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Standard Guide for Strategies for Surface Sampling of Metals and Metalloids for Worker Protection¹

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1. Scope

1.1 This guide provides criteria to be used in defining strategies for sampling for metals and metalloids on surfaces for workplace health and safety monitoring or evaluation.

1.2 Guidance provided by this standard is intended for sampling of metals and metalloids on surfaces for subsequent analysis using methods such as atomic spectrometry, mass spectrometry, X-ray fluorescence, or molecular fluorescence. Guidance for evaluation of data after sample analysis is included.

1.3 Sampling for volatile organometallic species (for example, trimethyl tin) is not within the scope of this guide.

1.4 Sampling to determine levels of metals or metalloids on the skin is not within the scope of this guide.

1.5 Sampling for airborne particulate matter is not within the scope of this guide. Guide E1370 provides information on air sampling strategies.

1.6 Where surface sampling is prescribed by law or regulation, this guide is not intended to take the place of any requirements that may be specified in such law or regulation.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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2. Referenced Documents

2.1 ASTM Standards:²

- D1356 Terminology Relating to Sampling and Analysis of Atmospheres
- D3670 Guide for Determination of Precision and Bias of Methods of Committee D22
- D5438 Practice for Collection of Floor Dust for Chemical Analysis
- D6399 Guide for Selecting Instruments and Methods for Measuring Air Quality in Aircraft Cabins
- D6620 Practice for Asbestos Detection Limit Based on Counts
- D6966 Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Determination of Metals
- D7035 Test Method for Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
- D7144 Practice for Collection of Surface Dust by Microvacuum Sampling for Subsequent Determination of Metals and Metalloids
- D7202 Test Method for Determination of Beryllium in the Workplace by Extraction and Optical Fluorescence Detection
- D7296 Practice for Collection of Settled Dust Samples Using Dry Wipe Sampling Methods for Subsequent Determination of Beryllium and Compounds
- D7439 Test Method for Determination of Elements in Airborne Particulate Matter by Inductively Coupled Plasma–Mass Spectrometry
- D7440 Practice for Characterizing Uncertainty in Air Quality Measurements
- D7822 Practice for Dermal Wipe Sampling for the Subsequent Determination of Metals and Metalloids
- E1216 Practice for Sampling for Particulate Contamination by Tape Lift

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- [E1370 Guide for Air Sampling Strategies for Worker and Workplace Protection](#)
- [E1402 Guide for Sampling Design](#)
- [E1542 Terminology Relating to Occupational Health and Safety](#)
- [E1613 Test Method for Determination of Lead by Inductively Coupled Plasma Atomic Emission Spectrometry \(ICP-AES\), Flame Atomic Absorption Spectrometry \(FAAS\), or Graphite Furnace Atomic Absorption Spectrometry \(GFAAS\) Techniques \(Withdrawn 2021\)³](#)
- [E1728/E1728M Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Lead Determination](#)
- [E1792 Specification for Wipe Sampling Materials for Lead in Surface Dust](#)
- [E2271 Practice for Clearance Examinations Following Lead Hazard Reduction Activities in Multifamily Dwellings](#)
- [E3193 Test Method for Measurement of Lead \(Pb\) in Dust by Wipe, Paint, and Soil by Flame Atomic Absorption Spectrophotometry \(FAAS\)](#)
- [E3203 Test Method for Determination of Lead in Dried Paint, Soil, and Wipe Samples by Inductively Coupled Plasma-Optical Emission Spectroscopy \(ICP-OES\)](#)

2.2 ISO and European Standards:⁴

- [ISO TR 14294 Workplace atmospheres — Measurement of dermal exposure — Principles and methods](#)
- [ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories](#)
- [ISO 18158 Workplace air — Terminology](#)

2.3 Other Documents:

- [40 CFR 745 Lead-Based Paint Poisoning Prevention in Certain Residential Structures⁵](#)

