regression equation in Table 5). A true concentration of 40 µg/wipe for a UC sample would correspond to a reported value rounded to the nearest whole number of 35 µg/wipe (see Table 5). For an ELPAT sample, a true concentration of 40 µg/wipe corresponds to a DataChem reported value of 40 µg/wipe, because the negative bias was not as large for the ELPAT samples. Estimates of the reported concentration at the 250 and 400 µg/wipe levels are reported in Table 5. In both cases, the reported concentrations for the ELPAT samples are higher (i.e., closer to the clearance level) than those of the UC samples. (Recall that the ELPAT estimated values are consensus values of more than

100 analytical measurements, while the UC estimated values are weighed values, so this finding is not surprising.)

The user is reminded that the data obtained during this verification test represent performance at one point in time. The data produced by DataChem at some other time after the writing of this report may or may not be similar to what has been produced here. To understand a method's performance at critical clearance levels, it is recommended that the user perform their own assessment of the method's performance by including samples of known concentration (at or near the clearance levels) along with the analysis of "real-world" samples.

Table 4. False Positive/False Negative Error Rates for DataChem Measurements

Evaluation Parameter	Sample Source	Number of Samples			
		40 µg/wipe	250 µg/wipe	400 µg/wipe	Total
fp: # samples where DataChem reported the result as > CL[a] of the # samples where the estimated concentration was < CL	UC	0 of 15	0 of 12	0 of 14	0 of 41
	ELPAT	0 of 4	2 of 8	0 of 0 [b]	2 of 12
fn: # samples where DataChem reported the result as < CL of the # samples where the estimated concentration was > CL	UC	4 of 5	6 of 8	6 of 6	16 of 19
	ELPAT	1 of 12	5 of 8	1 of 8	7 of 28

[a] CL = clearance level

[b] Because all eight ELPAT values were above 400 µg/wipe, no samples were available to assess fp results at this level.

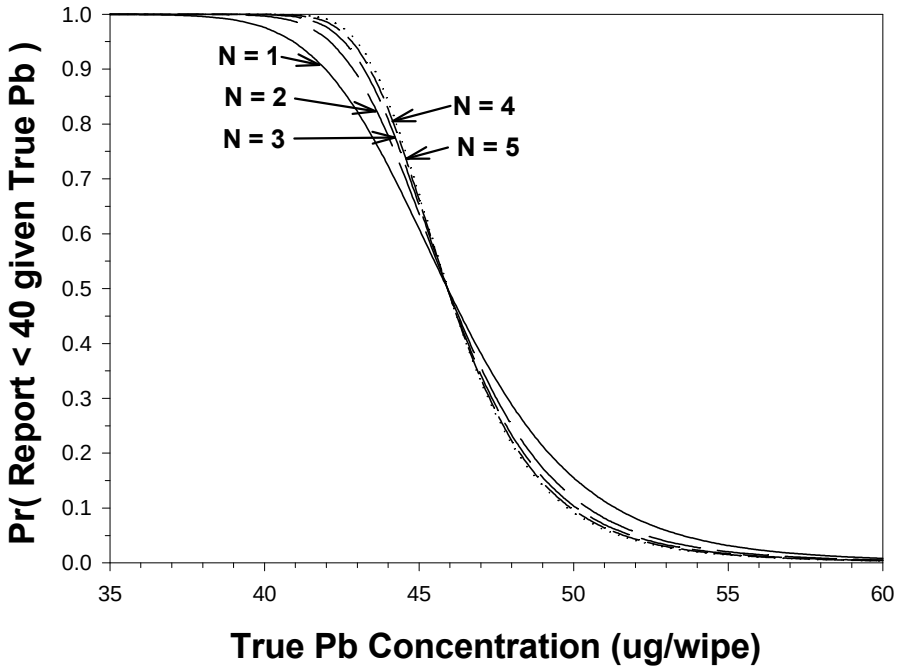

Figure 4. False negative probabilities for DataChem reporting average concentrations at a target concentration level of 40 µg/wipe.

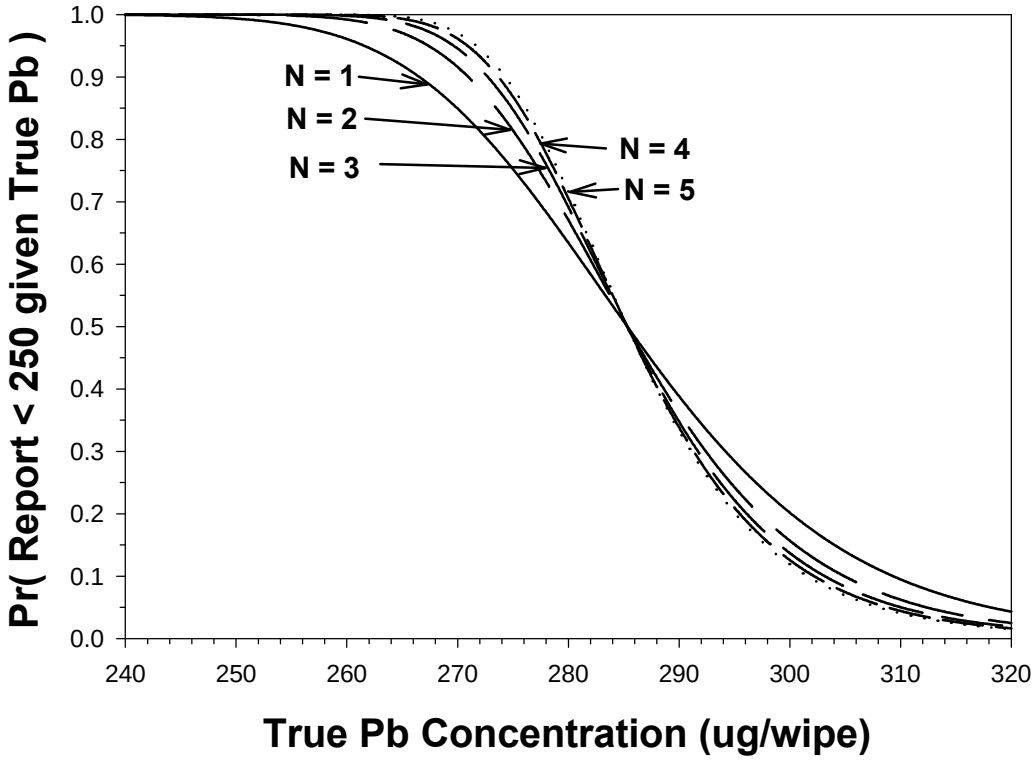

Figure 5. False negative probabilities for DataChem reporting average concentrations at a target concentration level of 250 μg/wipe.

