Designation: D5956 – 21

Standard Guide for
Sampling Strategies for Heterogeneous Wastes[1]

This standard is issued under the fixed designation D5956; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide is a practical, nonmathematical discussion for heterogeneous waste sampling strategies. This guide is consistent with the particulate material sampling theory as well as inferential statistics, and may serve as an introduction to the statistical treatment of sampling issues.

1.2 This guide does not provide comprehensive sampling procedures, nor does it serve as a guide to any specification. It is the responsibility of the user to ensure appropriate procedures are used.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.4 *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.*

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D5681 Terminology for Waste and Waste Management

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, see Terminology D5681.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *component, n*—an easily identified item such as a large crystal, an agglomerate, rod, container, block, glove, piece of wood, or concrete.

3.2.2 *composite sample, n*—a combination of two or more samples.

3.2.2.1 *Discussion*—When compositing samples to detect hot spots or whenever there may be a reason to determine which of the component samples that constitute the composite are the source of the detected contaminant, it can be helpful to composite only portions of the component samples. The remainders of the component samples then can be archived for future reference and analysis. This approach is particularly helpful when sampling is expensive, hazardous, or difficult.

3.2.3 *correlation, n*—the mutual relation of two or more things.

3.2.4 *item, n*—a distinct part of a population (for example, microscopic particles, macroscopic particles, and 20-ft long steel beams).

3.2.4.1 *Discussion*—The term *component* defines a subset of items. Components are those items that are easily identified as being different from the remainder of items that constitute the population. The identification of components may facilitate the stratification and sampling of a highly stratified population when the presence of the characteristic of interest is correlated with a specific component.

3.2.5 *practical homogeneity, n*—the condition of the population under which all items of the population are not identical. For the characteristic of interest, however, the differences between individual physical samples are not measurable or significant relative to project objectives.

3.2.5.1 *Discussion*—For practical purposes, the population is homogeneous.

3.2.6 *random, n*—lack of order or patterns in a population whose items have an equal probability of occurring.

3.2.6.1 *Discussion*—The word *random* is used in two different contexts in this guide. In relation to sampling, random means that all items of a population have an equal probability of being sampled. In relation to the distribution of a population

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[1] This guide is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.01 on Planning for Sampling.

Current edition approved Oct. 1, 2021. Published October 2021. Originally approved in 1996. Last previous edition approved in 2015 as D5956 – 15. DOI: 10.1520/D5956-21.

[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.

characteristic, random means that the characteristic has an equal probability of occurring in any and all items of the population.

3.2.7 *sample variance, n*—a measure of the dispersion of a set of results. Variance is the sum of the squares of the individual deviations from the sample mean divided by one less than the number of results involved. It may be expressed as $s^2 = \sum (x_i - \bar{x})^2/(n-1)$.

4. Significance and Use

4.1 This guide is suitable for sampling heterogeneous wastes.

4.2 The focus of this guidance is on wastes; however, the approach described in this guide may be applicable to non-waste populations as well.

4.3 Sections 5 – 10 describe a guide for the sampling of heterogeneous waste according to project objectives. Appendix X1 describes an application of the guide to heterogeneous wastes. The user is strongly advised to read Annex A1 prior to reading and employing Sections 5 – 10 of this guide.

4.4 Annex A1 contains an introductory discussion of heterogeneity, stratification, and the relationship of samples and populations.

4.5 This guide is intended for those who manage, design, or implement sampling and analytical plans for the characterization of heterogeneous wastes.

