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Standard Guide for Evaluating Asbestos in Dust on Surfaces by Comparison Between Two Environments[1]

This standard is issued under the fixed designation D7390; 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 There are multiple purposes for determining the loading of asbestos in dust on surfaces. Each particular purpose may require unique sampling strategies, analytical methods, and procedures for data interpretation. Procedures are provided to facilitate application of available methods for determining asbestos surface loadings and/or asbestos loadings in surface dust for comparison between two environments. At present, this guide addresses one application of the ASTM surface dust methods. It is anticipated that additional areas will be added in the future. It is not intended that the discussion of one application should limit use of the methods in other areas.

1.2 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* For specific warning statements, see 5.7.

1.3 *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]

D5755 Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Structure Number Surface Loading

~~D5756 Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Mass Surface Loading (Withdrawn 2017)~~[3]

[1] This guide is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.07 on Sampling and Analysis of Asbestos.

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[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.

D6480 Test Method for Wipe Sampling of Surfaces, Indirect Preparation, and Analysis for Asbestos Structure Number Surface Loading by Transmission Electron Microscopy
~~D6620 Practice for Asbestos Detection Limit Based on Counts~~
~~E105 Practice for Probability Sampling of Materials~~
~~E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process~~
E456 Terminology Relating to Quality and Statistics
E2356 Practice for Comprehensive Building Asbestos Surveys
~~2.2 *Other Document:*~~
~~Environmental Protection Agency, U.S. (EPA), (Pink Book) Asbestos in Buildings: Simplified Sampling Scheme for Surfacing Materials, EPA 560/5/85/030A, U.S. Environmental Protection Agency, Washington, DC, 1985~~[4]

3. Terminology

3.1 *Definitions*—Unless otherwise noted all statistical terms are as defined in Terminology E456.

3.1.1 *activity generated* ~~*aerosol—*~~*aerosol, n—*a dispersion of particles in air that have become airborne due to physical disturbances such as human activity, sweeping, airflow, etc.

3.1.2 *background* ~~*samples—*~~*samples, n—*samples taken from surfaces that are considered to have concentrations of asbestos in surface dust that are representative of conditions that exist in an environment that is affected by only prevailing conditions and has not experienced events, disturbances or activities unusual for the environment.

3.1.3 ~~*control—*~~*control, n—*an area that is used as the basis for a comparison. ~~This could be an area where the dust has been previously characterized, an area thought to be suitable for occupancy, an area that has not experienced a disturbance of asbestos-containing materials, or that is for some other reason deemed to be suitable as the basis for a comparison.~~

3.1.3.1 *Discussion—*

This could be an area where the dust has been previously characterized, an area thought to be suitable for occupancy, an area that has not experienced a disturbance of asbestos-containing materials, or that is for some other reason deemed to be suitable as the basis for a comparison.

3.1.4 *control* ~~*samples—*~~*samples, n—*samples collected for comparison to the study samples. ~~These differ from background samples in that they are collected: either: in an area where the dust has been previously characterized, or in an area that has not experienced a disturbance of asbestos-containing materials, or in an area that is for some other reason deemed to be suitable as the basis for comparison.~~

3.1.4.1 *Discussion—*

These differ from background samples in that they are collected: either: in an area where the dust has been previously characterized, or in an area that has not experienced a disturbance of asbestos-containing materials, or in an area that is for some other reason deemed to be suitable as the basis for comparison.

3.1.5 ~~*dust—*~~*dust, n—*any material composed of particles in a size range of <1 mm.

3.1.6 ~~*environment—*~~*environment, n—*well defined three-dimensional area and everything that is in it.

3.1.7 *homogeneous* ~~*samples—*~~*samples, n—*group of samples that are collected from surfaces that are visually similar in texture, dust loading and environment.

3.1.8 *laboratory* ~~*blank—*~~*blank, n—*a cassette or wipe taken from laboratory stock that are not affected by field activities.

3.1.9 ~~*loading—*~~*loading, n—*quantity of asbestos in the dust found on a surface as measured by the ASTM standard methods for evaluating asbestos in dust on surfaces.

3.1.10 *open field* ~~*blank—*~~*blank, n—*cassette or wipe opened in the field as if for sample collection and then immediately ~~closed. This blank~~ closed that is analyzed in the same manner as a regular sample.

3.1.11 ~~*power—*~~*power, n—*power of the test is the probability, expressed as a decimal fraction, that a specified difference between asbestos surface loadings in two environments will be detected by the test.

3.1.12 ~~*replicates—*~~*replicates, n—*samples collected from an area that is visually identified as homogeneous.

3.1.13 *sampling* ~~*set—*~~*set, n—*samples collected on the same day on surfaces in an area for the purpose of characterizing the asbestos loading in the dust of the samples surfaces in that area.

3.1.14 *sealed field* ~~*blank—*~~*blank, n—*cassette or wipe taken to the field but remaining closed at all times.

3.1.15 *study samples—samples, n—*samples collected in an area believed to have experienced events, disturbances or activities affecting asbestos-containing materials. The area in which these samples are taken is called the study area. Study samples are compared to background samples or control samples.

3.1.15.1 *Discussion—*

The area in which these samples are taken is called the study area. Study samples are compared to background samples or control samples.

4. Summary of Guide

4.1 The guidance contained in this document was developed for applications of Test Methods D5755, D5756, and D6480. The application addressed in this document is sampling to test for differences in surface loading in two or more environments including comparison to environments that may be considered to be "background."

4.2 Factors affecting the selection of sampling sites and types of samples to be collected are described in Appendix X1. These factors include:

4.2.1 Uniformity and distribution of dust within a building,
4.2.2 The nature of dust found within buildings,
4.2.3 The nature of the surface from which samples are to be collected,
4.2.4 Past disturbances of asbestos-containing materials,
4.2.5 Environmental conditions,
4.2.6 Ventilation,
4.2.7 Building history,
4.2.8 Occupation and activity of occupants, and
4.2.9 Outdoor sampling.

