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Indoor air —

Part 7:
Sampling strategy for determination of airborne asbestos fibre concentrations

Air intérieur —

Partie 7: Stratégie d'échantillonnage pour la détermination des concentrations en fibres d'amiante en suspension dans l'air

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take Part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16000-7 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

ISO 16000 consists of the following parts, under the general title *Indoor air* :

— *Part 1: General aspects of sampling strategy*

— *Part 2: Sampling strategy for formaldehyde*

— *Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

— *Part 4: Determination of formaldehyde — Diffusive sampling method*

— *Part 5: Sampling strategy for volatile organic compounds (VOCs)*

— *Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas-chromatography using MS/FID*

— *Part 7: Sampling strategy for determination of airborne asbestos fibre concentrations*

— *Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions*

— *Part 9: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test chamber method*

— *Part 10: Determination of the emission of volatile organic compounds from building products and furnishing — Emission test cell method*

— *Part 11: Determination of the emission of volatile organic compounds from building products and furnishing —Sampling, storage of samples and preparation of test specimens*

— *Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)*

— *Part 13: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Collection on sorbent-backed filters*

— *Part 14: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) — Extraction, clean-up and analysis by high-resolution gas chromatography/mass spectrometry*

— *Part 15: Sampling strategy for nitrogen dioxide (NO_2)*

— *Part 16: Detection and enumeration of moulds — Sampling by filtration*

— *Part 17: Detection and enumeration of moulds — Culture-based method*

The following parts are under preparation:

— *Part 18: Detection and enumeration of moulds — Sampling by impaction*

— *Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials*

— *Part 24: Performance test for evaluating the concentration reduction of volatile organic compounds and carbonyl compounds except formaldehyde by sorptive building materials*

— *Part 25: Determination of the emission of semi volatile organic compounds for building products — Micro chamber method*

The following parts are planned:

— *Part 19: Sampling strategy for moulds*

— *Part 20: Detection and enumeration of moulds — Sampling from house dust*

— *Part 21: Detection and enumeration of moulds — Sampling from materials*

— *Part 22: Detection and enumeration of moulds — Molecular methods*

— *Part 26: Road vehicle interior test stand — Determination of VOC, SVOC and carbonyls including formaldehyde in car interiors*

Furthermore, two International Standards, ISO 16017-1 on pumped sampling and ISO 16017-2 on diffusive sampling, focus on volatile organic compound (VOC) measurements.

Introduction

Measurements of airborne asbestos fibre concentrations in indoor atmospheres are made for several reasons related to short-term or long-term exposure of building occupants to asbestos. One application of such measurements is to ensure that airborne asbestos fibres dispersed in areas of a building that are undergoing asbestos abatement do not result in unacceptable exposures of occupants in other areas of the building. After asbestos abatement is completed, measurements are made prior to removal of containment barriers and before safety precautions are discontinued to determine whether any residual asbestos that may remain in the abated area could give rise to unacceptable airborne asbestos exposures when the areas are re-occupied.

The characterization and assessment of ambient air at a fixed position, whether in a building or outside, is normally based on a series of measurements made over a long period of time, generally months or years. However, the release of asbestos fibres into ambient air is not constant and human, or in some cases animal, activity will result in short-term release episodes. Maintenance activity in particular will disturb asbestos-containing materials and settled dust in buildings. Control and monitoring of these activities will determine the long-term exposure levels [1][2]. Workplace atmospheres are also assessed by a series of repeated measurements, the number of measurements depending on the difference between the measured value and the control limit.

In contrast to the strategy used for assessment of long-term asbestos fibre concentrations and personal exposures, the assessment of asbestos fibre concentrations in connection with asbestos abatement measures is nearly always based on a set of measurements made at one time. This special situation needs to be taken into account, both when planning the measurements, and during collection of the air samples. It is not possible to predict long-term changes of airborne asbestos fibre concentrations resulting from any deterioration of asbestos-containing material or the type of usage of the rooms. However, through the use of an appropriate sampling strategy and sampling technique, and by taking extreme, but realistic, conditions into consideration, it is possible to simulate and estimate the short-term maximum asbestos fibre concentrations that can occur.