5. Sampling Difficulties

5.1 There are numerous difficulties that can complicate efforts to sample a population. These difficulties can be classified into four general categories:

5.1.1 Population access problems making it difficult to sample all or portions of the population;

5.1.2 Sample collection difficulties due to physical properties of the population (for example, unwieldy large items or high viscosity);

5.1.3 Planning difficulties caused by insufficient knowledge regarding population size, heterogeneity of the contaminant of interest, item size, or a combination thereof; and

5.1.4 Budget problems that prevent implementation of a workable, but too costly, sampling design.

5.2 The difficulties included in the first three categories are a function of the physical properties of the population being sampled. The last sampling difficulty category is a function of budget restraints that dictate a less costly sampling approach that often results in a reduced number of samples and a reduced certainty in the estimates of population characteristics. Budget restraints can make it difficult to balance costs with the levels of confidence needed in decision-making. These difficulties may be resolved by changing the objectives or sampling/analytical plans since population attributes or physical properties of the population can seldom be altered. Documents on DQOs discuss a process for balancing budgets with needed levels of confidence.

5.3 Population access and sample collection difficulties often are obvious and, therefore, more likely either to be addressed or the resulting limitations well documented. A field notebook is likely to describe difficulties in collecting large items or the fact that the center of a waste pile could not be accessed.

5.4 Population size, heterogeneity, and item size have a substantial impact on sampling. The cost and difficulty of accurately sampling a population usually is correlated with the knowledge of these population attributes and characteristics. The least understood population attribute is heterogeneity of the characteristic of interest. If heterogeneity is not known through process knowledge, then some level of preliminary sampling or field analysis is often required prior to sampling design.

5.5 Sampling of any population may be difficult. However, with all other variables being the same, nonrandom heterogeneous populations are usually more difficult to sample. The increased difficulty in sampling nonrandom heterogeneous populations is due to the existence of unidentified or numerous strata, or both. If the existence of strata is not considered when sampling a nonrandom heterogeneous population, the resulting data will average the measured characteristics of the individual strata over the entire population. If the different strata are relatively similar in composition, then the mean characteristic of the population may be a good predictor for portions of the population and will often allow the project-specific objectives to be achieved. As the difference in composition between different strata increases, average population characteristics become less useful in predicting composition or properties of individual portions of the population. In this latter case, when possible, it is advantageous to sample the individual strata separately and, if an overall average of a population characteristic is needed, it can be calculated mathematically using the weighted averages of the sampling stratum means (**1**).[3]

6. Stratification

6.1 Strata can be thought of as different portions of a population which may be separated in time or space, with each portion having internally similar concentrations or properties, which are different from adjacent portions of the population (that is, concentrations/properties are correlated with space, time, component, or source). Fig. 1 is a graphical depiction of different types of strata.

6.1.1 A landfill may display spatially separated strata since old cells may contain different wastes than new cells (stratification over space).

6.1.2 A waste pipe may discharge temporally separated strata if night-shift production varies from the day shift (stratification over time).

6.1.3 Lead-acid batteries will constitute a strata separate from commingled soil if lead is the characteristic of interest (stratification by component).

6.1.4 Drums from an inorganic process may constitute a different strata from those co-disposed drums generated by an organic process (a subtype of stratification by component referred to as stratification by source).

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[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