3. Terminology

3.1 For definitions of terms relating to occupational health and safety, see Terminology [E1542](#).

3.2 For definitions of terms relating to sampling and analysis of atmospheres, see Terminology [D1356](#).

3.3 Definitions:

3.3.1 *analyte*—designated chemical species to be measured by a monitor or to be identified and quantified by an analyzer. **D6399**

3.3.2 *analytical sensitivity*—ability of an analytical method to detect small amounts of, or small changes in the amount of, the analyte of interest. **(1)⁶**

3.3.3 *analytical specificity*—ability of an analytical method to respond uniquely to the analyte of interest; that is, its ability

to measure accurately an analyte, both qualitatively and quantitatively. **(1)**

3.3.3.1 *Discussion*—Important factors in determining analytical specificity include freedom from interference by other components, and good precision and accuracy.

3.3.4 *confidence interval*—range of values that has a specified probability of including the true value of the parameter(s) of an underlying distribution. **(2)**

3.3.5 *data quality objectives (DQOs)*—qualitative and quantitative statements of the overall level of uncertainty that a decision maker is willing to accept in results or decisions derived from environmental data. **D6399**

3.3.5.1 *Discussion*—Minimum DQOs include method detection limit, precision, and bias.

3.3.6 *decision value*—a numerical value used as a boundary in a statistical test to decide between the null hypothesis and the alternative hypothesis. **D6620**

3.3.7 *descriptive statistics*—simple metrics of a sample distribution’s characteristics such as central tendency (for example, mean, median) and dispersion (for example, standard deviation, variance, range). **(2)**

3.3.7.1 *Discussion*—Additional examples are the number of samples and the actual fraction of samples above a decision value or an OELV.

3.3.8 *inferential statistics*—parameters used to make estimates about a distribution and underlying population. **(2)**

3.3.9 *occupational exposure limit value (OELV)*—limit of the time-weighted average of the concentration of a chemical agent in the air within the breathing zone of a worker in relation to a specified reference period. **ISO 18158**

3.3.9.1 *Discussion*—The term “limit value” is often used as a synonym for “occupational exposure limit value” but the term “occupational exposure limit value” is preferred because there is more than one limit value (for example, biological limit value and occupational exposure limit value).

3.3.9.2 *Discussion*—As used in this guide, examples of OELVs include occupational exposure limits established by regulation, or Threshold Limit Values established by the American Conference of Governmental Industrial Hygienists **(3)**. This should not be confused with analytical limits, such as method detection limit, as defined in Terminology [D1356](#).

3.3.10 *non-parametric statistical inference*—evaluation of a data set using statistical procedures whose validity do not depend on assuming a specified underlying distribution.

3.3.11 *parametric statistical inference*—evaluation of a data set based on assuming a specified underlying statistical model, such as normal or lognormal distributions.

3.3.12 *professional judgment*—application and appropriate use of knowledge gained from formal education, experience, experimentation, inference, and analogy. The capacity of an experienced professional to draw correct inferences from incomplete quantitative data, frequently on the basis of observations, analogy, and intuition. **(2)**

3.3.13 *reporting limit*—value at which reported data are censored.

3.3.13.1 *Discussion*—Values below the reporting limit are

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

⁶ The boldface numbers in parentheses refer to a list of references at the end of this standard.

typically reported as being less than the reporting limit, such as “<RL” or are reported at the reporting limit with a qualifier, such as “RL (U)”. (4)

3.3.14 *representative surface*—a surface that is taken to be typical of surface(s) at a given sampling location.

3.3.14.1 *Discussion*—A representative surface may be established as a result of directed sampling (see 7.3.1) or random sampling (see 7.3.2). Thus, “representative” should not be confused with “random.”

3.3.15 *sampling location*—a specific area within a sampling site that is subjected to sample collection.

E1728/E1728M/D6966

3.3.15.1 *Discussion*—Multiple sampling locations are commonly designated for a single sampling site (see 3.3.16).