The sampling strategy described in this part of ISO 16000 is based on VDI 3492 [3].

Indoor air —

Part 7:
Sampling strategy for determination of airborne asbestos fibre concentrations

1 Scope

This part of ISO 16000 specifies procedures to be used in planning of air measurements to determine the concentrations of asbestos in indoor atmospheres. Careful planning of the measurement strategy is important, because the results can become the basis of recommendations for major building renovations, or for the return of a building to normal occupancy status after removal of asbestos-containing materials.

This part of ISO 16000 uses the following definition for indoor environments as specified in ISO 16000-1:

— dwellings having living rooms, bedrooms, do-it-yourself (DIY) rooms, recreation rooms, cellars, kitchens and bathrooms;

— workrooms or workplaces in buildings which are not subject to health and safety inspections in regard to air pollutants (for example, offices and sales premises);

— public and commercial buildings (for example, hospitals, schools, kindergartens, sports halls, libraries, restaurants and bars, theatres and other function rooms);

— cabins of vehicles and public transport.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16000-1, *Indoor air — Part 1: General aspects of sampling strategy*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Sources and occurrence

Airborne fibres in building atmospheres can originate from various sources within or outside the building. Many of the fibres are organic, such as cotton or synthetic fibres released from upholstery fabrics or the clothing of the occupants, or cellulose fibres dispersed during manipulation of paper. Other organic fibres originating from vegetation can infiltrate the building from outside, or can be dispersed from potted plants. Inorganic fibres, such as asbestos, glass fibres, mineral wool fibres and gypsum can be released from various building materials. Release of airborne fibres from building materials can occur intermittently, particularly during disturbances of the materials during maintenance activities. Fragments of the materials can become detached when the materials are contacted, and, if not removed, these fragments can be pulverized by subsequent activities to form dust that can be dispersed into the atmosphere.

4 Terms and definitions

For the purposes of this part of ISO 16000, the following definitions apply.

4.1
abatement
activity undertaken to control the potential emission of asbestos fibres from an asbestos-containing building material by removing, enclosing or encapsulating the material, or by repairing damaged material

4.2
abatement containment area
space within which an asbestos abatement activity is performed and which is separated from the remainder of the building by a containment barrier

4.3
ambient sampling
air sampling to determine the airborne asbestos fibre concentration in the immediate vicinity of the building exterior

4.4
analytical sensitivity
calculated airborne asbestos fibre concentration, equivalent to counting of one asbestos fibre in the analysis

4.5
asbestos
term applied to a group of silicate minerals belonging to the serpentine and amphibole groups which have crystallized in the asbestiform habit, causing them to be easily separated into long, thin, flexible, strong fibres when crushed or processed.

NOTE NOTE The Chemical Abstracts Service Registry Numbers of the most common asbestos varieties are: chrysotile (12001-29-5), crocidolite (12001-28-4), grunerite asbestos (amosite) (12172-73-5), anthophyllite asbestos (77536-67-5), tremolite asbestos (77536-68-6) and actinolite asbestos (77536-66-4).

4.6
asbestos structure
term applied to an individual asbestos fibre, or any connected or overlapping grouping of asbestos fibres or bundles of asbestos fibres, with or without other particles

4.7
aspect ratio
ratio of length to width of a particle

4.8
background sampling
air sampling performed to determine the short-term asbestos fibre concentration in the air of occupied spaces during normal usage before an activity that can disturb asbestos

4.9
blank
unused filter submitted for analysis as a control

4.10
clearance sampling
air sampling performed following an asbestos abatement activity with the purpose of determining whether airborne levels of asbestos are below a specified level at which re-occupancy of an asbestos abatement area is permitted

4.11
cluster
structure in which two or more asbestos fibres, or bundles of asbestos fibres, are randomly oriented in a connected grouping

4.12
containment barrier
impervious barrier enclosing the asbestos abatement containment area

4.13
containment clearance
air sampling performed within the asbestos abatement containment area with the purpose of determining whether airborne levels of asbestos are below a specified level at which the containment barrier can be removed

4.14
electron diffraction
technique in electron microscopy in which the crystal structure of a small area of a sample is examined

4.15
energy-dispersive X-ray analysis
determination of elemental composition through measurement of the energies and intensities of X-rays by use of a solid state detector and multi-channel analyzer system

4.16
field blank
filter cassette which has been taken to the sampling site, opened, and then closed

NOTE Field blanks are used to determine whether contamination can have occurred during field handling of the cassettes.