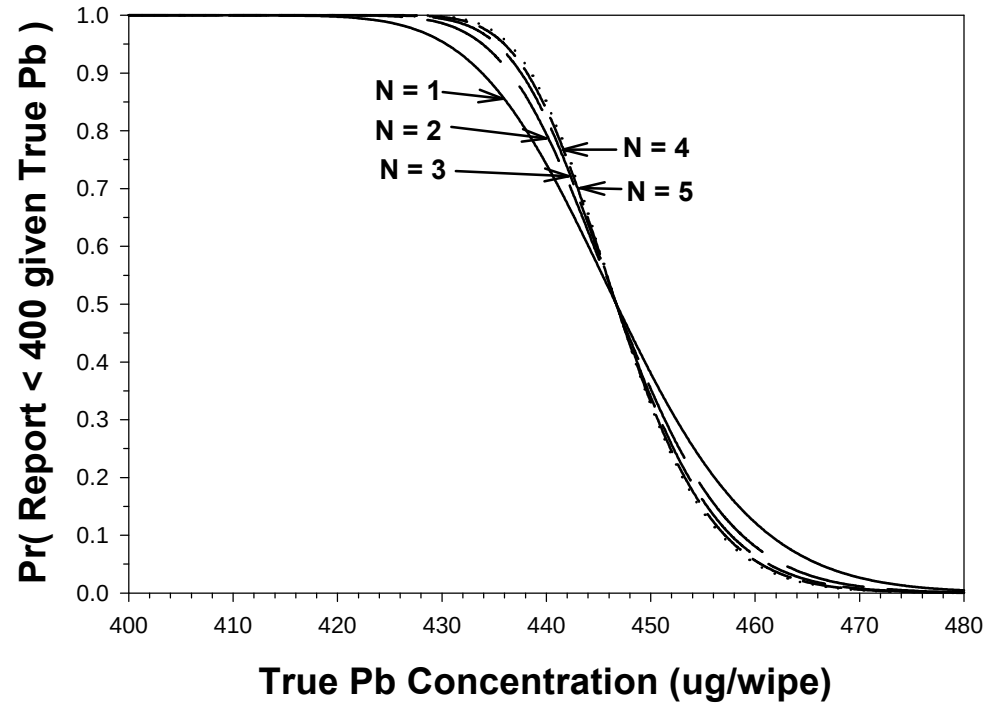

Figure 6. False negative probabilities for DataChem reporting average concentrations at a target concentration level of 400 μg/wipe.

Table 5. Summary of the Linear Regression Constants and Recovery Data for DataChem's Measurements Versus the Estimated Concentrations at the Clearance Levels

Evaluation Parameter	40 µg/wipe		250 µg/wipe		400 µg/wipe	
	UC	ELPAT	UC	ELPAT	UC	ELPAT
n	20	16	20	16	20	8
slope	0.787	1.612	0.912	0.578	0.956	2.394
intercept	3.844	-6.182	-10.169	90.826	-26.826	-575.771
correlation coefficient	0.705	0.840	0.759	0.549	0.916	0.492
average % recovery	89%	101%	87%	96%	89%	100%
SD of % recovery	6%	13%	5%	9%	2%	5%
Reported concentration at the CL	35 µg/wipe	40 µg/wipe	218 µg/wipe	234 µg/wipe	355 µg/wipe	382 µg/wipe

Section 5 — Technology Evaluation

Objective and Approach

The purpose of this section is to present a statistical evaluation of the SA-5000 data and determine the technology's ability to measure lead in dust wipe samples. This section includes an evaluation of comparability to NLLAP-recognized laboratory data. Other aspects of the technology (such as accuracy, precision, cost, sample throughput, hazardous waste generation, and logistical operation) are also evaluated in this section. The Appendix contains the raw data provided by the vendor during the verification test that were used to assess the performance of the SA-5000.

Precision

Precision is the reproducibility of measurements under a given set of conditions. Precision was determined by examining the results of blind analyses for replicate samples with estimated concentrations greater than the SA-5000's reporting limits (25 µg/wipe). For the ELPAT samples, precision was measured on each set of four samples from a particular round of ELPAT archives. For the 18 sets of samples, the SA-5000's average RSD value was 5%, with a range from 2 to 8%, indicating that the SA-5000 measurements of the ELPAT samples were very precise (see Table 6). For the UC samples, 20 samples were analyzed at each of three target concentration levels of 40, 250, and 400 µg/wipe. The average precision of the UC sample measurements by the SA-5000 was 8% RSD. With the expectation that UC was to prepare the samples as close to the target concentrations as possible, the allowable variability was 10% RSD. The actual variability of the UC preparation process was an average of 6% RSD.

Accuracy

Accuracy represents the closeness of the SA-5000's measured concentrations to the estimated content of spiked samples. One measure of accuracy is the number of results for the ELPAT samples that were reported within the acceptance ranges that have been established for those samples. The SA-5000 reported the results for all 72 ELPAT samples (> 25 µg/wipe) within the acceptance ranges. The results reported by the SA-5000 can also be compared to the ELPAT certificate value, i.e., the average concentration reported by 100+ laboratories who participated in previous rounds of ELPAT testing. The average percent recovery of 91% reported by the SA-5000 for the 72 ELPAT samples indicates a statistically significant negative bias, but such is well within the acceptable bias limits of 100 ± 25% (Table 7). The recovery values range from 74 to 107%. The results for the UC samples were also biased low, with an average percent recovery of 80%, and a range of values from 65 to 95%. When comparing these results to those of the NLLAP laboratory that was presented in Table 2, a similar trend is observed, in that the UC sample results were, on average, biased 10% lower than the ELPAT results. The possible explanations for this difference in performance include: 1) that ELPAT "estimated" values are in fact consensus values from a large number of laboratories that may be similar in performance to DataChem and to the SA-5000; and 2) the reference material used to prepare the UC samples may be more challenging than the ELPAT reference material.