4.3 This guide describes statistical procedures to be used for:

4.3.1 Defining sampling needs including the size, number and location of samples required to address a particular application; and

4.3.2 Interpreting analytical results—estimating loadings or loadings from single or multiple-sample results, establishing confidence intervals for such estimates, and comparing between such estimates.

5. Significance and Use

5.1 This guide describes factors to be considered by an investigator designing a sampling program to compare the asbestos dust loadings in two environments and presents statistical methods for making the comparison. Each user is responsible for the design of an investigation and the interpretation of data collected when using dust data.

5.2 This guide does not deal with situations where dusts of different compositions or from different surfaces are to be evaluated.

5.3 This guide describes methods for interpreting the results of sampling and analysis performed in accordance with Test Methods D5755, D5756, and D6480. It may be appropriate to use the procedures in this Guideguide with other dust collection and analysis methods, but it is the responsibility of the user to make this determination.

5.4 The methods described in this guide are not intended to be used alone. They are intended to be used along with various evaluation methods that may include consideration of building use, activities within the building, air sampling, asbestos surveys (refer to Practice E2356), evaluation of building history and study of building ventilation systems.

5.5 This guide describes methods for comparing environments and does not draw any conclusions relating asbestos surface loadings to the potential safety or habitability of buildings.

5.6 This guide does not address risk assessments or the use of dust sampling in risk assessment. Health based risk assessments are beyond the scope of this guide.

5.7 **Warning—**Asbestos fibers are acknowledged carcinogens. Breathing asbestos fibers can result in disease of the lungs including asbestosis, lung cancer, and mesothelioma. Precautions should be taken to avoid creating and breathing airborne asbestos particles when sampling and analyzing materials suspected of containing asbestos. Regulatory requirements addressing asbestos are defined by USEPA[3,4] and OSHA.[5]Asbestos fibers are acknowledged carcinogens. Breathing asbestos fibers can result in disease of the lungs including asbestosis, lung cancer, and mesothelioma. Precautions should be taken to avoid creating and breathing airborne asbestos particles when sampling and analyzing materials suspected of containing asbestos. Regulatory requirements addressing asbestos are defined by USEPA: and OSHA.

[3] USEPA, 40 CFR Part 61, Subpart M.
[4] USEPA, 40 CFR Part 763, Subpart E.
[5] OSHA, 29 CFR Parts 1910, 1915, and 1926.

6. Comparison Between Environments

6.1 One use of dust sampling is to compare the asbestos dust loadings on surfaces in two environments. This ~~Guide~~guide describes ~~two~~several ways in which such a comparison might be made. The user should consider these and other site-specific factors in Appendix X1, Factors Affecting Sample Collection, that may affect the interpretation of results and the need to proceed beyond the Baseline Calculations in Section 7.

6.1.1 *Comparison to Background Samples*—If one environment is considered to represent conditions that are typical of a building this could be used as the source of background samples against which study samples from areas in questions could be compared. Areas may be in question due to disturbance of an asbestos-containing material, damage to the building materials, change in occupancy or any other occurrence that could change the asbestos loading in dust.

~~6.1.2 *Comparison to Control*—One environment may be taken as a "Control" against which to compare study samples from other environments. For example, samples collected in a building to which cleaned items are to be delivered might be used as control samples. Samples collected on cleaned items would then be compared to these Control samples to determine if the cleaned items could be released for delivery.~~

6.2 *Sample Collection Requirements:*

6.2.1 *Homogeneous Dust*—A visual determination should be made about the homogeneity of the dust and ~~sample~~ site to be sampled. Samples ~~in each environment~~ should be collected from homogeneous ~~locations.~~ locations within each area—study and background. A location is considered to be homogeneous if:

6.2.1.1 The sample sites have visually similar depositions of dust on their ~~surfaces.~~surfaces, including the absence of visible dust.

6.2.1.2 The surfaces to be sampled have the same type of surface texture based upon a visual determination.

~~6.2.1.3 The efficiency of dust collection on a given surface is likely to be different for wipe and microvacuum methods (see Crankshaw et al, Ref (**1**)).[8] As such, the same sample collection method should be used for samples that are to be compared.~~

~~NOTE 1—If the laboratory reports comparing two areas indicate that the analytical sensitivities, particle sizes or structure types for any sample or a group of samples differ greatly from the balance of the samples, then this could indicate that the dust in the areas selected was not homogeneous. In these instances other methods of comparison may be considered.~~

6.2.2 The efficiency of dust collection on a given surface is likely to be different for wipe and microvacuum methods (see Crankshaw et al. (**1**)[6]). As such, the same sample collection method should be used for samples that are to be compared.

6.3 *Selection of Sampling Locations:*

6.3.1 ~~*Random Sampling*—~~*Representative Locations*—Samples should be collected from locations ~~that are selected at random from all available locations in the environment~~and surfaces that are representative of the environments to be tested. ~~Genuinely random procedure such as the grid and random number procedure set forth in the USEPA Pink Book, coin tosses, or a random number table are acceptable for this purpose.~~In the study area proximity to sources of asbestos fiber release may be a consideration.

~~6.3.1.1 In situations in which accessibility for sampling is limited the general location of samples should be determined by random means and the specific sample site determined by accessibility within the randomly selected area. The dust at the specific sampling site should be visually evaluated to determine if it is representative of conditions prevailing in the environment.~~

6.3.2 Depending on the configuration of the sampling site and surfaces to be sampled, it may be possible to randomize the selection of sampling locations with a random number table or other means. Accessibility of sites for sampling may be limited by safety, security, or other considerations.