4.17
fibre
elongated particle, with a minimum length to width ratio of 3:1

NOTE The dimensional parameters used to define a fibre are specific to the analytical method used, and are separately defined in each analytical method.

4.18
fibre bundle
structure composed of parallel, smaller-width fibres attached along their lengths

NOTE A fibre bundle can exhibit diverging fibres at one or both ends.

4.19
fibrous structure
fibre, or connected grouping of fibres, with or without other particles

4.20
HEPA filter
High Efficiency Particulate Absolute filter

NOTE Specifications for an HEPA filter (class H13) require that it has a collection efficiency of 99,95 % for the most penetrating particle size (MPPS) according to EN 1822 [4]. Filters with higher efficiency may be used.

4.21
indoor baseline concentration
long-term asbestos fibre concentration measured in a building during normal usage

4.22
interim corrective actions
any simple measures, short of full asbestos abatement, used to alleviate emissions of airborne asbestos fibres from building materials

4.23
investigative sampling
air sampling performed to determine the impact of an occurrence or a simulated activity on airborne asbestos fibre concentrations

4.24
leakage sampling
air sampling performed around the perimeter of an asbestos abatement containment area for the purposes of determining whether leakage of airborne asbestos fibres from the containment area has occurred or is occurring

4.25
limit of detection
numerical asbestos fibre concentration that will not be exceeded at a probability of 95 % by the actual asbestos fibre concentration, if no asbestos fibres are detected during analysis

4.26
long-term
period of time exceeding 24 h

4.27
matrix
structure in which one or more asbestos fibres, or bundles of asbestos fibres, touch, are attached to, or partially concealed by, a single particle or connected group of non-fibrous particles

4.28
negative pressure
pressure differential between an asbestos abatement containment area and its surroundings when the asbestos abatement containment area is maintained at a pressure lower than that of its surroundings

NOTE The expression is frequently loosely applied to the pressure in the asbestos abatement containment area.

4.29
negative pressure ventilation unit
device used to exhaust air from an asbestos abatement containment area in order to establish a negative pressure differential between the asbestos abatement containment area and its surroundings

NOTE Typically, the air is exhausted through an HEPA filter, or a filter of higher efficiency, to minimize the escape of airborne asbestos fibres from the asbestos abatement containment area to its surroundings.

4.30
outdoor baseline concentration
long-term asbestos fibre concentration measured outdoors and sufficiently close to a building to be representative of air drawn into the building

4.31
PCM-equivalent fibre
asbestos fibre of aspect ratio greater than or equal to 3:1, longer than 5 µm, and which has a width between 0,2 µm and 3,0 µm

4.32
PCM-equivalent structure
fibrous structure of aspect ratio greater than or equal to 3:1, longer than 5 µm, and which has a width between 0,2 µm and 3,0 µm

NOTE A PCM-equivalent structure does not necessarily contain any fibres longer than 5 µm, and can consist of a grouping of parallel asbestos fibres, all of which are shorter than 5 µm.

4.33
personal sampling
air sampling performed in the breathing zone of an individual in order to determine that individual's potential exposure to airborne asbestos fibres

4.34
phase contrast optical microscopy
microscopy technique in which the differential phase shift of the energy passing through a sample is converted into an amplitude effect.

NOTE In asbestos fibre monitoring, this technique is implemented on the light microscope and is widely accepted for monitoring asbestos exposure in a workplace.