Table 6. Precision of the SA-5000 Analyzer

Source	No. of sample sets	RSD, %		
		Average	Min	Max
ELPAT	18 [a]	5	2	8
UC	3 [b]	8	8	9
UC prep [c]	3	6	5	7

[a] 4 replicates in each sample set
[b] 20 replicates in each sample set
[c] precision of UC sample preparation process

Table 7. Accuracy of SA-5000 Analyzer

Statistic	% recovery	
	ELPAT	UC
n [a]	72	60
average % recovery	91	80
standard deviation	8	7
minimum % recovery	74	65
maximum % recovery	107	95

[a] Excludes estimated values < 25 µg/wipe

Another way to assess accuracy is to plot the results obtained from the SA-5000 versus the estimated values that are > 25 μg/wipe. The linear regression constants for the plot of the ELPAT and UC data are listed in Table 8. As expected, the conclusions produced from this assessment are similar to the above conclusions regarding the percent recovery calculations. The UC samples were generally reported lower than the ELPAT samples relative to the estimated concentrations, but overall the sample results had an acceptable amount of bias.

Comparability

Comparability refers to how well the SA-5000 and the NLLAP-recognized laboratory data agreed. In this evaluation, the laboratory results are not presumed to be the "correct" answers. Rather, these results represent what a typical fixed laboratory would report for these types of samples. A direct comparison of the SA-5000 results and the laboratory results was performed for all ELPAT (> 25 μg/wipe) and UC samples. Because each wipe was prepared individually, a true one-to-one matching of SA-5000 and laboratory results could not be performed. However, the average concentrations of the samples prepared at specific levels was compared for the SA-5000 and laboratory results. In Table 8, the regression constants for the average SA-5000 results versus the average DataChem results for both the ELPAT and UC values are presented. The difference between the regression slopes (m = 0.926 for ELPAT and m = 0.839 for UC) and a slope with a perfect agreement line (m = 1.000) is statistically significant, but the correlation coefficients (r = 0.990 for ELPAT and r = 1.000 for UC) show a strong linear relationship between DataChem and SA-5000 results. To illustrate the strong linear agreement between the SA-5000 and NLLAP laboratory results, Figure 7 is a plot of the average SA-5000 results versus the average DataChem results for both ELPAT and UC data. For clarity, only those values < 500 μg/wipe are shown.

Detectable Blanks

Of the samples that were prepared at < 2 μg/wipe, the SA-5000 correctly reported all 20 as < 25 μg/wipe, so no detectable blanks were reported. Performance was also assessed at concentrations near the reporting limit of 25 μg/wipe. Two sets of four ELPAT samples with estimated concentrations of 16.9 and 17.6 μg/wipe were all reported by the SA-5000 as < 25 μg/wipe. For the set of four ELPAT samples at 29.8 μg/wipe, the SA-5000 reported results between 28 and 32 μg/wipe.

Table 8. Linear regression constants for the plots of the SA-5000 versus the estimated values and versus the DataChem average measurements

Statistic	versus estimated values		versus DataChem average concentrations	
	UC	ELPAT	UC	ELPAT
n	60	72	3	18
slope (standard error)	0.754 (0.010)	0.916 (0.011)	0.839 (0.001)	0.926 (0.023)
intercept (standard error)	3.466 (2.773)	3.757 (5.151)	5.539 (0.224)	6.506 (10.860)
r	0.995	0.995	1.000	0.995

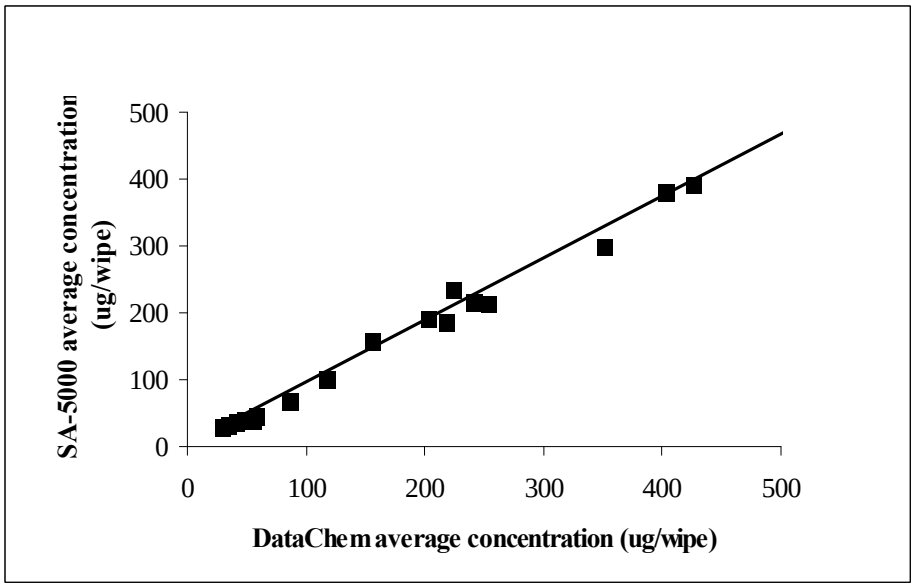

Figure 7. Plot of the SA-5000 average concentration versus the DataChem average concentration for all samples (n=21), shown for concentrations < 500 µg/wipe.