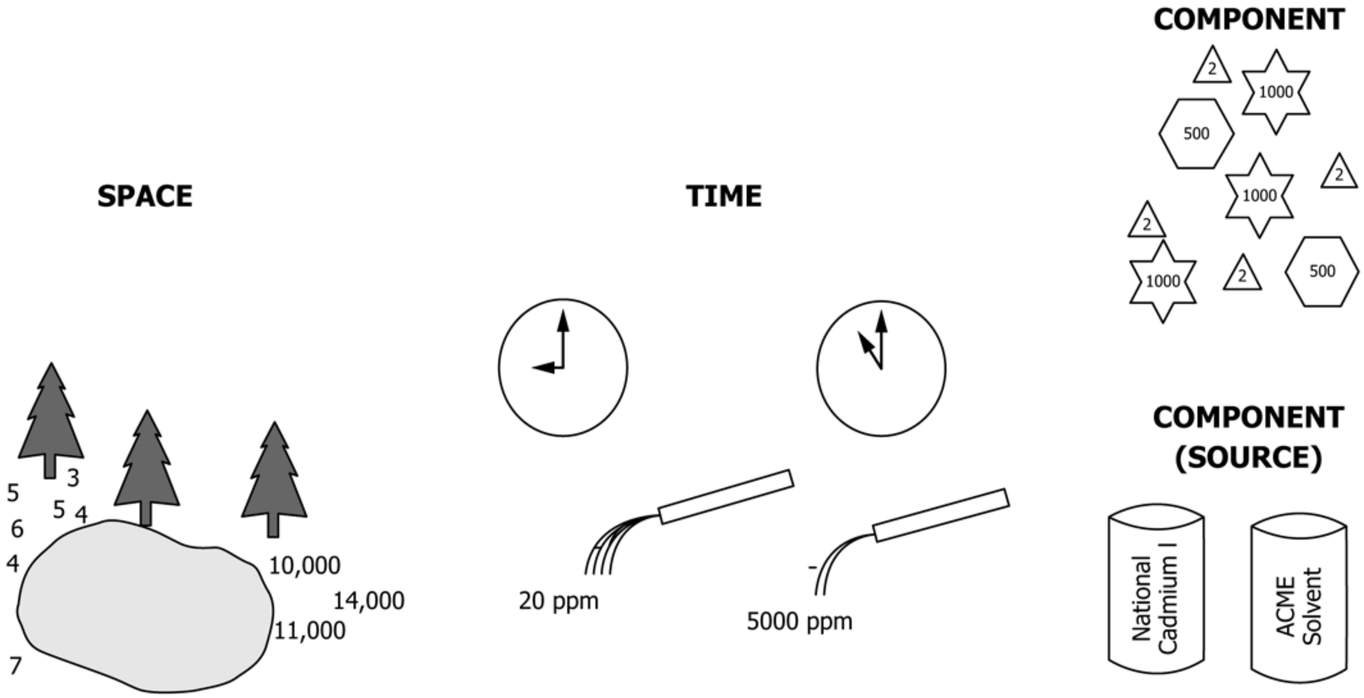

FIG. 1 Types of Stratified Heterogeneous Wastes

6.2 Different strata often are generated by different processes or a significant variant of the same process. The different origins of the strata usually result in a different concentration distribution and mean concentration.

6.3 Highly stratified populations, a type of nonrandom heterogeneous populations, have so many strata that they become difficult to sample and characterize. Classifying a population according to its level of stratification is a relative issue pertaining to the persons planning and performing the sampling, their experience, available equipment, and budgets. Highly stratified populations are such that it is not practical or effective to employ conventional sampling approaches to generate a representative database, nor would the mean concentration of a highly stratified population be a useful predictor (that is, the level of uncertainty is too great) for an individual subset that may be subjected to evaluation, handling, storage, treatment, or disposal.

NOTE 1—An example of a highly stratified population is a landfill, a candidate for remediation, that is contaminated with the pure and very viscous Aroclor 1260 and with solutions containing varying concentrations of Aroclor 1260. (Aroclor 1260 is viscous and can exist as globules of the pure Aroclor.) The detected concentration of Aroclors in analytical subsamples would reflect a highly stratified population if some samples contained globules of pure 1260, while other samples contained soils that came in contact with solvents containing varying concentrations of 1260. Highly nonrandom heterogeneous populations have numerous strata, each of which contains different distributions of contaminants or item sizes, or both, such that an average value for the population would not be useful in predicting the composition or properties of individual portions of the waste (that is, statistically speaking, the variance and standard error of the mean will be large).

A second and more visually obvious example of a highly stratified population would be a landfill that is filled with unconfined sludge, building debris, laboratory packs, automobile parts, and contained liquids with the constituent of interest having different concentrations in each strata.