3.3.16 *sampling site*—a local geographic area that contains the sampling locations (see 3.3.16). **E1728/E1728M/D6966**

3.3.16.1 *Discussion*—A sampling site is generally limited to an area that is easily covered by walking.

3.3.17 *stratified sampling*—sampling in which the population to be sampled is first divided into mutually exclusive subsets or strata, and independent samples taken within each stratum.

E1402

3.3.18 *Type I error*—selection, based on a statistical test, of the alternative hypothesis over the null hypothesis when the null hypothesis is, in fact, true; a false positive outcome of a statistical test.

D6620

3.3.19 *Type II error*—selection, based on a statistical test, of the null hypothesis over the alternative hypothesis when the alternative hypothesis is, in fact, true; a false negative outcome of a statistical test.

D6620

3.3.20 *upper tolerance limit (UTL)*— upper confidence limit (with specified confidence level) for a percentile of a distribution. (2)

3.3.20.1 *Discussion*—The UTL is the value below which a specified fraction of the population will be found, with a specified level of confidence. For example, the $UTL_{95\%, 95\%}$ is the value for which one would have 95 % confidence that 95 % of the population is below the UTL.

3.3.21 *wipe sample*—sample collected by wiping a representative surface of known area, as determined by Practice **E1728/E1728M**, or equivalent method, with an acceptable wipe material as defined in Specification **E1792**.

40 CFR 745.63, (5)

4. Significance and Use

4.1 This guide describes approaches which can be used to determine surface sampling strategies before any actual surface sampling occurs. The strategy selection process needs to consider a number of factors, including, but not limited to, purpose for sampling, fitness of the sampling strategy for that purpose, data quality objectives and how the data will be used, ability to execute the selected strategy, and ability of the analytical laboratory (fixed-site or in-field) to analyze the samples once they are collected.

4.2 For the purposes of sampling, and for the materials sampled, surface sampling strategies are matters of choice.

Workplace sampling may be performed for single or multiple purposes. Conflicts may arise when a single sampling strategy is expected to satisfy multiple purposes.

4.2.1 Limitations of cost, space, power requirements, equipment, personnel, and analytical methods need to be considered to arrive at an optimum strategy for each purpose.

4.2.2 A strategy intended to satisfy multiple purposes will typically be a compromise among several alternatives, and will typically not be optimal for any one purpose.

4.2.3 The purpose or purposes for sampling should be explicitly stated before a sampling strategy is selected. Good practice, regulatory and legal requirements, cost of the sampling program, and the usefulness of the results may be markedly different for different purposes of sampling.

4.3 This guide is intended for those who are preparing to evaluate a workplace environment by collecting samples of metals or metalloids on surfaces, or who wish to obtain an understanding of what information can be obtained by such sampling.

4.4 *This guide cannot take the place of sound professional judgment in development and execution of any sampling strategy.* In most instances, a strategy based on a standard practice or method will need to be adjusted due to conditions encountered in the field. Documentation of any professional judgments applied to development or execution of a sampling strategy is essential.

4.5 This guide should not be used as a stand-alone document to evaluate any given contaminant or chemical species.

4.6 The surface sampling techniques described in this guide are intended for the determination of metals and metalloids on surfaces, or for the determination of loadings of embedded metallic residues in surface coverings. These techniques may not accurately reflect the transferability or bioavailability of such residues by way of dermal contact or inhalation of resuspended respirable dust.

5. Surface Sampling—General

5.1 Surface sampling results are one of many sources of information about health and safety conditions in a workplace. Information obtained from surface sampling should not be used to the exclusion of other information. Additional sources of information may, as applicable, include air sampling, bioassay and biomonitoring results, clinical observations, quality and process control data, records of facility operations, and material balance studies.