False Positive/False Negative Results

Similar to the evaluation described and presented in Section 4 for DataChem, the number of false negative and false positive results reported by the SA-5000 relative to the estimated concentrations of both ELPAT and UC samples is summarized in Table 9. For every case where the estimated concentration was less than the clearance level (CL), the SA-5000 reported a result that was also less than the CL, indicating no fp results at any of the three CL for both ELPAT and UC samples. When the estimated concentration was greater than the clearance level, however, the SA-5000 reported many of the results as less than the clearance level. The SA-5000 had more false negative errors relative to the UC estimated concentrations (22 of 22 possible fn results) than when compared to the ELPAT estimated concentrations (17 of 28 possible fn results). This finding is not surprising, since the accuracy results reported above indicated that the SA-5000 results were more negatively biased for the UC samples.

In Figures 8, 9, and 10, the false negative probabilities at the three clearance levels are compared for the DataChem and SA-5000 results for the UC samples only (see previous discussion on false negatives in Section 4). In these figures, the two-sided 90% confidence intervals (not shown for clarity) are used to express uncertainty on the false negative curves. These confidence intervals overlap for the SA-5000 and DataChem at the 40 µg/wipe and the 250 µg/wipe clearance levels over the range of true lead concentrations shown in the Figures 8 and 9. The overlapping confidence intervals indicate the two methods are comparable when considering their uncertainty. In Figure 10, the 90% confidence intervals for the two methods only overlap for part of the true lead concentration range (425 to 472 µg/wipe). This result indicates that the SA-5000 appears to be more prone to false negatives at the 400 µg/wipe clearance level, when considering the uncertainty of the two methods.

Table 10 contains the linear regression constants for SA-5000 measured concentration versus estimated concentration for the three CLs, average percent recovery values and standard deviations, and an estimate of the reported SA-5000 concentration at the clearance levels for both the ELPAT and UC samples. The UC samples average recoveries indicate that the SA-5000 results were more negatively biased for the 250 and 400 µg/wipe levels than for the 40 µg/wipe level. This is also apparent in the estimated concentration that a user might require from the SA-5000 in order to be reasonably confident that the true result is below the clearance level. For the UC samples, both DataChem and the SA-5000 results reported as 35 µg/wipe correspond to a true concentration of 40 µg/wipe, but the reported values at the CLs for the 250 and 400 µg/wipe clearance levels are lower for

the SA-5000 (189 and 308 µg/wipe) than for DataChem (218 and 355 µg/wipe). The SA-5000 ELPAT sample results were negatively biased relative to the estimated concentrations, but not as low as the UC samples, so the estimates of a reported concentration at the CL are slightly higher for the ELPAT samples. Regardless of analytical technique, there is some uncertainty in assessing false positive and false negative error rates around critical action levels due to "normal" levels of variability (Song et al., 2001). Analytical values falling near the level of interest should be interpreted with care for both fixed-laboratory and field-based analytical methods.

Table 9. False Positive/False Negative Error Rates for SA-5000 Measurements

Evaluation Parameter	Sample Source	Number of Samples			
		40 µg/wipe	250 µg/wipe	400 µg/wipe	Total
fp: # samples where SA-5000 reported the result as > CL[a] of the # samples where the estimated concentration was < CL	UC	0 of 14	0 of 11	0 of 13	0 of 38
	ELPAT	0 of 4	0 of 8	0 of 0 [b]	0 of 12
fn: # samples where SA-5000 reported the result as < CL of the # samples where the estimated concentration was > CL	UC	6 of 6	9 of 9	7 of 7	22 of 22
	ELPAT	4 of 12	8 of 8	5 of 8	17 of 28

[a] CL = clearance level

[b] Because all eight ELPAT values were above 400 µg/wipe, no samples were available to assess fp results at this level.

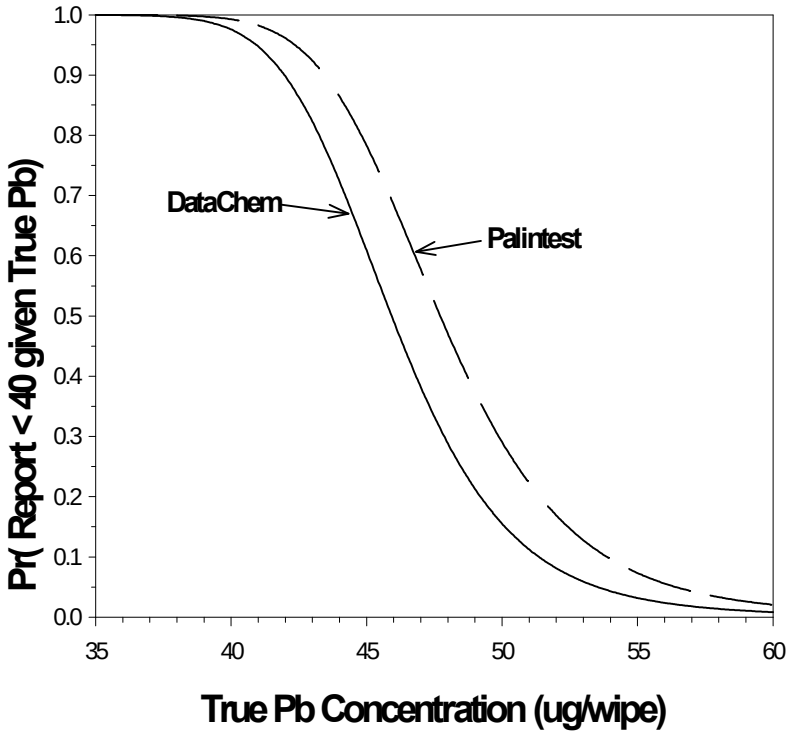

Figure 8. Comparison of the false negative probabilities for the SA-5000 and DataChem at a target concentration level of 40 µg/wipe.