6.4 Certain populations do not display any obvious temporal or spatial stratification, yet the distribution of the target characteristic is excessively erratic. For these populations, it may be helpful to consider stratification of the population by component. Stratification by component is applied to populations that contain easily identifiable items, such as large crystals or agglomerates, rods, blocks, gloves, pieces of wood, or concrete. Separating a population into sampling strata according to components is useful when a specific kind of component is distributed within the population and when a characteristic of interest is correlated with the component. Stratification by source (for example, organic process waste drums versus inorganic process waste drums) is a type of component stratification. Stratification by component is an important mechanism for understanding the properties of component-heterogeneous populations and for designing appropriate sampling and analytical efforts.

6.4.1 Component strata are not necessarily separated in time or space but are usually intermixed and the properties or composition of the individual components are the basis of stratification. For example, automobile batteries that are mixed in an unrelated waste would be a component that could constitute an individual strata if lead was a target characteristic. If one were to sequester the batteries, they would have a consistent distribution that was different from the rest of the waste.

6.4.2 There is usually no purpose in stratifying by component if different components have similar concentrations of the target characteristic or if the components are small enough such that the different components are represented in the chosen sample size. Even when components have similar composition, however, stratification and use of separate sampling strategies by component may be useful when the different components are so physically different that they cannot all be sampled with the same technique.

6.4.3 A primary objective for employing a stratified sampling strategy is to improve the precision of population parameters such as population means by dividing the population into homogeneous strata. The precision of the population parameters will increase as the sampling strata boundaries, chosen by the sampling team, more closely overlay the actual physical strata that exist within the population.

7. Sampling of Highly Stratified Heterogeneous Wastes

7.1 Sections 7 – 10 focus on the sampling of highly stratified wastes, a type of heterogeneous waste. It is strongly advised that Annex A1 be read and studied prior to the use of this guide. Annex A1 discusses heterogeneity and the relationship between samples and populations.

7.2 Nonrandom heterogeneous wastes contain two or more strata. Stratification of a waste does not always complicate the sampling process; at times, it could simplify sampling. Highly stratified populations, however, contain such a large number of strata that they become difficult to sample and characterize. Use of the word *highly* and the classification of wastes according to their level of stratification is a relative issue pertaining to the persons planning and performing the sampling, their experience, available equipment, budgets, and objectives. Highly stratified wastes are such that it is not practical or effective to employ conventional sampling approaches, nor would the mean concentration of a highly stratified waste be a useful predictor (that is, the level of uncertainty is too great) for an individual subset that may be subjected to evaluation, handling, storage, treatment, or disposal.

7.3 A structured approach to sampling planning, such as the DQO process, is a useful approach for the sampling of all wastes regardless of their level of heterogeneity. The first step in characterizing any heterogeneous waste is to gather all available information, such as the need for waste sampling; objectives of waste sampling; pertinent regulations, consent orders, and liabilities; sampling, shipping, laboratory, health, and safety issues; generation, handling, treatment, and storage of the waste; existing analytical data and exacting details on how it was generated; and treatment and disposal alternatives. This information will be used in the planning of the sampling and analytical effort.

7.4 If enough information is available, the planning process may uncover the existence of stratification that may prevent achievement of objectives. If information is lacking, a preliminary sampling/analytical effort may identify and evaluate variability. It is not cost effective to characterize highly stratified waste by conventional methods, which becomes apparent during the planning process.

7.5 Sections 8 – 10 consider approaches that lessen the impact of stratification and allow for more cost-effective sampling. Some of these approaches require changes in objectives, waste handling, or disposal methods, and some require compromises, but all approaches require the above types of information.

7.6 Heterogeneity is a necessary condition for the existence of strata. Wastes can be heterogeneous in particle size or in composition, or both, allowing for the existence of the following:

7.6.1 Strata of different-sized items of similar composition,

7.6.2 Strata of similar-sized items of different composition, and,

7.6.3 Strata of different-sized items and different composition.

8. Strata of Different-Sized Items with Similar Composition

8.1 Wastes having stratification due only to different-sized items will by definition have the same composition or property (that is, for compositional characteristics there is no significant intersample variance and no correlation with space, time, or component) throughout its different strata. The different-sized items may be separated in space or in time. Unless one is attempting to measure particle size for which there is significant intersample variance, this type of population is the simplest of the highly stratified waste types to characterize. All items in these types of wastes usually are generated by the same process (for example, the discussion of silver nitrate powder and crystals in Annex A1), which is the reason for similar composition across all item sizes. These types of wastes, which are compositionally homogeneous and only heterogeneous in item size, are not commonly encountered.