5.2 Agreement among separately obtained sources of information should increase confidence in the interpretation of workplace hazard assessments. Disagreement should be cause for concern, and should result in efforts to determine why the disagreement occurred.

5.3 The factors discussed in Sections 6 through 10 of this guide are interdependent and may need to be applied in an iterative fashion to develop an optimum strategy.

6. Purposes for Surface Sampling

6.1 *General Considerations*—Purposes for surface sampling are based on the following general considerations:

6.1.1 *Drivers for sampling*; that is, the “why” for performing the sampling campaign. Generally, the “why” should fall into one of the following three areas:

6.1.1.1 *Health impact*, or evaluation of the potential health risk from the contaminant or chemical species.

6.1.1.2 *Hazard management*, or evaluation of the source of the contaminant or chemical species, extent of exposure area, and effectiveness of controls.

6.1.1.3 *Hazard compliance*, or evaluation of compliance against regulations or policies.

6.1.2 *Goals* for the sampling campaign, which are based on how the data will be used.

6.1.3 *Data quality objectives*, which define how well the collection and analysis of the samples must be performed.

6.1.4 *Available resources* to conduct the sampling campaign, laboratory analyses, and data evaluation.

6.2 *Examples*—The following are examples of purposes for surface sampling based on the general considerations in 6.1:

6.2.1 *Hazard Identification and Evaluation*—Estimation of one or both of the expected, or maximum, concentrations of analyte(s) of interest in the workplace. The information obtained is used to evaluate risk, recommend worker protection requirements and to assess the probability of sensitization or hypersensitivity reactions.

6.2.2 *Exposure Assessment for Epidemiology*—Collection of a data base for performing epidemiological studies, when the existence of a health hazard is known or postulated. It is focused on categories of workers, rather than on an individual worker, and requires, within limitations such as those described in 7.1.4, the use of instruments and methods that offer the lowest available analytical reporting limits.

6.2.3 *Facility Characterization*—Determination of the levels of one or more analyte(s) of interest within a facility at an initial or baseline point, during or after process operations, or as part of facility decommissioning.

6.2.4 *Housekeeping*—Determination of the effectiveness of housekeeping actions. Typically, wipe samples are collected both before and after the cleaning procedure used was effective in removing the analyte(s) of interest.

6.2.5 *Selection of Engineering controls*—Determination, for analyte(s) of interest that are not totally contained, the collection or capture efficiencies of control devices necessary to bring specific contaminant concentrations below applicable limits at specific sampling locations, and evaluation of spill clean-up procedure effectiveness.

6.2.6 *Evaluation of Engineering Controls*—Measurement of the quantities of analyte(s) of interest passing or escaping from a control device due to leaks, wear, damage, inadequate maintenance, overloading, or accidents.

6.2.7 *Evaluation of Exposure Pathways*—Measurements used as part of an evaluation of the potential contribution of an analyte of interest on surfaces to worker exposure. **Appendix X1** contains additional information on exposure pathways and mass transport processes.

6.2.8 *Selection of Personal Protective Equipment*—Determination of requirements for personal protective equipment in order for a worker to safely inhabit a contaminated or potentially contaminated area for a specific period of time.

6.2.9 *Compliance with Regulations and Standards*—Measurements required to satisfy regulatory or legal requirements, such as 40 CFR 745, or to determine if exposures in the workplace are below occupational exposure limits.

6.2.10 *Source Identification*—Determination of the contribution from each of many potential sources to the presence of analyte(s) of interest, based on the unique characteristics of each of the analyte(s).

6.2.11 *Education and Training*—Sampling used to educate workers in the importance of sound control practices (for example, engineering controls, personal protective equipment, good housekeeping).

6.2.12 *Investigation of Complaints*—Resolution of concerns expressed by workers, management, or other stakeholders.