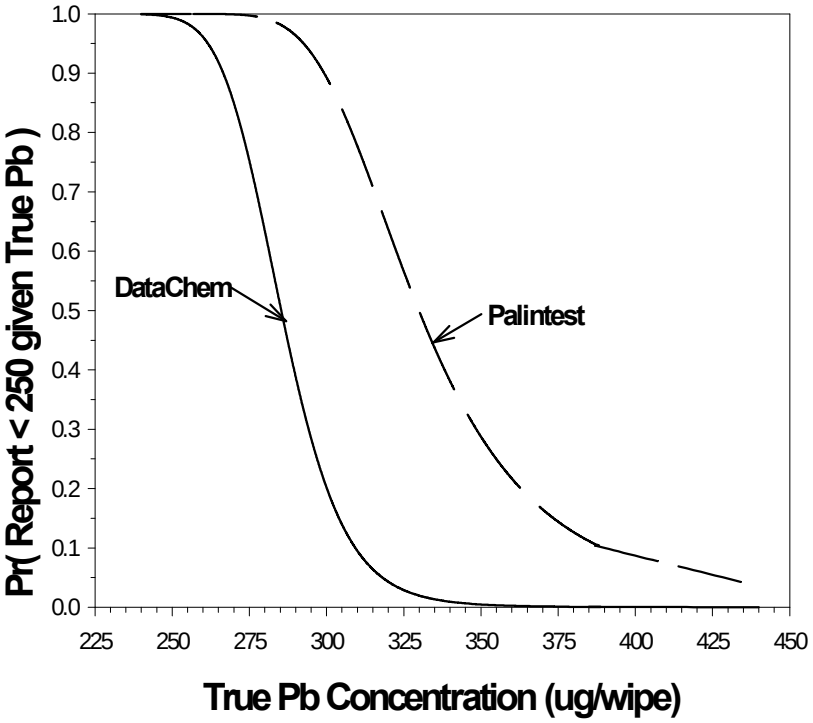

Figure 9. Comparison of the false negative probabilities for the SA-5000 and DataChem at a target concentration level of 250 µg/wipe.

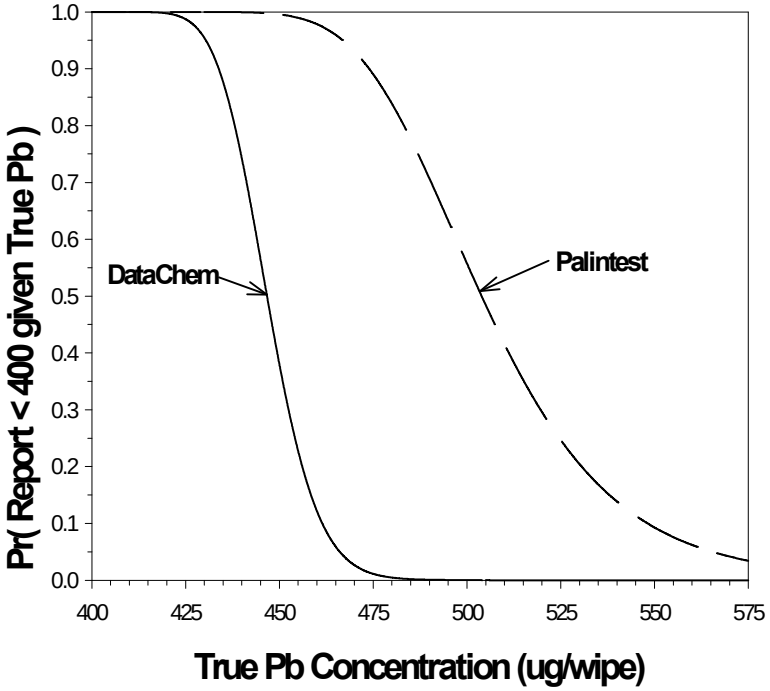

Figure 10. Comparison of the false negative probabilities for the SA-5000 and DataChem at a target concentration of 400 µg/wipe.

Table 10. Summary of the Linear Regression and Recovery Data for the SA-5000 Response versus the Estimated Concentrations

Evaluation Parameter	40 µg/wipe		250 µg/wipe		400 µg/wipe	
	UC	ELPAT	UC	ELPAT	UC	ELPAT
n	20	16	20	16	20	8
slope	0.652	0.559	0.764	0.570	0.883	1.170
intercept	8.880	13.791	-1.898	78.537	-44.860	-95.766
correlation coefficient	0.694	0.904	0.616	0.697	0.780	0.323
average % recovery	88%	90%	76%	90%	77%	94%
SD of % recovery	5%	9%	5%	7%	4%	4%
Reported concentration at CL	35 µg/wipe	36 µg/wipe	189 µg/wipe	221 µg/wipe	308 µg/wipe	372 µg/wipe

Completeness

Completeness is defined as the percentage of measurements that are judged to be usable (i.e., the result was not rejected). Valid results were obtained by the technology for all 160 dust wipe samples. Therefore, completeness was 100%.

Sample Throughput

Sample throughput is representative of the estimated amount of time required to prepare and analyze the samples and perform the data analysis. Operating in the field, one Palintest analyst accomplished a sample throughput rate of approximately eighty samples per day. The analyst prepared and analyzed all 160 dust wipe samples in two 12-hour days, completing duplicate analysis on each sample and operating two instruments simultaneously.

Ease of Use

The technology can be operated by a single person. Users unfamiliar with the technology may need approximately one-half day of additional training to operate the instrument. No particular level of educational training is required for the operator. The analyst who operated the instrument during the verification test was a Palintest expert.

Cost Assessment

The purpose of this economic analysis is to estimate the range of costs for analysis of lead in dust wipe samples using the SA-5000 and a conventional analytical laboratory method. The analysis was based on the results and experience gained from this verification test, costs provided by Palintest, and representative costs provided by the NLLAP analytical laboratory to analyze the samples. To account for the variability in cost data and assumptions, the economic analysis is presented as a list of cost elements and a range of costs for sample analysis by the SA-5000 instrument and by the laboratory.

Several factors affected the cost of analysis. Where possible, these factors were addressed so that decision makers can complete a site-specific economic analysis to suit their needs. The following categories are considered in the estimate:

- sample shipment costs,
- labor costs, and
- equipment costs.

Each of these cost factors is defined and discussed and serves as the basis for the estimated cost ranges presented in Table 11. This analysis assumed that the individuals performing the analyses were fully trained to operate the technology. Costs for sample acquisition and pre-analytical sample preparation, tasks common to both methods, were not included in this assessment.