8.2 The complexity of dealing with these types of wastes is in proving that the waste has similar composition across the varying item sizes. This determination can be made by using process knowledge or by sampling the different-sized items to determine if there are significant compositional differences. If the determination is made using knowledge of the waste, it is advisable to perform limited sampling to confirm the determination. The characterization process is greatly simplified once a determination has been made that the waste has similar composition or properties across the various item sizes. The sampling and subsequent analysis can be performed on items that are readily amenable to the sampling and analytical process, and the resulting data can be used to characterize the waste in its entirety.

8.3 It is important to periodically verify the assumption that the different-sized items are composed of materials having the same concentration levels and distributions of the contaminant of interest. This verification is especially important when there are any changes to the waste generation, storage, treatment, or disposal processes. Similarity of composition between items has to be verified for each characteristic of interest. The effect of different-sized items also must be considered when measuring properties such as the leachability of waste components.

9. Strata of Similar-Sized Items and Different Composition

9.1 Stratification due only to composition or property (that is, there is a correlation of composition or property with time, space, or component) by definition necessitates that item sizes will be consistent across different strata. The strata may be separable in space, time, or by component or source. Identifying and sampling the individual strata may simplify the characterization process. An example of this waste type is a long-term accumulation of wastewater sludge produced by the processing of materials having different composition, through the same waste-generation process (that is, batch processing that results in waste having uniform item size but different composition from batch to batch).

9.2 Wastes having uniform item size and different composition or properties can be sampled using the same strategy as described for waste containing strata having different composition and different item size (see Section 10).

10. Strata of Different-Sized Items and Different Composition

10.1 Wastes having excessive stratification due to both composition/property and item size (that is, particle size and composition or property, or both, are correlated with time, space, or component) are usually the most difficult wastes to characterize. The difficulty in sampling highly stratified waste can result from:

10.1.1 Various item sizes and waste consistency that makes sampling difficult and conventional sampling approaches cost prohibitive;

10.1.2 Extraordinary concentration gradients between different components or innumerable strata that lead to such excessive variance in the data, that project objectives cannot be achieved; and

10.1.3 Wastes that exhibit the properties in 10.1.1 and 10.1.2.

10.2 Fig. 2 summarizes an approach to characterizing these types of highly stratified wastes. If a waste is highly stratified, conventional methods of sampling will not allow objectives to be achieved cost effectively. To sample cost effectively a highly stratified waste, one must use a nonconventional approach, such as modification of the sampling, sample preparation, or analytical phase of the process. If after modifying the sampling and analysis the objectives still cannot be achieved in a