6.4 ~~A sufficient number of samples need to be collected to be able to discern differences that may exist between the environments. The Annex describes methods for determining the number of samples necessary to accomplish this goal. The number of samples required depends, in part, upon the sensitivity of the analysis. As this sensitivity will not be known until the analysis is complete it is prudent to collect additional samples in case the sensitivity of actual samples does not match preliminary estimates used in planning the sampling.~~*Number of Samples:*

6.4.1 A sufficient number of samples should be collected to be able to discern differences that may exist between the study area and background area. For the examples of Baseline Calculations in Section 7 this number is defined as five study samples and, where taken, five background samples. Cost and accessibility being factors that affect the number of samples taken, this combination of sample sets is seen as the minimum from which a reasonable comparison of results may be made. If the user cannot do so, additional samples or statistical tests as described in Appendix X2 may be considered.

~~6.5 *Sampling and Analytical Requirements:*~~

~~6.5.1 Collect and analyze samples as described in Test Methods D5755, D5756, or D6480.~~

6.5 ~~*Quality Control*~~ *Sampling and Analytical* *Requirements:*

6.5.1 Collect and analyze samples as described in Test Methods D5755 and D6480.

6.5.2 ~~*Blanks*—~~*Quality Control Requirements*—The following blanks should be collected as part of the sampling:

6.5.2.1 A sealed field blank per lot of cassettes or wipes.

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

6.5.2.2 One open field blank for each ~~ten samples (a minimum of~~ set of five study samples and one open field blank ~~per environment sampled).~~for each set of five background samples, if taken.

6.5.2.3 Blanks should be sent to the laboratory for analysis in the same manner as a regular sample. Blanks need not be analyzed if no asbestos is found in the study samples or background samples. If asbestos is found ~~in the study samples the~~ the "Open Field Blanks" should be analyzed. If asbestos is found on the "Open Field Blanks," then the "Sealed Field Blanks" should be analyzed. If no asbestos is found on the "Open Field Blank" there is no need to analyze the sealed blanks. If any blank is found to contain more than the limit set forth in the section on blanks in the appropriate method then the sampling may be considered to be suspect. Do not adjust the sample results with the results of the blank filter analyses.

6.6 *Data Interpretation:*

6.6.1 For each sample set the Analytical Parameters tabulated for the examples in Section 7 should be extracted from the laboratory report. For each sample the number of asbestos structures counted, analytical sensitivity of the analysis, and surface loading should be entered in the tables for the study samples and background samples. Where both study samples and background samples are taken, the upper and lower 95 % confidence limits (95 % combined upper confidence limit (95 % UCL) and 95 % combined lower confidence limit (95 % LCL)) can be calculated for the background samples and study samples, respectively, using the procedures in Section 7. The example most descriptive of the user's investigation should be used as a guide.

6.6.2 For each sample set the Combined Measurements tables in Section 7 should be completed according to the instructions provided. Where both study samples and background samples are taken, if the 95 % LCL of the study samples is less than the 95 % UCL of the background samples the distributions overlap, indicating no statistical difference.

6.6.3 Where no background samples are taken, Section 7 presents appropriate comparisons from which the user may also draw reasonable inferences. After reviewing the results of the study sample analyses and, in consultation with the laboratory, the user may want to dispense with analysis of the background samples if the information from them would not justify the cost or time required.

6.6.4 If the overlap or separation of the confidence intervals is small the Baseline Calculations in Section 7 may be augmented with other statistical tests described in Appendix X2 to confirm the conclusion.

6.7 ~~*Data Interpretation:*~~ *Asbestos Structure Types and Sizes:*

~~6.7.1 For each sample the number of asbestos structures counted, analytical sensitivity of the analysis, and asbestos loading should be extracted from the laboratory reports. The upper and lower 95 % confidence limits should be calculated using the procedures in Annex A1. Refer to Note 1 in 6.2.1.3 regarding analytical sensitivity.~~

~~6.7.1.1 For each group of samples for an environment the procedures of Annex A1 should be applied to the data in 6.7.1 to calculate the total asbestos structures counted, sum of sensitivity weights, and estimate of asbestos loading for the environment along with upper and lower 95 % confidence limits on this estimate.~~

~~6.7.2 There are two ways to make a decision about whether there is a difference between two areas. The first of these is to simply compare the confidence limits of the two sets of samples. If this comparison shows that the two sets of samples are clearly the same, or are clearly different then no further comparison is required. However, if there is a question about the comparison of the confidence limits or this comparison is inconclusive a Z-test may clarify the issue.~~

~~6.7.2.1 If the confidence limits of the sample sets from two homogeneous areas overlap then the two areas can be considered to have the same asbestos loading in the dust on the sampled surfaces. If the confidence limits do not overlap then the asbestos loadings are different. Confidence limits are considered to be overlapped if the upper confidence limit of group of samples with the lower estimated mean exceeds the lower confidence limit of the group of samples with the higher estimated mean. This simple test may be augmented with other statistical tests to confirm the conclusion. This is particularly appropriate if the overlap or separation of the confidence intervals is small. Refer to Annex A1 for more information on the use of confidence limit comparison.~~

~~6.7.2.2 Another way of making a comparison is with the Z-test. Annex A1 describes a statistical test using a normal distribution approximation and a Z-test.~~

~~6.7.2.3 If the statistical tests in 6.7.2.1 and 6.7.2.2 give conflicting results then it is recommended that additional samples be collected to clarify the situation.~~

6.7.1 ~~Consideration of the mineral form~~The mineral form(s) of the asbestos found during analysis of ~~settled dust samples may help with interpretation of the data.~~ dust samples should be considered. If the mineral form of the asbestos ~~in the two sets of samples (study samples and control or background samples) is different, the sites cannot be considered equivalent in terms of dust loadings and additional investigation may be necessary.~~within or between sample sets (study and background) differs, the user shall consider the impact on the interpretation of the data and the decisions derived therefrom.