SA-5000 Costs

The costs associated with using the instrument included labor and equipment costs. No sample shipment charges were associated with the cost of operating the instrument because the samples were analyzed on site.

Table 11. Estimated analytical costs for lead dust wipe samples

Analysis method: SA-5000 **Analyst/manufacturer:** Palintest **Sample throughput:** 80 samples/day		**Analysis method:** EPA SW846 6010b **NLLAP Laboratory:** DataChem **Actual turnaround:** 18 working days	
Cost category	**Cost ($)**	**Cost category**	**Cost ($)**
Sample shipment	0	**Sample shipment**	
		Labor	100–200
		Overnight shipping	50–100
Labor		**Labor**	
Rate	50–100/h per analyst	Rate	30 per sample
Equipment		**Equipment**	Included [a]
Instrument purchase price	3850		
Reagents/supplies	7 per sample [b]		
Waste Disposal	250	**Waste Disposal**	Included

[a] "Included" indicates that the cost is included in the labor rate.

[b] Price per sample when purchased as one 10-test kit. Discounts are given for higher volume purchases.

Labor

Labor costs included on-site labor to perform the analyses. The cost of the on-site labor was estimated at a rate of $50–100/h, depending on the required expertise level of the analyst. This cost element included the labor involved during the entire analytical process, comprising sample preparation, sample management, analysis, and reporting. If the user would have to travel to the site, the cost of mobilization and demobilization, travel, and per diem expenses should also be considered. However, in a typical application where the SA-5000 might be used, the analysis would usually be carried out by a person located on site.

Equipment

Equipment costs included purchase of equipment and the reagents and other consumable supplies necessary to complete the analysis.

- *Instrument purchase*. The instrument can be purchased for $3,850. This includes the SA-5000 Scanning Analyzer, deluxe carrying case, 1-mL and 5-mL pipettors, and an ultrasonicator.
- *Reagents and supplies*. The dust sample preparation and electrode pack costs $72.45 for one pack of ten tests and contains: electrodes, SoluPrep SP-B tablets, crushing and stirring rods, and sonicator tubes. Discounts are given for larger volume purchases.

Laboratory Costs

Sample Shipment

The costs of shipping samples to the laboratory included overnight shipping charges as well as labor charges associated with the various organizations involved in the shipping process.

- *Labor*. This cost element included all of the tasks associated with shipping the samples to the NLLAP laboratory. Tasks included packing the shipping coolers, completing the chain-of-custody documentation, and completing the shipping forms. The estimate to complete this task ranged from 2 to 4 h, at $50 per hour.
- *Overnight shipping*. The overnight express shipping service cost was estimated to be $50 - 100 for two boxes of samples.

Labor, Equipment, and Waste Disposal

The labor quotes from commercial analytical laboratories that offered to perform the analyses for this verification test ranged from $20 to $30 per sample, with turnaround time estimates ranging from 7 to 14 days. Some laboratories can provide a 1-2 day turnaround, but the quick turnaround was not necessary for this test. The quotes were dependent on many factors, including the perceived difficulty of the sample matrix, the current workload of the laboratory, data packaging, and the competitiveness of the market. This rate was a fully loaded analytical cost that included equipment,

labor, waste disposal, and report preparation. The cost for DataChem to analyze samples for this verification test was $30 per sample, with a turnaround time of 18 working days.

Cost Assessment Summary

An overall cost estimate for use of the SA-5000 instrument versus use of the NLLAP- laboratory was not made because of the extent of variation in the different cost factors, as outlined in Table 11. The overall costs for the application of any technology would be based on the number of samples requiring analysis, the sample type, and the site location and characteristics. Decision-making factors, such as turnaround time for results, must also be weighed against the cost estimate to determine the value of the field technology's providing immediate answers versus the laboratory's provision of reporting data within 18 days of receipt of samples.

Miscellaneous Factors

The following are general observations regarding the field operation and performance of the SA-5000 instrument:

- The SA-5000 required no electrical power and worked continuously through a 12-hour workday without the need for recharging the battery.
- The Palintest analyst was ready for the first set of samples within 1 h of arriving on site. If the nitric acid is pre-prepared, and the equipment is packaged in a carrying case and brought to the test site, a typical set-up time is 15 min. The set-up took a little longer for the verification test because the equipment had to be unpacked from sealed boxes and the concentrated nitric acid had to be diluted.
- Tests with the SA-5000 generated a 5-gal bucket of vials containing dilute nitric acid waste, which cost approximately $250 to dispose by a commercial vendor. The actual volume of waste was approximately 2.1 gallons (8 L). The disposable electrodes have passed leaching tests for mercury and silver, so they were thrown away in the regular trash.
- The Palintest analyst analyzed all of the samples in duplicate (i.e., analyzed each sample with two different electrodes). The duplicate analysis was performed for Palintest's interests only, so the result reported was the first result of the duplicate measurements. Even though this added some time to the analysis, the analyst confirmed each of the results and still was able to analyze all 160 samples in a two working days because he operated two instruments.
- The shelf-life of the electrodes is approximately 18 months.
- Solu-Prep tablets are added to each vial prior to analysis. The main ingredient is potassium chloride. The tablet is colored red so the analyst can quickly know that the right pellet is being used.
- On the last day of testing, 15 potential users attending a nearby conference on lead-safe housing observed the technology in operation and completed a survey about its user friendliness. Most (n=10) thought the system was user-friendly and commented that the relatively low cost (<$4,000) was attractive when considering purchase options. Some of the participants (n=6) stated they would consider purchasing or using this instrument based on their observations and felt a new user could be trained in 2 to 4 hours. A few observers reported that the SA-5000 seemed like it should be operated in a laboratory rather than in a field setting because of the 45 min digestion period and the hazardous waste that is generated.

Summary of Performance

A summary of performance is presented in Table 12. Note that performance is based on the specific protocols employed for this verification test. If different testing protocols are used, different performance results may be obtained. The verification test found that the SA-5000 instrument was relatively simple for a trained analyst to operate in the field, requiring less than an hour for initial setup. The sample throughput of the SA-5000 was eighty samples per day with a single operator.