4.35
pre-activity (background) concentration
short-term asbestos fibre concentration measured immediately before an activity

4.36
prevalent level sampling
air sampling performed within an area to determine asbestos fibre concentrations during normal occupancy of, and during normal activities in, that area

4.37
procedure validation sampling
air sampling to determine the impact on prevalent levels resulting from maintenance or other activities in a building in which asbestos-containing materials are installed

4.38
replicate sample
one or more air samples collected in close proximity to another air sample, such that the analytical results from the samples are expected to be consistent

4.39
room unit
room that has a maximum floor area of 100 m^2 and a maximum length of 15 m

NOTE In special situations, up to four smaller rooms, for which the total floor area does not exceed 100 m^2, can be considered as a single room unit, provided that there is efficient air exchange between the rooms. Otherwise, a small, individual room is considered as a single room unit.

4.40
short-term
period of time less than or equal to 24 h

4.41
simulation
activity designed to replicate specific activities performed under controlled conditions in order to test the impact of these activities on airborne asbestos fibre concentrations

4.42
small room
room of area of less than 10 m^2

4.43
structure
single fibre, fibre bundle, cluster or matrix

4.44
stratified sampling
air sampling conducted according to a defined strategy in which the samples are grouped on the basis of detailed knowledge of the building characteristics

5 Symbols and abbreviations

5.1 Symbols

n_{RU} the number of room units

A the area of a room in square metres, m^2

L_{LCL} factor by which a PCM fibre concentration shall be multiplied to obtain the lower 95 % confidence limit

L_{UCL} factor by which a PCM fibre concentration shall be multiplied to obtain the upper 95 % confidence limit

s_R the subjective component of the interlaboratory coefficient of variation for PCM fibre counts

x the number of fibres counted

x_{LCL} the lower 95% confidence limit of a fibre count made by either SEM or TEM

x_{UCL} the upper 95% confidence limit of a fibre count made by either SEM or TEM

α statistical significance level

D_1 for a fibre count of x, the value of the χ^2 distribution with $2x$ degrees of freedom and a significance level of $(1 - \alpha/2)$

D_2 for a fibre count of x, the value of the χ^2 distribution with $2(x + 1)$ degrees of freedom and a significance level of $\alpha/2$

E limit of detection

z standard normal deviate

5.2 Abbreviations

ED Electron diffraction

EDXA Energy dispersive X-ray analysis

HEPA High efficiency particle absolute

MEC Mixed esters of cellulose

PC Polycarbonate

PCM Phase contrast optical microscopy

SAED Selected area electron diffraction

SEM Scanning electron microscopy

TEM Transmission electron microscopy

TSP Total suspended particulate

6 Measurement strategy

6.1 Planning of measurements

6.1.1 General

Depending on the applicable regulations, phase contrast optical microscopy (PCM), scanning electron microscopy (SEM) or transmission electron microscopy (TEM) may be specified for the analysis of air samples. The air sampling parameters depend on the objective of the measurements, the regulatory control limit and the method of analysis. It should be noted that the analytical capabilities of the methods above are different, and that results obtained from PCM, SEM or TEM may not be comparable.

Some regulations specify that the interpretation of indoor asbestos fibre concentrations be based on a comparison with simultaneous measurements made outside. Weather conditions can restrict the ability to collect satisfactory air samples in the outdoor environment. Whenever possible, sampling should be carried out in low-wind, low-humidity conditions. Detailed records of the weather conditions, wind speed and direction during the sampling period should be made. Collect all air samples at a height between 1,2 m and 1,5 m from the floor, with the filter cassette facing downwards at an angle of approximately 45°. All available information concerning local topography, and the types and positions of sources should be recorded.

All sampling data that may be of significance for later analysis shall be carefully recorded. The location of the sampling apparatus shall be documented in the form of a sketch and, if possible, a photograph.

6.1.2 Measurement objectives

The objectives of indoor air monitoring for asbestos are as follows.

1) To determine the asbestos fibre concentrations during normal occupancy and usage of an area within a building for diagnostic purposes; such monitoring may be performed periodically to verify the long-term effectiveness of an abatement activity. This is known as “prevalent level sampling”.