~~Note 2—If the size or type of asbestos structures differs between the study samples and control or background samples this also may indicate a difference in the dust loadings at each site. For example, if one set of samples consists of small fibers and the other set has large matrices, then these areas would appear to be different. As such, additional investigation may be necessary in such an instance, even if statistical analysis of the number or mass of particles finds no difference between the sites.~~

6.7.2 If the size or type of asbestos structures differs between the study samples and background samples this also may indicate a difference in the dust loadings at each site. For example, if one set of samples consists of small fibers and the other set has large matrices, then these areas would appear to be different. As such, additional investigation may be necessary in such an instance, even if statistical analysis of the number or mass of particles finds no difference between the sites.

6.8 *Reporting:*

6.8.1 The user's report should contain sufficient information to allow the reader to locate the sampling sites, and repeat the sampling. sampling if conditions permit.

6.8.2 The complete data set should be reported, including results of blanks and background samples.

6.8.2.1 For each sample the number of asbestos structures, analytical sensitivity, asbestos loading and upper and lower 95 % confidence limits on the asbestos loading should be tabulated.tabulated according to the examples and procedures in Section 7.

6.8.2.2 For each group Combined Set of samples for a homogeneous environment the total asbestos structures counted, sum of sensitivity weights, and estimate of asbestos loading for the environment along with upper and lower 95 % confidence limits on this estimate should be reported.tabulated according to the examples and procedures in 7.

6.8.2.3 The If statistical tests other than those in Section 7 are used, the type of statistical comparisons and results of these comparisons should be given.

6.8.3 Laboratory reports should be included as an appendix to the report.

6.9 *Example 1*—The following example illustrates application of the procedures described in this guide.

6.9.1 *Situation*—An uncarpeted 20 by 20-ft storage room that has a visible layer of dust which is suspected to have come from known asbestos-containing material in the room. This area is designated as the study area.

6.9.2 *Choice of Analytical Method*—Any of the ASTM asbestos dust sampling methods could be used for this example. For the sake of illustration it is assumed that the investigator chose to use structure number loading from microvacuum collection (Test Method D5755) due to familiarity with this method.

6.9.3 In this example a background area in the same facility was chosen that matched the study area closely in its configuration, construction, use, and occupancy. This included type of surface area. The chosen area was in the same portion of the facility as the study area so it shared a common history, but was remote enough that it would not have been affected by a disturbance in the study area. Generally a study area will be selected that is considered to be acceptable for occupancy.

6.9.4 *Determination of Sample Number*—The table in A1.8.2 was used to determine the number of samples to be collected in each environment. The surfaces were relatively clean so it was assumed that the analytical sensitivity of the analysis would be no greater than 2000 s/cm^2. It was hypothesized that the loading in the study area would be about 5000 and in the background area would be around 1000 s/cm^2. The same number of samples will be collected in each area. For these conditions the table indicates that 5 samples will be needed in each area.

6.9.5 *Selection of Sampling Locations*—Both the study and background area contained bookshelves. There was visible dust on the shelves in the study area that was thought to have come from the disturbance of ACM. The book shelves in both locations were constructed of painted wood and as such are expected to have similar sample collection characteristics. The bookshelves were selected as the sample location.

6.9.5.1 Each individual shelf was given an identification number. Five shelves in each location were selected by use of a random number table. Samples were collected prior to routine cleaning of the study area.

6.9.6 *Quality Control*—In this example a sealed field blank was selected for the building, one field blank was taken for the study area, and one field blank was taken for the background area.

6.9.7 *Interpretation of Analytical Data*—Tables 1-3 give data from a hypothetical laboratory report and the calculations of the upper and lower 95 % confidence limits as described in Annex A1.

6.9.7.1 In Table 3 the measurements are combined into a weighted average as described in Annex A1. As described in 6.7.2.1 the confidence limits of the study area are compared to the confidence limits for the background area. The confidence limit of the samples for the study area and the background area overlap indicating, as described in 6.7.2.1, that there is no statistical difference between the areas.

6.9.7.2 Inspection of the data in Table 3 finds that there is substantial overlap between the confidence limits for the study area and background area. It is decided that no further statistical testing in necessary.

(1) Example 1 is based on the hypothetical laboratory parameters (see Table 2) as would be found in reports from Test Methods D5755, D5756, and D6480. These parameters are typical for a nominal analytical sensitivity equal to 200 s/cm^2.

(2) To compare these two environments the sensitivity weights of the individual measurements are added together and a "Weighted Analytical Sensitivity" is calculated by taking the reciprocal of the "Sum of Sensitivity Weights." The "Estimate" of the concentration in each space is calculated by multiplying the "Weighted Analytical Sensitivity" by the "Total Structures" counted in the space. The 95 % upper and lower confidence limits for this estimate are calculated in the same manner as was used for the individual measurements.

Note—Refer to Practice D6620 for information on dealing with situations where there are zero structure counts.

(3) As can be seen by inspection of Table 3 the confidence limits for the study area and the background area overlap. As such there is not a statistically significant difference between the asbestos loadings in the two locations.

6.10 *Example 2*—Table 4 presents hypothetical results for the same situation described in Example 1 but where there was a need to perform serial dilutions during the analysis resulting in higher value for the analytical sensitivity for two of the samples from the study area. This affects the spread of the confidence limits resulting in broader confidence limits for the study area. As with example 1 the calculation procedures from Annex A1 have been applied. The laboratory parameters for this set of evaluations are given in Table 5.