The overall performance of the SA-5000 for the analysis of lead in dust wipe samples was characterized as having an acceptable amount of negative bias, very precise, and has a strong linear relationship with the NLLAP-laboratory results.

ORNL and ETV remind the reader that, while the ETV test provides valuable information in the form of a snapshot of performance, state, tribal, or federal requirements regarding the use of the technologies (such as NLLAP recognition for analysis of clearance samples where required) need to be followed.

Table 12. Performance Summary for the Scanning Analyzer SA-5000 System

Feature/parameter		Performance summary			
		UC Samples		ELPAT Samples	
Precision : average RSD		8%		5%	
Accuracy: average % recovery		80%		91%	
Positive results on "detectable blank" samples (< 2 μg/wipe)		n/a		0 of 20 samples	
False positive results		DataChem 0 of 41	SA-5000 0 of 38	DataChem 2 of 12	SA-5000 0 of 12
False negative results		DataChem 16 of 19	SA-5000 22 of 22	DataChem 7 of 28	SA-5000 17 of 28
Comparison with NLLAP-recognized laboratory results (excluding < 25 μg/wipe samples)	slope	0.839		0.926	
	intercept	5.539		6.506	
	correlation coefficient	1.000		0.995	
Overall evaluation		- Statistically significant negative bias but within the acceptable bias range - Very Precise - Strong linear relationship to the NLLAP lab results - No fp results - Higher number of fn results		- Statistically significant negative bias but within the acceptable bias range - Very Precise - Strong linear relationship to the NLLAP lab results - No fp results - Higher number of fn results	
Completeness		100% of 160 dust wipe samples			
Size and Weight		6 3/4" x 5 1/8" x 2 1/8"; 13.3 oz			
Sample throughput (1 analyst)		80 samples/12-hr day			
Power requirements		battery operated (eight - AA)			
Training requirements		One-half day instrument-specific training			
Cost		Purchase: $3,850 Reagents/Supplies: $72.45 for one pack of 10 tests (discounts for larger volume purchases)			
Waste generated		5-gal bucket of vials of diluted nitric acid/extract dust wipes 2.1 gallons (8 L) for 160 samples analyzed			

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Appendix

Palintest's SA-5000 Results Compared with Laboratory Results

Sample Analysis Order	Source	Rep	Palintest SA-5000		DataChem	
			Result	Estimated	Result	Estimated
			µg/wipe	µg/wipe	µg/wipe	µg/wipe
138	ELPAT	1	<25	1.3	<20	1.3
133	ELPAT	2	<25	1.3	<20	1.3
35	ELPAT	3	<25	1.3	<20	1.3
12	ELPAT	4	<25	1.3	<20	1.3
9	ELPAT	1	<25	1.3	<20	1.3
77	ELPAT	2	<25	1.3	<20	1.3
100	ELPAT	3	<25	1.3	<20	1.3
3	ELPAT	4	<25	1.3	<20	1.3
112	ELPAT	1	<25	1.3	<20	1.3
11	ELPAT	2	<25	1.3	<20	1.3
19	ELPAT	3	<25	1.3	<20	1.3
59	ELPAT	4	<25	1.3	<20	1.3
152	ELPAT	1	<25	1.3	<20	1.3
82	ELPAT	2	<25	1.3	<20	1.3
40	ELPAT	3	<25	1.3	<20	1.3
92	ELPAT	4	<25	1.3	<20	1.3
41	ELPAT	1	<25	1.3	<20	1.3
48	ELPAT	2	<25	1.3	<20	1.3
139	ELPAT	3	<25	1.3	<20	1.3
25	ELPAT	4	<25	1.3	<20	1.3
34	ELPAT	1	<25	16.9	<20	16.9
126	ELPAT	2	<25	16.9	<20	16.9
104	ELPAT	3	<25	16.9	<20	16.9
74	ELPAT	4	<25	16.9	<20	16.9
44	ELPAT	1	<25	17.6	30	17.6
72	ELPAT	2	<25	17.6	<20	17.6
5	ELPAT	3	<25	17.6	<20	17.6
128	ELPAT	4	<25	17.6	<20	17.6
65	ELPAT	1	30	29.8	33	29.8
7	ELPAT	2	32	29.8	26	29.8
79	ELPAT	3	30	29.8	28	29.8
10	ELPAT	4	28	29.8	28	29.8

Sample Analysis Order	Source	Rep	Palintest SA-5000		DataChem	
			Result	Estimated	Result	Estimated
			µg/wipe	µg/wipe	µg/wipe	µg/wipe
14	UC LAB	1	38	39.9	33	35.4
125	UC LAB	2	32	35.1	32	35.7
143	UC LAB	3	38	43.3	31	38.5
58	UC LAB	4	36	42.1	29	36.4
78	UC LAB	1	36	38.8	32	35.1
4	UC LAB	2	38	42.8	38	40.7
151	UC LAB	3	30	35.0	37	39.4
30	UC LAB	4	32	36.4	36	41.0
105	UC LAB	1	32	38.5	37	41.0
53	UC LAB	2	34	38.9	37	38.8
134	UC LAB	3	36	38.8	33	39.3
109	UC LAB	4	34	37.6	41	44.7
135	UC LAB	1	34	43.1	32	36.0
103	UC LAB	2	38	41.1	38	44.7
123	UC LAB	3	34	37.3	30	39.9
95	UC LAB	4	30	35.1	35	37.5
27	UC LAB	1	36	44.5	36	37.4
158	UC LAB	2	34	36.4	31	36.7
119	UC LAB	3	36	38.8	34	35.8
145	UC LAB	4	30	39.2	34	39.7
149	ELPAT	1	36	41.3	37	41.3
147	ELPAT	2	36	41.3	42	41.3
108	ELPAT	3	40	41.3	44	41.3
1	ELPAT	4	40	41.3	41	41.3
144	ELPAT	1	42	49.0	43	49.0
142	ELPAT	2	38	49.0	52	49.0
45	ELPAT	3	42	49.0	49	49.0
84	ELPAT	4	40	49.0	48	49.0
102	ELPAT	1	38	49.1	70	49.1
38	ELPAT	2	40	49.1	54	49.1
51	ELPAT	3	42	49.1	48	49.1
66	ELPAT	4	45	49.1	44	49.1
57	ELPAT	1	47	58.6	64	58.6
121	ELPAT	2	51	58.6	55	58.6
55	ELPAT	3	44	58.6	56	58.6
94	ELPAT	4	47	58.6	52	58.6