2) To determine the short-term asbestos fibre concentration in occupied spaces during normal usage before an activity that can disturb asbestos. This is known as “background sampling”.

3) To determine the impact on airborne asbestos fibre concentrations resulting from routine maintenance activities in a building in which asbestos-containing materials are installed. This is known as “procedure validation sampling”.

4) To determine changes of airborne asbestos concentrations which can result from a simulated activity, changes of building usage, or as a consequence of inadvertent damage to asbestos-containing materials. This is known as “investigative sampling”.

5) To establish whether the airborne asbestos fibre concentration is below a specified level at which time containment barriers can be removed or safety precautions discontinued, and occupancy of an abated area can be resumed, after either interim corrective actions to reduce the asbestos fibre exposure risk have been taken, or after an asbestos abatement activity has been completed. This is known as “clearance sampling”.

6) To establish whether, during abatement work, leakage of contaminated air from the containment area into the local environment has occurred or is occurring. This is known as “leakage sampling”.

7) To determine the exposure of an individual to airborne asbestos fibres; air sampling for this purpose is performed in the breathing zone of the individual. This is known as “personal sampling”.

These objectives are described in more detail in Table 1.

Table 1 — Types of indoor air monitoring and simulation of the conditions of use

Question	Objective of measurement	Sampling conditions (see 6.2)
How high is the airborne asbestos fibre concentration during normal use of the room?	To establish the long-term prevalent asbestos fibre concentrations in indoor air for diagnostic purposes or to verify the effectiveness of asbestos abatement [prevalent level sampling, 6.1.2 (1)].	No simulation is required. Collect air samples during normal building occupancy and usage.
What is the base-line asbestos fibre concentration against which the effects of an activity are to be compared?	To determine the short-term background asbestos fibre concentration in occupied spaces during normal usage before an activity that can disturb asbestos [background sampling, 6.1.2 (2)].	No simulation is required. Collect air samples during normal occupancy and usage shortly before the planned activity.
What are the asbestos fibre concentrations in a room when activities such as changing light bulbs, cleaning of walls and floors, or replacing ceiling tiles take place?	To determine whether unacceptable airborne asbestos fibre concentrations result from routine maintenance activities [procedure validation sampling, 6.1.2 (3)].	No simulation is required. Collect static and personal air samples during the operations or maintenance activity.
Are interim corrective actions necessary if the room is to be used for other purposes?	To determine whether airborne asbestos fibre concentrations are acceptable if usage of a room is changed [investigative sampling, 6.1.2 (4)].	Disturb surfaces, produce air movements and vibrations typical of those that will occur under the proposed conditions of occupancy.
Has the airborne asbestos fibre concentration been reduced to an acceptable value such that safety precautions can be discontinued? Were the interim corrective actions successful?	To confirm, after interim corrective actions have been taken, and prior to discontinuation of safety precautions, that representative activities in the area do not generate unacceptable concentrations of airborne asbestos fibres [clearance sampling, 6.1.2 (5)].	Disturb surfaces, produce air movements and vibrations typical of those that will occur under the proposed conditions of occupancy.
After completion of asbestos abatement conducted in a containment, is the asbestos fibre concentration under extreme disturbance conditions below a specified permissible limit value?	Final clearance air monitoring to determine whether the area within the containment has been cleaned sufficiently so that containment barriers can be removed and the area of the building re-occupied [clearance sampling, 6.1.2 (5)].	Produce air movements exceeding those that will occur during normal building use. Use various vibration methods and surface disturbances with air mixing to simulate extreme conditions.
Are containment barriers, negative pressure and other protective precautions effective in preventing release of asbestos fibre contamination into areas outside the work area? Has the area outside the work area been contaminated with asbestos fibres?	Air monitoring to assure that all protective precautions are effective during abatement activities [leakage sampling, 6.1.2 (6)].	Collect air samples around the perimeter of the containment during the work.
Is the asbestos fibre concentration associated with an activity likely to result in an unacceptable personal exposure?	Air monitoring to determine the exposure of an individual [personal sampling, 6.1.2 (7)].	Collect air samples in the breathing zone of the individual during performance of the activity.