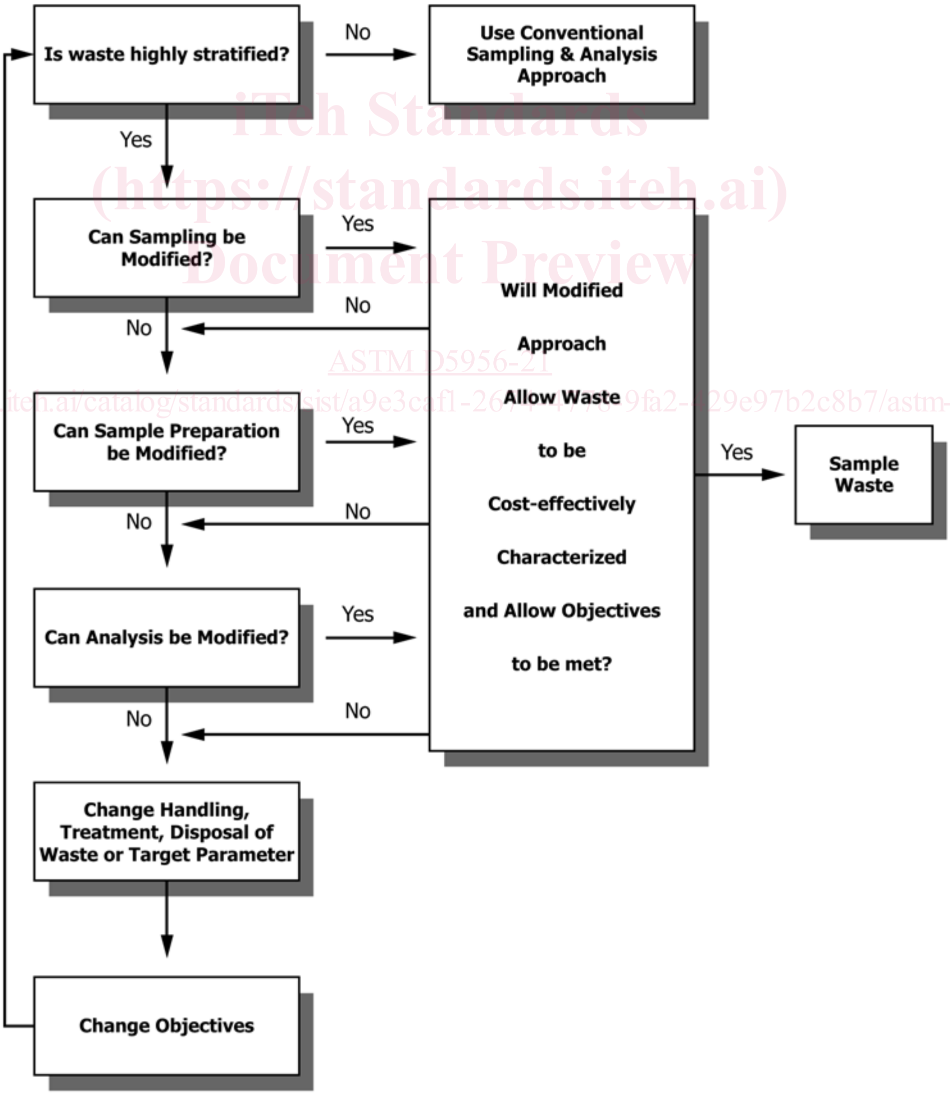

FIG. 2 Approach for the Characterization of Heterogeneous Wastes

cost-effective manner, then the original plan of waste handling, treatment, or disposal has to be examined and changed so the waste can be characterized according to new and achievable objectives.

10.3 *Design of the Sampling Approach:*

10.3.1 The first efforts to resolve the difficulty in characterizing a highly stratified waste are focused usually on sampling. A strategy for designing a sampling plan for such highly stratified waste may include the following five steps:

10.3.1.1 Use a planning process such as the DQO process to identify the target characteristics, the population boundaries, the statistic of interest, confidence levels, and other critical issues.

10.3.1.2 Determine whether characteristics of interest are correlated with item size, space, time, components, or sources.

10.3.1.3 Determine if any waste components or strata can be eliminated from consideration during sampling because they do not contribute significantly to the target characteristic.

10.3.1.4 Determine if small items in a stratum represent the stratum, as well as large, more difficult-to-sample items. If yes, sample the smaller items and only track the volume/mass contribution of the larger items.

10.3.1.5 Determine if the target characteristic is innate or surface adsorbed. Is the target characteristic surface adsorbed, which would allow the material to be sampled representatively by wipe sampling? Can large items be wiped and smaller items extracted, leached, or digested? Can waste be stratified according to impervious and nonimpervious waste and sampled and analyzed accordingly?

10.3.1.6 It is essential that all assumptions (that is, any correlations) be verified at least by knowledge of the waste, and preferably confirmed by sampling and analysis.