6.10.1 Comparison of the 95 % confidence limits in Table 6 finds that there is an overlap of the confidence intervals. The simple confidence limit test of 6.7.2 thus indicates that there is no statistical difference between the two environments. This is despite the fact that the estimated asbestos loadings in the two environments appear substantially different. The 3508 s/cm^2 in the Study Area appears higher than the 2133 s/cm^2 in the Background Area. Closer inspection of the data in Table 6 discovers that the overlap between the 95 % confidence limits is small. At 2796 s/cm^2 the 95 % UCL for the Background Area overlaps the 2620 s/cm^2 for the 95 % LCL for the Study Area by only 157 s/cm^2. It is decided that additional statistical testing using the Z-test is appropriate.

6.10.2 Application of the Z-test procedure described in A1.4.3 results in a Z of 2.5 and a p-value of <0.012 which indicates that there is a significant difference between the environments.

6.10.2.1 The p-value for the Z-statistic should be reported. The convention is to conclude that the levels in the two areas being compared are different if the p-value is 0.05 or less. The p-value is the probability of a Type I error (false positive outcome) and should be judged accordingly for decision-making based on the consequences of a Type I error, as interpreted by the individual conducting the test.

6.10.3 The conflict between the results of the two tests likely arises from the fact that the actual analytical sensitivities for samples from the study area exceed the 2,000 estimated when a determination was made about the number of samples required. Based on these results it is recommended that additional samples be collected to resolve the conflict. The number of additional samples can be calculated by using the equation in A1.8.1 of Annex A1.

6.10.3.1 The additional number of samples should be determined using the procedures described in A1.8 of the Annex using sensitivities that are equal to the average of the observed sensitivities in the initial sampling.

(1) Example 2 is based on the hypothetical laboratory parameters (see Table 5) as would be found in reports from Test Methods D5755, D5756, and D6480.

(2) To compare these two environments the sensitivity weights of the individual measurements are added together and a "Weighted Analytical Sensitivity " is calculated by taking the reciprocal of the "Sum of Sensitivity Weights." The "Estimate" of the concentration in each space is calculated by multiplying the "Weighted Analytical Sensitivity" by the "Total Structures" counted in the space. The 95 % upper and lower confidence limits for this estimate are calculated in the same manner as was used for the individual measurements. The results of these calculations are shown in Table 6.

(3) As can be seen by inspection of Table 6 the 95 % upper confidence limit of the background area (2797) is higher than the 95 % lower confidence limit of the study area (2620) indicating that there is not a statistically significant difference between the asbestos loadings in the two locations. However, the overlap is small.

(4) The Z-test calculations were performed as described in the Annex with the results given in Table 7.

7. Examples of Baseline Calculations

7.1 Each of the eight examples in this section illustrates the calculation procedures to compare study samples to background samples or other criteria. The examples describe typical scenarios encountered in settled dust sampling and analysis for asbestos, and have the following attributes.

7.1.1 All examples are based on five study samples and, where applicable, five background samples.

7.1.2 The tables in each example illustrate separately calculations for the individual study samples and, where applicable, the individual background samples, followed by calculations for the combined study samples and, where applicable, the combined background samples, then comparing the distributions of the combined sample sets.

7.1.3 The combined sample sets are compared by calculating the 95 % Lower Confidence Limit (95 % LCL) of the study samples to the 95 % Upper Confidence Limit (95 % UCL) of the background samples. If the confidence limits overlap the user can reasonably conclude that there is no significant statistical difference at the 95 % confidence level.

7.1.4 Test Method D5755 directs the analyst to "stop on grid opening No. 10 or the grid opening which contains the 100th asbestos structure, whichever comes first." It is not uncommon for the analyst to identify 100 asbestos structures before counting ten grid openings. If that happens with one or more of the study samples the 95 % LCL will far exceed the 95 % UCL of background samples taken in an uncontaminated background environment. The user may conclude that there is a statistical difference between surface loadings in the study and uncontaminated background areas, and dispense with the collection or analysis of background samples. No calculations are needed to support this decision.

7.2 These calculations may suffice for the user to make a decision based on the results or may be considered an initial screening to be followed by additional sampling and analysis, or the application of further statistical tests as described in Appendix X2.

7.3 The 95 % LCL and 95 % UCL are determined from the Poisson distribution in Table 1. For each number of structures, N, the 95 % LCL and 95 % UCL in Table 1 have been calculated by the following formulas: (IF(N>0,(CHIINV(0.975,2·N)/2),0)) for the 95% LCL and (IF(N>0,(CHIINV(0.025,2·(N+1))/2),(CHIINV(0.05,2)/2))) for the 95% UCL.

7.3.1 The 95 % LCL and 95 % UCL in Table 1 refer to the number of structures at these limits, not the surface loading, which is calculated from the analytical parameters as shown in the examples.

TABLE 1 ~~Example 1—Hypothetical Dust Sample Results~~

~~Study Area~~						~~Background Area~~					
~~Number of Structures~~	~~Analytical Sensitivity (s/cm²)~~	~~Sensitivity Weights~~	~~Result (s/cm²)~~	~~95 % LCL (s/cm²)~~	~~95 % UCL (s/cm²)~~	~~Number of Structures~~	~~Analytical Sensitivity (s/cm²)~~	~~Sensitivity Weights~~	~~Result (s/cm²)~~	~~95 % LCL (s/cm²)~~	~~95 % UCL (s/cm²)~~
~~6~~	~~205.1~~	~~0.0049~~	~~1231~~	~~452~~	~~2679~~	~~4~~	~~205.1~~	~~0.0049~~	~~820~~	~~224~~	~~2101~~
~~4~~	~~205.1~~	~~0.0049~~	~~820~~	~~224~~	~~2101~~	~~5~~	~~205.1~~	~~0.0049~~	~~1026~~	~~333~~	~~2393~~
~~7~~	~~205.1~~	~~0.0049~~	~~1436~~	~~577~~	~~2958~~	~~6~~	~~205.1~~	~~0.0049~~	~~1231~~	~~452~~	~~2679~~
~~2~~	~~205.1~~	~~0.0049~~	~~410~~	~~−50~~	~~1482~~	~~4~~	~~205.1~~	~~0.0049~~	~~820~~	~~224~~	~~2101~~
~~3~~	~~205.1~~	~~0.0049~~	~~615~~	~~127~~	~~1798~~	~~6~~	~~205.1~~	~~0.0049~~	~~1231~~	~~452~~	~~2679~~