6.1.3 Choice of analytical method

Mandatory national standard analytical methods can have been defined for determination of the concentrations of asbestos fibres in indoor atmospheres. If no national standard analytical method has been defined, one of four ISO analytical methods can be selected for use with this sampling strategy. The characteristics of ISO standard methods based on PCM, SEM and direct-transfer TEM and indirect-transfer TEM are described in Annex B.

6.1.4 Number of sample locations

The number of air samples to be collected depends on the number, size and arrangement of the rooms in the building. It is convenient to express the nature of the building in terms of "room units", from which the number of samples to be collected for any particular purpose can be calculated. A minimum of two samples shall be collected for each separate containment area, except for very small rooms of area less than 10 m^2, each of which shall be considered as one room unit. For large rooms, calculate the number of room units using the empirical Equation (1), and round up to the next integer.

$$n_{\mathrm{RU}} = \frac{14A}{730 + A} \tag{1}$$

where

n_{RU} is the number of room units;

A is the area of the large room in square metres, m^2.

The numbers of samples that are necessary to evaluate a particular area for prevalent or investigative sampling, and for background, clearance or leakage sampling, are specified in Table 2.

Elevated locations (for example, lighting platforms, crane operator's stands, galleries, work platforms in shafts) shall be assessed separately.

Table 2 — Minimum number of random samples required for evaluation of large buildings

Number of room units under evaluation N [a]	Minimum number of samples required	
	Prevalent or investigative sampling	Background, clearance or leakage sampling
1 to 2	2	2
3 to 4	2	3
5 to 6	3	4
7 to 8	3	5
9 to 11	3	6
12 to 14	3	7
15 to 17	4	8
18 to 20	4	9
21 to 25	5	10
26 to 31	5	11
32 to 38	6	12
39 to 46	6	13
47 to 55	7	14
More than 55	N/8 (Round upwards)	N/4 (Round upwards)

[a] N is the value of n_{RU}, rounded upwards.

6.1.5 Choice of sampling locations

The room units chosen may be selected such that increased weight is given to locations where potential asbestos sources are suspected on the basis of a prior survey and analysis of building materials. Where this is done, the results from such stratified samples shall be clearly separated from samples that are randomly distributed. In buildings with a large number of small individual rooms, or in very large rooms, randomly positioned samples may be taken. Air samplers should generally be located at least 2 m away from walls, with the filter cassette positioned between 1,2 m and 1,5 m above the floor. The positions of air supply diffusers should be taken into account, so that the air samples collected are as representative as possible of the air in the room.

If one or more of the measured asbestos fibre concentrations exceeds the permissible limit value, another cycle of measurements shall be carried out after appropriate corrective actions have been taken to reduce the asbestos fibre concentration.

The subsequent re-determination of the number of random samples shall include both the room units in which the limit value has been exceeded and the room units in which sampling has not yet been carried out.

With several sampling locations in a large room or in several small rooms connected to each other, simulate the conditions of usage over the whole area of the room, and in all rooms that are combined into one room unit.

In definition and selection of room units in the individual stories of a building, or in large rooms, the different usage patterns and the furnishings in the room shall be taken into consideration to ensure that the measurements will accurately represent the designated area. Furthermore, preference shall be given to sampling locations that represent high exposure potential, due to the location, accessibility and the nature of asbestos-containing materials.

In staircases or accessible shafts enabling draught effects at least one sampling location shall be chosen in the upper section of the staircase or the shaft, respectively. Alternatively, sealing all openings can minimize the draught effects in inaccessible shafts or similar rooms. The bottom of the shaft shall then be chosen as the sampling location.

6.1.6 Measurements in return air ducts of air-conditioned buildings

Air samples may be collected in the return air system of an air-conditioned building, at the position immediately before the return air is filtered and re-circulated. The particulate material in the air at this location is generally representative of the average situation in the occupied spaces of the building. The air conditioning system should be operating during the collection of air samples. The air velocities in return air ducts are sufficiently low that, for the range of fibre diameters of interest, isokinetic sampling is not necessary.