7. Development of Surface Sampling Plans

7.1 General Considerations:

7.1.1 Sampling plans should be fit for the intended purpose or purposes. In general, this means that the outcome of the sampling campaign will be a set of data that meets data quality objectives and can be evaluated to provide the intended information. The intended purpose or purposes should be explicitly stated before evaluating sampling options or selecting a sampling strategy.

7.1.2 Consideration should be given to the expected means by which the material being sampled was deposited on the surface or surfaces being sampled, as this can impact the selected sampling strategy and methods. Conversely, the distribution and level of a material on surfaces may provide information on how the material deposition occurred. Additional guidance on surface deposition mechanisms is provided in **Appendix X2**.

7.1.3 Principles of good practice, as well as applicable regulatory or legal requirements, should be considered and addressed during development of the sampling plan.

7.1.4 Limitations of the sampling plan should be considered and addressed. These include, but may not be limited to, the following:

7.1.4.1 ability to collect samples at desired sampling locations;

7.1.4.2 resource limitations such as time, cost, equipment, or trained personnel;

7.1.4.3 ability of the analytical laboratory to detect and report the analyte(s) of interest in the given sample matrix, with the required data quality objectives at the anticipated analyte concentration(s); and

7.1.4.4 ability to evaluate the data, especially from a statistical perspective.

7.1.5 Due to one or more of the limitations described in 7.1.4, it may be necessary to develop a single sampling plan intended to accomplish multiple purposes (see 6.2). When this is the case, conflicts may emerge with one or more of the criteria given in 7.2 through 7.5, and compromises will typically be required to optimize the overall sampling strategy. When this occurs, the resulting strategy may not be optimal for any one purpose.

7.1.6 Whether to collect a single sample, or a set of samples, is a key decision. Collection of a set of samples, rather than a

single sample, is normally recommended for proper data evaluation. A set of samples, rather than a single sample, is normally required in the following instances:

7.1.6.1 When a comparison of “hot spots” to background locations is needed;

7.1.6.2 When required to meet regulatory requirements, for example, surface cleanliness;

7.1.6.3 When a statistical evaluation of the data is needed.

7.1.7 The following are examples of when a single sample may be appropriate:

7.1.7.1 When physical limitations, such as collecting a sample on a small item or accessibility limitations, prevent the collection of multiple samples.

7.1.7.2 When multiple operations are being performed simultaneously; in this instance, it may not be possible to collect more than one sample per operation.

7.1.8 In cases where sampling is performed in response to an emergency or other urgent situation, the sampling plan typically will be based primarily on professional judgment, since planning time is at a minimum.

7.1.9 The sampling plan should include appropriate quality assurance measures that will provide documentation, throughout the sampling event and subsequent collection and evaluation of data from the samples, that appropriate quality standards have been met.

7.1.10 Documentation of how the sampling plan was developed is of great benefit in the event that issues arise in collecting or analyzing the samples, or in evaluating the data. Considerations include, for example, whether the sampling plan was statistically based, and whether sampling was random, stratified, or a combination of both. Additional guidance is provided in [Appendix X3](#).

7.2 Number of Samples to Collect:

7.2.1 When collecting a set of samples, the number of samples to collect is critical. The limitations cited in [7.1.2](#) through [7.1.5](#) often affect the number of samples collected. However, these limitations must be balanced against the need to collect a statistically valid number of samples. The number of samples to be collected should typically be the minimum number required to accomplish the intended purpose(s) for sampling.

7.2.2 In general, use of a parametric statistical inference is preferred over a non-parametric statistical inference. However, when a large proportion of the samples are expected to be below the laboratory’s reporting limit, a non-parametric statistical inference, which typically calls for larger sample sets, may be required ([6](#)).

7.2.3 For situations where only a limited number of samples can be collected, and there is some prior knowledge to which professional judgment can be applied, techniques such as Bayesian Decision Analysis ([2](#)) may be considered.