TABLE 1 Upper and Lower 95 % Confidence Limits for the Poisson Distribution

N = Number of Structures			N = Number of Structures			N = Number of Structures			N = Number of Structures		
N	95 % LCL	95 % UCL	N	95 % LCL	95 % UCL	N	95 % LCL	95 % UCL	N	95 % LCL	95 % UCL
0	0.000	3.0	50	37.1	65.9	100	81.4	122	150	127	176
1	0.025	5.6	51	38.0	67.1	101	82.3	123	151	128	177
2	0.24	7.2	52	38.8	68.2	102	82.3	124	152	129	178
3	0.62	8.8	53	39.7	69.3	103	84.1	125	153	130	179
4	1.1	10.2	54	40.6	70.5	104	85.0	126	154	131	180
5	1.6	11.7	55	41.4	71.6	105	85.9	127	155	132	181
6	2.2	13.1	56	42.3	72.7	106	86.8	128	156	132	182
7	2.8	14.4	57	43.2	73.9	107	87.7	129	157	133	184
8	3.5	15.8	58	44.0	75.0	108	88.6	130	158	134	185
9	4.1	17.1	59	44.9	76.1	109	89.5	131	159	135	186
10	4.8	18.4	60	45.8	77.2	110	90.4	133	160	136	187
11	5.5	19.7	61	46.7	78.4	111	91.3	134	161	137	188
12	6.2	21.0	62	47.5	79.5	112	92.2	135	162	138	189
13	6.9	22.2	63	48.4	80.6	113	93.1	136	163	139	190
14	7.7	23.5	64	49.3	81.7	114	94.0	137	164	140	191
15	8.4	24.7	65	50.2	82.8	115	94.9	138	165	141	192
16	9.1	26.0	66	51.0	84.0	116	95.9	139	166	142	193
17	9.9	27.2	67	51.9	85.1	117	96.8	140	167	143	194
18	10.7	28.4	68	52.8	86.2	118	97.7	141	168	144	195
19	11.4	29.7	69	53.7	87.3	119	98.6	142	169	144	196
20	12.2	30.9	70	54.6	88.4	120	99.5	143	170	145	198
21	13.0	32.1	71	55.5	89.6	121	100	145	171	146	199
22	13.8	33.3	72	56.3	90.7	122	101	146	172	147	200
23	14.6	34.5	73	57.2	91.8	123	102	147	173	148	201
24	15.4	35.7	74	58.1	92.9	124	103	148	174	149	202
25	16.2	36.9	75	59.0	94.0	125	104	149	175	150	203
26	17.0	38.1	76	59.9	95.1	126	105	150	176	151	204
27	17.8	39.3	77	60.8	96.2	127	106	151	177	152	205
28	18.6	40.5	78	61.7	97.3	128	107	152	178	153	206
29	19.4	41.6	79	62.5	98.5	129	108	153	179	154	207
30	20.2	42.8	80	63.4	99.6	130	109	154	180	155	208
31	21.1	44.0	81	64.3	101	131	110	155	181	156	209
32	21.9	45.2	82	65.2	102	132	110	157	182	157	210
33	22.7	46.3	83	66.1	103	133	111	158	183	157	212
34	23.5	47.5	84	67.0	104	134	112	159	184	158	213
35	24.4	48.7	85	67.9	105	135	113	160	185	159	214
36	25.2	49.8	86	68.8	106	136	114	161	186	160	215
37	26.1	51.0	87	69.7	107	137	115	162	187	161	216
38	26.9	52.2	88	70.6	108	138	116	163	188	162	217
39	27.7	53.3	89	71.5	110	139	117	164	189	163	218
40	28.6	54.5	90	72.4	111	140	118	165	190	164	219
41	29.4	55.6	91	73.3	112	141	119	166	191	165	220
42	30.3	56.8	92	74.2	113	142	120	167	192	166	221
43	31.1	57.9	93	75.1	114	143	121	168	193	167	222
44	32.0	59.1	94	76.0	115	144	121	170	194	168	223
45	32.8	60.2	95	76.9	116	145	122	171	195	169	224
46	33.7	61.4	96	77.8	117	146	123	172	196	170	225
47	34.5	62.5	97	78.7	118	147	124	173	197	170	227
48	35.4	63.6	98	79.6	119	148	125	174	198	171	228
49	36.3	64.8	99	80.5	121	149	126	175	199	172	229

~~where:~~
~~Number of Structures = The number of structures counted as contained in the report from the analysis.~~
~~Analytical Sensitivity = The concentration represented by a single count as contained in the report from the analysis.~~
~~Sensitivity Weight = The reciprocal of the analytical sensitivity (1/analytical sensitivity).~~
~~Result = The "analytical sensitivity" multiplied by the "number of structures." This should equal the result reported by the analytical method.~~
~~95 % LCL = The lower 95 % confidence limit as calculated using the formulas in the Annex.~~
~~95 % UCL = The upper 95 % confidence limit as calculated using the formulas in the Annex.~~

7.3.2 The following terms are used in the tables in the examples. All of the Analytical Parameters should be in the laboratory report or available from the laboratory. (See also 3.1, Definitions.)

7.3.2.1 Effective filter area is the area of the filter on which the rinse solution aliquot is deposited for TEM analysis. It is not the area of the filter in the sample collection cassette, which is not analyzed.