Sample Analysis Order	Source	Rep	Palintest SA-5000		DataChem	
			Result	Estimated	Result	Estimated
			µg/wipe	µg/wipe	µg/wipe	µg/wipe
62	ELPAT	1	75	88.0	82	88.0
136	ELPAT	2	71	88.0	83	88.0
80	ELPAT	3	65	88.0	79	88.0
56	ELPAT	4	67	88.0	100	88.0
90	ELPAT	1	96	117.0	120	117.0
70	ELPAT	2	104	117.0	120	117.0
6	ELPAT	3	110	117.0	120	117.0
155	ELPAT	4	100	117.0	110	117.0
43	ELPAT	1	155	162.3	150	162.3
68	ELPAT	2	162	162.3	160	162.3
106	ELPAT	3	157	162.3	150	162.3
20	ELPAT	4	157	162.3	160	162.3
111	ELPAT	1	200	201.6	200	201.6
69	ELPAT	2	186	201.6	190	201.6
97	ELPAT	3	194	201.6	200	201.6
115	ELPAT	4	192	201.6	220	201.6
96	ELPAT	1	225	239.0	230	239.0
33	ELPAT	2	194	239.0	250	239.0
75	ELPAT	3	221	239.0	250	239.0
150	ELPAT	4	231	239.0	230	239.0
49	UC LAB	1	164	249.5	210	244.0
37	UC LAB	2	182	239.0	250	274.4
114	UC LAB	3	168	245.1	230	252.8
99	UC LAB	4	178	225.7	230	258.9
91	UC LAB	1	186	244.0	200	241.7
29	UC LAB	2	176	269.4	240	274.9
2	UC LAB	3	211	258.9	210	244.5
76	UC LAB	4	192	250.0	210	236.2
88	UC LAB	1	225	270.0	220	244.0
71	UC LAB	2	198	263.9	220	242.3
130	UC LAB	3	170	240.1	230	260.0
83	UC LAB	4	166	237.3	170	228.5
18	UC LAB	1	213	255.6	190	242.3
64	UC LAB	2	205	262.8	210	267.2
54	UC LAB	3	196	258.9	210	236.2
124	UC LAB	4	176	225.7	250	275.5
156	UC LAB	1	178	228.5	220	262.2
17	UC LAB	2	194	240.6	210	226.3
36	UC LAB	3	192	255.0	210	227.4
67	UC LAB	4	180	241.2	220	243.4

Sample Analysis Order	Source	Rep	Palintest SA-5000		DataChem	
			Result	Estimated	Result	Estimated
			µg/wipe	µg/wipe	µg/wipe	µg/wipe
46	ELPAT	1	200	256.7	290	256.7
110	ELPAT	2	207	256.7	240	256.7
52	ELPAT	3	211	256.7	230	256.7
116	ELPAT	4	239	256.7	250	256.7
89	ELPAT	1	225	260.8	220	260.8
120	ELPAT	2	246	260.8	250	260.8
85	ELPAT	3	223	260.8	210	260.8
113	ELPAT	4	246	260.8	210	260.8
26	UC LAB	1	285	366.2	320	377.8
23	UC LAB	2	293	388.9	360	395.0
22	UC LAB	3	303	401.6	350	399.4
153	UC LAB	4	266	372.3	340	385.0
86	UC LAB	1	318	429.3	350	395.5
8	UC LAB	2	311	391.7	340	382.8
50	UC LAB	3	274	370.1	370	413.8
73	UC LAB	4	307	401.1	340	374.0
107	UC LAB	1	274	376.7	370	426.5
160	UC LAB	2	274	367.9	340	378.9
127	UC LAB	3	339	383.9	370	401.1
140	UC LAB	4	278	385.0	390	423.2
93	UC LAB	1	317	388.3	330	372.9
117	UC LAB	2	278	365.1	320	362.9
60	UC LAB	3	299	385.0	330	384.5
122	UC LAB	4	324	421.5	360	411.0
148	UC LAB	1	337	428.2	340	397.2
137	UC LAB	2	274	367.3	360	393.3
129	UC LAB	3	315	405.5	390	437.6
32	UC LAB	4	322	403.8	330	375.1
118	ELPAT	1	409	408.7	360	408.7
21	ELPAT	2	388	408.7	430	408.7
39	ELPAT	3	378	408.7	410	408.7
42	ELPAT	4	355	408.7	410	408.7
132	ELPAT	1	407	418.1	440	418.1
98	ELPAT	2	378	418.1	410	418.1
131	ELPAT	3	403	418.1	430	418.1
141	ELPAT	4	386	418.1	420	418.1

Sample Analysis Order	Source	Rep	Palintest SA-5000		DataChem	
			Result	Estimated	Result	Estimated
			µg/wipe	µg/wipe	µg/wipe	µg/wipe
63	ELPAT	1	581	561.9	580	561.9
157	ELPAT	2	515	561.9	540	561.9
81	ELPAT	3	551	561.9	560	561.9
101	ELPAT	4	558	561.9	540	561.9
87	ELPAT	1	523	564.7	560	564.7
47	ELPAT	2	521	564.7	560	564.7
15	ELPAT	3	576	564.7	570	564.7
13	ELPAT	4	541	564.7	530	564.7
61	ELPAT	1	809	805.1	760	805.1
159	ELPAT	2	780	805.1	770	805.1
24	ELPAT	3	817	805.1	760	805.1
16	ELPAT	4	841	805.1	740	805.1
154	ELPAT	1	1257	1482.6	1500	1482.6
31	ELPAT	2	1322	1482.6	1500	1482.6
28	ELPAT	3	1236	1482.6	1500	1482.6
146	ELPAT	4	1416	1482.6	1400	1482.6