7.2.4 Additional guidance is provided in Guide [E1402](#).

7.3 Where to Sample:

7.3.1 Directed sampling is most appropriate for situations such as, for example, exposure estimation or selection of engineering controls. Such sampling may be based on professional judgment, the need for a representative sampling set, or

the need to sample at the sampling locations likely to have the highest levels of the analyte(s) of interest.

7.3.2 Random sampling is most appropriate when performing initial evaluations of analyte(s) of interest in an area or building, or when performing basic research. Use of commercially available software may provide valuable assistance in establishing random sampling locations. Additional guidance on random sampling is found in Practice [E2271](#).

7.3.3 A combination of directed and random approaches, such as stratified sampling, may be appropriate in some instances, based on prior knowledge and professional judgment.

7.3.4 Samples taken for the purpose of regulatory compliance should use the rules of good practice to the maximum extent possible while complying with all applicable regulatory requirements.

7.4 What to Sample:

7.4.1 For most purposes, sampling should be performed for the analyte(s) of interest.

7.4.2 In some cases, such as source identification, selection of engineering controls, and evaluation of engineering controls, a marker material other than the analyte(s) of interest may be sampled with greater ease or sensitivity, or both, as long as the marker material concentration is proportional to the source strength of the analyte(s) of interest.

7.5 When to Sample:

7.5.1 Sampling should be performed when required by applicable regulations or policies.

7.5.2 Sampling should be performed when there is a probability that one or more individuals may be exposed to significant concentrations of a hazardous material in the settled particulate matter.

7.5.3 Sampling should be performed when it is desired to determine the effectiveness of housekeeping practices; that is, whether cleaning processes are effective. In this instance, sampling both before and after the cleaning activities would normally be performed.

7.5.4 Frequency of sampling should consider the type of operation involved. This may include one or more of the following:

7.5.4.1 Repetitive Operations, such as production lines, where the same, or very similar, operation or cycle of operations is carried out day after day.

7.5.4.2 Non-repetitive or Irregular Operations, such as maintenance or research, where each operation is essentially unique.

7.5.4.3 Enclosed Operations or Processes, whether routine or unusual, where there is little or no human contact with the analyte(s) of interest unless a leak or spill occurs.

8. Selection of Surface Sampling Methods

8.1 The following factors must be considered in the selection of an appropriate surface sampling method:

8.1.1 Nature of surface being sampled, including whether the surface is smooth, rough, porous, fragile, or hard. Some surfaces, such as carpets and cloth upholstery, cannot be properly sampled using wipe sampling techniques.

8.1.2 Amount of settled dust on the surface. Substantial quantities of settled dust may require bulk or vacuum sampling techniques.

8.2 A listing of standards from ASTM International is provided in Table 1. Additional standard methods have been promulgated by the National Institute for Occupational Safety and Health (NIOSH (7)), and the Occupational Safety and Health Administration (OSHA (8)). Further information on bulk sampling methods may be found in Special Technical Publication 1282 (9) and from the Environmental Protection Agency (EPA) (10).

8.3 When utilizing wipe sampling methods, selection of appropriate wipe sampling media is essential. Considerations for selection of a wiping material are as follows:

- 8.3.1 Suitability for the application.
- 8.3.2 Suitability for the surface to be wiped.
- 8.3.3 Compatibility with the analyte(s) of interest.
- 8.3.4 Suitability for the analytical method which will be used.

8.4 Wetted wipes, as described in Specification E1792, are preferred over dry wipes. The wetting agent should be selected with consideration for the surface. For example, if the surface is oily, an alcohol may provide better performance as a wetting agent than water (11).

8.5 Dry wipes, such as those described for beryllium in Practice D7296, may be preferred for surfaces that would be damaged by or reactive with wetting agents.

8.6 Commonly used wiping materials include paper laboratory filters and pre-packaged wipes. Other materials may be considered for special situations, but their fitness for purpose should be evaluated prior to routine use.