7.3.2.2 Sample area is the area of the surface sampled by the user and is assumed to be 100 cm² unless the user specifies otherwise. It may vary for different samples.

7.3.2.3 Volume filtered is the volume of the rinse solution aliquot deposited on the filter for TEM analysis. It may vary for different samples.

7.3.2.4 Analytical Sensitivity is the surface loading calculated on the basis of finding one structure in the sample and is a function of the analytical parameters. It may vary for different samples.

7.3.2.5 Number of Structures is the total number counted in all grid openings for the sample according to the counting rules of the analytical method.

7.3.2.6 Sensitivity Weight is the reciprocal of the Analytical Sensitivity for each sample.

7.3.2.7 Structures 95 % LCL is the lower 95 % confidence limit of the study samples and Structures 95 % UCL is the upper 95 % confidence limit of the background samples, based on the Poisson distribution in Table 1. (See 7.3.)

7.4 *Example 1 — Study Samples Exceed Background Sample but No Statistical Difference* (Tables 2-6):

7.4.1 Example 1 illustrates a hypothetical situation where a contractor scraped off small sections of asbestos-containing fireproofing on one floor of an office building. The work was done at several locations and when the error was discovered the area was cleaned up using a high efficiency particulate air filtered vacuum cleaner and wet wiping of all surfaces. The building owner demanded the air and surfaces in the affected area be at least as clean as other parts of the building not affected. To answer the surface cleanliness question five samples were collected from non-porous surfaces in the affected area and five samples from another floor on a different ventilation system (unaffected or background area). The results and analysis of the data are described in Tables 2-6.

7.4.2 This example uses the analytical parameters in Table 2 that are taken from the laboratory report.

7.4.3 The analytical parameters are used to calculate the study area results in Table 3 and Table 4.

7.4.4 In Table 3:

(1) The number of structures and analytical sensitivity are taken from the laboratory report.

(2) The Estimated Loading is the product of the Number of Structures and the Analytical Sensitivity.

(3) Structures 95 % LCL is read from Table 1.

(4) Loading 95 % LCL is the product of the Structures 95 % LCL and the Analytical Sensitivity.

7.4.5 In Table 4:

(1) Total Structures is the sum of the Number of Structures in Table 3.

(2) The Sum of Sensitivity Weights is the sum of Sensitivity Weights in Table 3.

(3) The Weighted Analytical Sensitivity is the reciprocal of the Sum of Sensitivity Weights.

(4) The Estimated Loading is the product of the Total Structures and the Weighted Analytical Sensitivity.

(5) 95 % LCL Structures is read from Table 1.

(6) Loading is the product of 95 % LCL Structures and Weighted Analytical Sensitivity.

7.4.6 The same analytical parameters are used to calculate the background area results in Table 5 and Table 6.

7.4.7 The calculation procedures for the background samples in Table 5 and Table 6 are the same as for the study samples in Table 3 and Table 4. For example, Table 5 shows that a structure count of 3 for sample B1 has a 95 % UCL of 8.8 structures, giving a 95 % UCL loading of 1804 s/cm^2. In Table 6 Total Structures is the sum of the structures in Table 5.

TABLE 2 ~~Hypothetical Laboratory Parameters~~

~~Effective filter area (EFA)~~	~~923 mm²~~
~~Number of grid openings examined (GO)~~	~~10~~
~~Average grid opening area (GOA)~~	~~0.009 mm²~~
~~Sample area (SPL)~~	~~100 cm²~~
~~Total Volume~~	~~100 mL~~
~~Volume filtered (V)~~	~~50 mL~~
~~Calculated Analytical Sensitivity~~	~~205.1 s/cm²~~

TABLE 2 Analytical Parameters for Example 1

Effective filter area	923 mm²
Number of grid openings examined	10
Average grid opening area	0.009 mm²
Sample area	100 cm²
Total volume	100 mL
Volume filtered	50 mL
Analytical sensitivity	205 s/cm²

TABLE 3 Example 1—Comparison of Spaces—Combine Measurements in a Weighted Average

Study Area						Background		
Total Structures	Weighted Analytical Sensitivity (s/cm²)	Sum of Sensitivity Weights	Estimate (s/cm²)	95 % LCL (s/cm²)	95 % UCL (s/cm²)	Total Structures	Weighted Analytical Sensitivity (s/cm²)	S… Se… W…
22	41.0	0.024	902	566	1366	25	41.0	0…

TABLE 3 Study Samples for Example 1

Sample Number	Number of Structures	Analytical Sensitivity (s/cm²)	Sensitivity Weight	Estimated Loading (s/cm²)	Structures 95 % LCL (Table 1)	Loading 95 % LCL (s/cm²)
S1	10	205	0.0049	2050	4.8	984
S2	4	205	0.0049	820	1.1	226
S3	13	205	0.0049	2665	6.9	1415
S4	4	205	0.0049	820	1.1	226
S5	6	205	0.0049	1230	2.2	451

TABLE 4 Example 2—Hypothetical Dust Sample Results

Study Area						Background	
Number of Structures	Analytical Sensitivity (s/cm²)	Sensitivity Weights	Result (s/cm²)	95 % LCL (s/cm²) 95 % LCL (s/cm²)	95 % UCL (s/cm²)	Number of Structures 95 % UCL (s/cm²)	An… Se… (…
		2	205.1	0.0049	410	50	
6	205.1	0.0049	1231	452	2679	19	
15	205.1	0.0049	3077	1722	5074	2	
10	10 255.6	0.0001	102 556	49 179	188 603	10	
19	10 255.6	0.0001	194 856	117 316	304 291	6	

TABLE 4 Combined Measurements of Study Samples for Example 1

Total Structures	Sum of Sensitivity Weights	Weighted Analytical Sensitivity (s/cm²)	Estimated Loading (s/cm²)	95 % LCL	
				Structures (Table 1)	Loading (s/cm²)
37	0.024	41.0	1517	26.1	1070