6.1.7 Measurement in rooms with low volume

The application of this method of measurement in rooms characterized by low air exchange and low volume may reduce the asbestos fibre concentration during sampling as the sampling device itself functions as an air filter when the emission of asbestos fibres into the air does not continue during the entire period of sampling. This is the case, for example, when the simulation of the conditions of usage is performed. Therefore, the total hourly sampled volume for all samples in a room should not exceed one tenth of the room volume, otherwise the outcome of the sampling can result in underestimation of the actual situation. If sampling is carried out in rooms where this effect is expected, and the sample analyses are to be conducted using direct-transfer analytical methods, it is recommended that filters of 25 mm in diameter be used in order to minimize the sampled air volume requirement.

6.1.8 Sampling conditions in containment areas

The surfaces within the containment area shall be dry before sampling is commenced. If sampling is conducted in a containment area after surfactants or sealants have been used, sampling shall be started only after a sufficiently long period of time has elapsed to ensure that the surfactants or sealants have settled out. If sampling is started too early, the filter surface can become heavily covered with the surfactant or sealant, which can often be only partly removed in the specimen preparation process, depending on the type of surfactant or sealant. The presence of these materials on the sample diminishes the visibility of thin asbestos fibres, reduces the sensitivity of the measurement, and can cause the sample to be rejected.

6.1.9 Effects of high particulate loading on filters

A lower limit of detection for a measurement can, in principle, be achieved by increasing the sampled air volume and the area of the filter examined. When either the sampling period or the volume flow-rate is increased, thus increasing the volume of air sampled, the concentration of non-fibrous particles in the indoor air can result in an increase in the formation of agglomerates on the filter. This can lead to clogging of the filter during sampling, and consequently to an unacceptable pressure drop across the filter such that the flow-rate decreases. The higher filter loadings of non-fibrous particles can also result in obscuration of asbestos fibres, thus introducing a negative bias. Particle loading should not exceed 10 % of the surface area of the filter.

The selection of the appropriate sampling period, the intensity and frequency of simulation and the area of sample to be examined is thus a problem of optimization that shall be resolved at the planning stage with regard to the particular objective of measurement. A pilot study can be useful for determining the optimum sampling conditions needed.

6.1.10 Blank measurements

Filters used for field blanks shall pass through the complete sample preparation procedure. The number of field blanks submitted to the laboratory and analyzed shall be at least 10 % of the number of air samples analyzed, with a minimum of one per site and one per day.

6.1.11 Air sample collection inside buildings

Air samples are often collected inside buildings in which asbestos-containing construction materials are present, in order to determine whether these materials contribute to the asbestos concentration in the building atmosphere. The optimum positions for collection of air samples can be determined only after a complete survey of the building has been conducted to establish the location and type of asbestos-containing materials present, the air movement patterns and activities of the occupants. Multiple samples should be collected in the area where asbestos-containing materials are present, and comparison samples should be collected in an adjacent area where no airborne asbestos fibres would be expected. The external intakes for air conditioning systems are frequently used as the exterior sample collection locations. Whenever possible, static samples should be taken over a period exceeding 4 h during normal activity in the building.

All sampling data that can be of significance for later analysis shall be recorded. The location of the sampling apparatus shall be documented in the form of a sketch and, if possible, a photograph. An example of a suitable sample data form is shown in Annex C.

Do not conduct air sampling if high concentrations of dust or smoke are present in the air, because the sample collection filters can either become overloaded to the point that microscopical examination is not possible, or it will be necessary to terminate sampling prematurely, resulting in a measurement with insufficient analytical sensitivity.

If a decrease in temperature is expected during the period of air sampling, the relative humidity should be less than 70 %. If the temperature falls below the dew point, water droplets can be collected on the filter surface, resulting in increased flow resistance.