8.7 Measures should be taken to properly preserve samples from the point of collection through transport to the analytical laboratory. Depending on the analyte(s) of interest, these measures may include refrigeration, packing in shock resistant materials, or addition of a fixative or preservative to the sample.

8.8 Measures should be taken to maintain the integrity, security and custody of the samples at all times. This includes documentation of the chain of custody, and may also include provision of a secure receptacle for samples awaiting analysis when not in the documented custody of a responsible person.

8.9 Samples should be carefully handled to avoid cross contamination. That is, the material collected in one sample

should not be allowed to spill onto, or contaminate, another sample. This is of particular concern during transfer or shipment of samples, where the opportunities for cross contamination are greatest.

9. Selection of Analytical Methods

9.1 The following items should be considered in the selection of the analytical method that will be used:

9.1.1 Sensitivity of the Method—If a screening-level method is fit for purpose, it will typically be faster and less costly than highly-sensitive methods.

9.1.2 Specificity of the Method—The selected method should be specific for the analyte(s) of interest, taking into consideration any analytical interferences that may be present.

9.1.3 Need and ability for the method to be performed in a field location as opposed to a fixed laboratory location. Field methods are typically faster, but may be less sensitive than fixed-laboratory methods.

9.1.4 Whether the method will be affected adversely by the sampling media.

9.1.5 Whether the laboratory performing the method needs to be accredited by an appropriate external accrediting organization.

9.2 Table 2 provides examples of ASTM International analysis standards for metals and metalloids. Additional standard methods have been promulgated by agencies such as NIOSH (7), OSHA (8), and EPA (12).

10. Data Evaluation

10.1 Data Quality Indicators—An evaluation of key figures of merit, such as those described below, should be performed. These indicators are typically based on the applicable measurement quality objectives (see Appendix X3 for more information). The degree of formality of this review will depend upon the size of the data set (that is, informal for a single datum or small data sets, with more formality for larger data sets). Typical data quality indicators include the following (13):

10.1.1 Data representativeness, which refers to the fitness for purpose of the number and location of samples collected and analyzed.

10.1.2 Data completeness, which refers to the proportion of planned samples that are successfully collected and analyzed.

10.1.3 Precision and bias, as described in Guide D3670 for analytical methods, or uncertainty as described in Practice D7440 for sampling and analytical methods.

TABLE 1 ASTM International Surface Sampling Standards for Metals and Metalloids

Standard	Media/Device	Surfaces
ASTM D6966	Wet wipe	Smooth / Hard
ASTM D7296 ^A	Dry wipe	Oily / Fragile
ASTM D7144	Micro-vacuum	Rough / Fragile
ASTM D5438	Vacuum cleaner	Carpets
ASTM D7822	Wet wipe	Dermal
ASTM E1216	Adhesive tape	Smooth
ASTM E1728/E1728M ^B	Wet wipe	Smooth / Hard

^A This practice is specific for beryllium and compounds. Prior to use for other purposes, its fitness for those purposes should be evaluated.

^B This practice is specific for lead. Prior to use for other purposes, its fitness for those purposes should be evaluated.

TABLE 2 ASTM International Analytical Standard Methods for Metals and Metalloids

Standard	Analytical Technique	Analyte(s)	Field, Lab, or Both
ASTM D7035	ICP-AES	Metals/metalloids	Lab
ASTM D7202	Fluorescence	Beryllium	Both
ASTM D7439	ICP-MS	Metals/metalloids	Lab
ASTM E1613	ICP-AES, Atomic Absorption (Flame and Graphite Furnace)	Lead	Lab
ASTM E3193	Flame Atomic Absorption	Lead	Lab
ASTM E3203	ICP-AES	Lead	Lab

10.1.4 Analytical sensitivity (3.3.2), which can be nominally represented by the laboratory reporting limit and associated precision.