10.3.2 All steps taken to optimize sampling should be well documented.

10.3.3 Appendix X1 contains a case study that applies the above process for optimizing sampling to highly stratified waste. If optimization of sampling design is not sufficient by itself to allow the project objectives to be met cost effectively, changes to sample preparation or analysis should be considered.

10.4 *Modification of the Sample Preparation Method:*

10.4.1 Information gleaned from the analysis of samples is used to make inferences regarding population attributes. The perception of population homogeneity, as indicated by no significant intersample variance, or the perception of population heterogeneity (that is, as indicated by significant intersample variance) is analytical sample-mass dependent. Usually, the larger the sample mass/volume subjected to analysis the more representative the analytical sample. To improve representativeness of analytical samples and to accommodate large-sized items, conventional sample preparatory methods can be altered. All modifications of methods should be well documented.

10.4.2 In the laboratory, the term *sample preparation* is commonly meant to include two separate steps: (*1*) the subsampling of a field sample to generate an analytical sample, and (*2*) the preparation of the analytical sample for subsequent analysis.

10.4.3 Regarding subsampling, the previously discussed logic for field sampling (see 10.3) is applicable also for the generation of analytical subsamples. Knowledge of concentration distributions within the waste can be used to simplify subsampling by considering the following:

10.4.3.1 Using process knowledge or the results of testing to eliminate any waste components or strata that do not contribute significantly to the concentration of the target compound;

10.4.3.2 Using process knowledge or the results of testing to discriminate against large items, and only select small items when small items represent the waste, as well as the large items; and

10.4.3.3 Using process knowledge or the results of testing to restrict sampling to surface wipes of larger items and the extraction or digestion of fines if surface contamination is the source of the target characteristic.

10.4.4 If the approaches in 10.4.3.1 – 10.4.3.3 are not applicable to a field sample, the field sample will have to be subjected to particle size reduction (PSR) prior to subsampling or the sample preparation method will have to be modified to accommodate the entire field sample.

NOTE 2—Prior to modifying a sample preparatory method, it is advisable to consult the end user of the data to see if modifications could have any adverse effects. For example, PSR could dramatically alter leaching data.

10.4.5 The PSR is useful for handling field samples, which have items too large for proper representation in an analytical subsample. The intent of PSR is to decrease the maximum item size of the field sample so that the field sample then can be split or subsampled, or both, to generate a representative subsample. The difficulties in applying PSR to waste samples are the following:

10.4.5.1 Not all materials are easily amenable to PSR (for example, stainless steel artifacts);

10.4.5.2 Adequate PSR capabilities and capacities do not exist in all laboratories;

10.4.5.3 The PSR can change the properties of material (for example, leachability);

10.4.5.4 The PSR can be a source of cross-contamination;

10.4.5.5 The PSR often is not applicable to volatile and labile compounds; and

10.4.5.6 Large mass/volumes may have to be shipped, handled, and disposed.

10.4.6 Modification of sample preparative methods can include the extraction, digestion, or leaching of much larger sample masses than specified. The advantage of this approach is that the characteristic of interest from a larger and more representative sample mass is dissolved into a relative homogeneous extract or digestate that is more suitable for subsampling. This approach is particularly important for volatile organic compounds that may suffer from substantial losses if subjected to PSR. For volatile organic compound analysis, larger portions of the wastes can be subjected to methanol extraction or possibly the entire field sample can be subjected to heated headspace analysis as one sample or as a series of large aliquots, or possibly the entire field sample can be preserved in the field with an equal volume of methanol or methanol/water solution.