TABLE 5 Background Samples for Example 1

Sample Number	Number of Structures	Analytical Sensitivity (s/cm²)	Sensitivity Weights	Loading (s/cm²)	Structures 95 % UCL (Table 1)	Loading 95 % UCL (s/cm²)
B1	3	205	0.0049	615	8.8	1804
B2	4	205	0.0049	820	10.2	2091
B3	3	205	0.0049	615	8.8	1804
B4	4	205	0.0049	820	10.2	2091
B5	6	205	0.0049	1230	13.1	2686

TABLE 6 Combined Measurements of Background Samples for Example 1

Total Structures	Sum of Sensitivity Weights	Weighted Analytical Sensitivity (s/cm²)	Estimated Loading (s/cm²)	95 % UCL	
				Structures (Table 1)	Loading (s/cm²)
20	0.024	41.0	820	30.9	1267

7.4.8 The 95 % LCL for the combined set of study samples in Table 4 — 1070 s/cm² — is less than the 95 % UCL for the background samples — 1267 s/cm² — in Table 6 . Since the distributions for the two sample sets overlap, there is no statistical difference at the 95 % confidence level.

7.5 *Example 2 — Clear Statistical Difference Between Study and Background Samples* (Tables 7-11):

7.5.1 Example 2 illustrates a hypothetical situation where a contractor scraped off small sections of asbestos-containing fireproofing on one floor of an office building. The work was done at several locations and when the error was discovered the area was cleaned up using a high efficiency particulate air filtered vacuum cleaner only. The building owner demanded the air and surfaces in the affected area be at least as clean as other parts of the building not affected. To answer the surface cleanliness question five samples were collected from non-porous surfaces in the affected area and five samples from another floor on a different ventilation system (unaffected or background area). The results and analysis of the data are described in Tables 7-11.

7.5.2 This example uses the analytical parameters in Table 7 that are taken from the laboratory report.

7.5.3 The analytical parameters are used to calculate the study area results in Table 8 and Table 9.

TABLE 7 Analytical Parameters for Example 2

Effective filter area	923 mm^2
Number of grid openings examined	10
Average grid opening area	0.009 mm^2
Sample area	100 cm^2
Total volume	100 mL
Volume filtered	50 mL
Analytical sensitivity	205 s/cm^2

TABLE 8 Study Area Samples for Example 2

Sample Number	Number of Structures	Analytical Sensitivity (s/cm^2)	Sensitivity Weight	Estimated Loading (s/cm^2)	Structures 95 % LCL (Table 1)	Loading 95 % LCL (s/cm^2)
S1	41	205	0.0049	8405	29.4	6027
S2	27	205	0.0049	5535	17.8	3649
S3	57	205	0.0049	11685	43.2	8856
S4	22	205	0.0049	4510	13.8	2829
S5	46	205	0.0049	9430	33.7	6908

TABLE 9 Combined Measurements of Study Samples for Example 2

Total Structures	Sum of Sensitivity Weights	Weighted Analytical Sensitivity (s/cm^2)	Estimated Loading (s/cm^2)	95 % LCL	
				Structures (Table 1)	Loading (s/cm^2)
193	0.024	41.0	7913	167	6847

TABLE 10 Background Area Samples for Example 2

Sample Number	Number of Structures	Analytical Sensitivity (s/cm^2)	Sensitivity Weights	Loading (s/cm^2)	Structures 95 % UCL (Table 1)	Loading 95 % UCL (s/cm^2)
B1	3	205	0.0049	615	8.8	1804
B2	4	205	0.0049	820	10.2	2091
B3	3	205	0.0049	615	8.8	1804
B4	4	205	0.0049	820	10.2	2091
B5	6	205	0.0049	1230	13.1	2686

TABLE 11 Combined Measurements of Background Samples for Example 2

Total Structures	Sum of Sensitivity Weights	Weighted Analytical Sensitivity (s/cm^2)	Estimated Loading (s/cm^2)	95 % UCL	
				Structures (Table 1)	Loading (s/cm^2)
20	0.024	41.0	820	30.9	1267

7.5.4 In Table 8:

(1) The number of structures and analytical sensitivity are taken from the laboratory report.

(2) The Estimated Loading is the product of the Number of Structures and the Analytical Sensitivity.

(3) 95 % LCL is read from Table 1.

(4) Loading 95 % LCL is the product of the Structures 95 % LCL and the Analytical Sensitivity.

7.5.5 In Table 9:

(1) Total Structures is the sum of the Number of Structures in Table 8.

(2) The Sum of Sensitivity Weights is the sum of Sensitivity Weights in Table 8.

(3) The Weighted Analytical Sensitivity is the reciprocal of the Sum of Sensitivity Weights.

(4) The Estimated Loading is the product of the Total Structures and the Weighted Analytical Sensitivity.

(5) 95 % LCL Structures is read from Table 1.

(6) Loading is the product of 95 % LCL Structures and Weighted Analytical Sensitivity.

7.5.6 The same analytical parameters are used to calculate the background area results in Table 10 and Table 11.

7.5.7 The calculation procedures for the background samples in Table 10 and Table 11 are the same as for the study samples in Table 8 and Table 9. For example, Table 10 shows that a structure count of 3 for sample B1 has a 95 % UCL of 8.8 structures, giving a 95 % UCL loading of 1804 s/cm^2. In Table 11 Total Structures is the sum of the structures in Table 10.

7.5.8 The 95 % LCL for the combined set of study samples in Table 9 — 6847 s/cm^2 — is more than the 95 % UCL for the background samples — 1267 s/cm^2 — in Table 11. Since the distributions for the two sample sets do not overlap, the study samples are statistically higher at the 95 % confidence level. The surfaces are therefore not clean enough.