10.1.5 Analytical specificity (3.3.3).

10.2 Evaluation of individual measurements:

10.2.1 When decisions are to be made based on individual measurements, the decision is typically one of the following binary comparisons:

10.2.1.1 Qualitative, where the result is expressed as the presence or absence of an analyte (14, 15), or as a relative comparison such as the degree of coloration of colorimetric wipes.

10.2.1.2 Semi-quantitative or quantitative, where a numerical result is obtained and compared, with consideration of precision and bias (or uncertainty), against a decision value. Semi-quantitative methods typically have less precision, greater bias, or both, than quantitative methods (14, 15).

10.2.2 Acceptable levels should be defined *a priori* for the rates, or likelihoods, of decision errors as described below:

10.2.2.1 For qualitative results, false negatives occur when the analyte is reported to be absent when it is actually present. False positives occur when the analyte is reported to be present when it is actually absent.

10.2.2.2 For semi-quantitative or quantitative results, Type I errors occur when an analyte is reported as being below the decision value when it is actually above the decision value. Type II errors occur when an analyte is reported as being above the decision value when it is actually below the decision value.

10.2.2.3 These likelihoods depend on the actual quantity that is present for an analyte of interest. Acceptable levels of the likelihoods of these errors, as well as evaluations of these likelihoods for a given sampling and analysis scenario, should therefore be phrased in terms of (estimated) likelihoods as functions of true value (concentration, etc.).

10.2.3 To obtain a level of confidence that a reported value is truly below the decision value, calculate the upper confidence limit (UCL), for the desired level of confidence (for example, 95 %), associated with that value and the applicable precision and bias. If the resulting UCL is below the decision value, there is confidence, at the established confidence level (for example, 95 %), that the reported value is in fact below the decision value.

10.3 Evaluation of Data Sets:

10.3.1 Evaluation of data sets using descriptive statistics (for example, measures of central tendency and dispersion), when used with professional judgment, may be sufficient when there is not a decision value for comparison, or when most of the data points are well below, or well above, the decision

value. Descriptive statistics may also be most appropriate for small data sets, when there are not enough data points to utilize inferential statistics.

10.3.2 Inferential statistics should be used for larger data sets when data points are near, or include, the decision value.

10.3.2.1 Use of a parametric statistical inference is appropriate when the data set can be assumed, or shown through probability plotting or goodness-of-fit testing, to follow a statistical model such as the normal or log-normal distributions adequately for the intended statistical inference.

10.3.2.2 Use of a non-parametric statistical inference is necessary when the data set does not adequately follow a parametric statistical model.

10.3.2.3 If the data set contains a high percentage of censored data (that is, values below the laboratory reporting limit that are shown as “less than” the reporting limit rather than the actual value), use of a parametric statistical inference, such as log-normal, may not be valid, or may be overly conservative (13). In these instances, a non-parametric statistical inference may be necessary; however, non-parametric methods may require large data sets, depending on the desired statistical inference.

10.3.2.4 In selected instances, such as facility characterization (see 6.2.3), utilization of data below the laboratory reporting limit, when available, may improve data evaluation (4, 13). Appropriate data qualifiers are required to denote that such data are, in fact, below the reporting limit.

10.3.2.5 When evaluating a data set against an OELV, the UTL is frequently compared with the OELV.

10.3.3 Data sets should be evaluated with the assistance of personnel knowledgeable in the appropriate statistical treatment for each data set. This is particularly important for data sets with a high percentage of data below the laboratory’s reporting limit. A number of available software programs can assist with proper data evaluation.

10.3.4 Application of professional judgment, including any prior knowledge of the area(s) being sampled, is particularly important for small data sets.

10.3.5 Additional information on descriptive and inferential statistics, as applicable to workplace health and safety sampling, is found in references such as Milz and Mulhausen (16). Information in Grams and Davis (13) on data quality and reporting, while specific to beryllium, can be generally applied to other metals and metalloids.

11. Quality Assurance

11.1 Conclusion of the sampling event should include verification of the final project package to ensure that the data