10.5 *Modification of Analytical Method:*

10.5.1 The analytical phase of a sampling and analytical program allows another opportunity to simplify the characterization of a highly stratified waste. Examples of different classes of analytical methods are:

10.5.1.1 Screening methods,

10.5.1.2 Portable methods,

10.5.1.3 Field laboratories methods,

10.5.1.4 Nonintrusive methods,

10.5.1.5 Nondestructive methods,

10.5.1.6 Innovative methods, and

10.5.1.7 Fixed laboratory methods.

10.5.2 Screening, portable, and field laboratory methods have the distinct advantage that they allow for the cost-effective analysis of more samples. These methods generate more data, making it easier to detect correlations between concentration levels and waste strata or components. Also, some screening methods may analyze a larger sample volume than what is traditionally analyzed in a fixed laboratory.

10.5.3 Nonintrusive methods (for example, geophysical methods) can be useful when there are health and safety issues regarding exposure to the waste. These methods also may be used to evaluate large-volume wastes qualitatively or semi-quantitatively.

10.5.4 Nondestructive methods are useful in that the integrity of the samples is maintained for additional analyses or evidence, or both.

10.5.5 Innovative methods may provide more cost-effective or timely results or improve sensitivity or accommodate larger and more representative sample sizes.

10.5.6 Fixed laboratory methods usually have the advantage of regulatory approval, established quality assurance/quality control requirements, and often greater sensitivity than that achievable by screening, portable, or field laboratory methods.

10.6 *Modification of the Waste Handling, Treatment, Disposal Plan:*

10.6.1 If modifications to sampling, sample preparation, and analysis are not appropriate for a given waste, or are appropriate but still do not allow the objectives to be met cost effectively, then the reasoning behind the original program must be reconsidered. It may be possible to achieve the program objectives by means of an alternative approach. For example, a change in waste treatment, handling, or disposal technologies may require analysis for different characteristics or may allow for simplified sampling. Alternatively, the waste population could be defined differently by employing smaller remediation or exposure units that would be sampled separately as opposed to characterizing the entire population. The need behind the waste characterization objectives has to be examined and an approach for simplifying the characterization process devised. This process is addressed in the optimization step of the planning process.

10.6.2 For example, consider a hypothetical waste that must be evaluated prior to waste disposal to determine if it is hazardous. An initial attempt to characterize the waste failed to meet the objective, indicated that the waste was highly stratified, and proved that portions of the waste are hazardous. After reviewing this preliminary information and the costs to attempt a defensible characterization of the waste, it could be decided that it is resourceful and cost effective to consider all the waste hazardous and treat it as a hazardous waste by incineration. Under this scenario, the sampling and analytical requirements change, requiring simplified testing for general characteristics prior to incineration, and more comprehensive analysis of the less heterogeneous and more easily sampled incinerator ash to determine if it is within compliance.

10.7 *Changing Objectives*—If the project objectives are not met and none of the strategies can be changed or modified, the objectives need to be reconsidered. After changing the objectives, the sampling and analysis plans also should be adjusted. These iterations will continue until the project objectives can be met.

11. Keywords

11.1 analysis; heterogeneity; homogeneity; nonrandom; populations; random; sample preparation; samples; sampling; strata; stratified; stratum

ANNEX

(Mandatory Information)

A1. DISCUSSION OF HETEROGENEITY AND STRATIFICATION OF WASTES AND RELATIONSHIP OF SAMPLES AND POPULATIONS

A1.1 *Introduction*—This annex contains a practical non-mathematical discussion of issues pertinent to heterogeneous waste sampling. The discussion deals with heterogeneity, stratification, and the relationship of samples and populations in sampling design. It is consistent with sampling theory and statistics and may serve as an introduction to the statistical treatment of sampling issues (**2-10**). The content of this annex is applicable to the sampling of wastes regardless of their degree of heterogeneity.

A1.2 *Population Attributes:*

A1.2.1 A population is the total collection of items to be studied. Theoretically, the classification of a population as being homogeneous or heterogeneous is straightforward. If all of the items in the population are identical, then the population is homogeneous. If one or more of the items are dissimilar, the population is heterogeneous. Theoretical homogeneity, the equivalent to nonheterogeneity, is a unique state of absolute uniformity for all items in the population, while heterogeneity