6.2 Simulation of the conditions of usage

6.2.1 General

It is well known that asbestos may not be detected in air samples collected under passive conditions, even though substantial amounts of asbestos can exist on surfaces in the area where the air samples were collected. Simulated activity is specified for one of two purposes: 1) to obtain measurements of airborne asbestos fibre concentrations under the conditions of current usage; or 2) to demonstrate that a newly abated area can be released for occupancy by generating the highest possible airborne asbestos concentration. Air sampling may be carried out during normal occupancy and usage, in which case no simulation is necessary.

Prior to conducting any simulated activity, the area should be inspected for the presence of any suspected asbestos-containing dust or debris. Examination of dust and debris samples by polarized light microscopy can provide guidance in determining whether such simulated activity should be carried out.

6.2.1.1 Simulation of current usage conditions

For the purpose of measuring airborne asbestos concentrations that arise under current usage conditions, activities comparable to those that normally take place are simulated [3]. Simulation of the conditions of usage is a process in which any dust that can be on surfaces in a room, possibly containing asbestos fibres, is suspended into the indoor air in a manner comparable to that which would occur during the most active usage when normally occupied. For example, office cleaning is a routine activity that can simulate the most active usage of an office, while bouncing a basketball and running can simulate the most active usage in a sports hall. Simulation is achieved by producing air movements, surface disturbance and/or vibrations. The types of simulation methods are listed in Annex A. The methods in Annex A should be used uniformly throughout the study to aid the comparability of the results. Any departure from the specified methods shall be justified in each individual case.

Other than the type of simulation activity, factors such as the energy or effort used when simulating the activity, when it is first carried out, the duration of the activity, the frequency with which it is repeated and the period over which the air sampling is conducted will all affect the measured airborne asbestos fibre concentration. Given the range of situations that will be encountered, it is not realistic to have rigid protocols, but it is required that the summary report adequately documents the above variables.

This simulation activity is designed to reproduce aerosols generated by normal activity. If asbestos is present in the indoor environment, the simulation can generate an asbestos aerosol in the study area. All persons involved in such studies should use personal protective equipment to avoid possible exposure to a potentially hazardous aerosol. The investigator should carefully consider this potential to create an exposure hazard and should take steps to ensure that no bystanders are exposed during the activity. Precautions such as containment barriers and environmental air controls to guard against expanding a contaminated area during the simulation should also be considered.

6.2.1.2 Simulations for post-abatement clearance

For the purpose of post-abatement clearance, aggressive air sampling is specified, during which surfaces are disturbed to disperse any residual dust and create the highest possible airborne asbestos concentration. Prior to carrying out any simulation activities, carry out a visual inspection of surfaces in the area. If visible asbestos-containing debris is present on surfaces, do not perform any simulation as the area will need to be cleaned.

NOTE A detailed procedure for visual inspection of newly abated areas is provided in Reference [8].

6.2.2 Type of simulation to be used

The type of simulation that shall be used is dependent on the objectives of the measurement, and appropriate methods are specified in Table 1.

The simulation may be omitted partially or completely if the normal conditions themselves result in suspension of asbestos fibres. For example, sports activities in gymnasiums, activities during a school day, or the normal cleaning of rooms with a conventional vacuum-cleaner can be considered sufficient levels of disturbance.

6.2.3 Timing of simulation procedures

Provided that no other regulatory requirements are specified, the simulation procedure shall be carried out directly before air sampling is commenced and can be repeated. It is recommended that the period of time during which the simulation procedure is carried out not exceed 10 % of the overall sampling time.

6.3 Sampling parameters

6.3.1 Number of samples to be collected

For prevalent, investigative, background, clearance or leakage sampling, the number of samples collected shall be in accordance with Table 2.

6.3.2 Prevalent level sampling

To ensure that the sampling is representative of conditions during normal occupancy, the air conditioning shall be on and the following precautions shall be taken:

a) in order to avoid dilution of the asbestos fibre concentration in indoor air, all windows, doors and other similar openings shall be kept closed for a minimum period of 3 h before air sampling is commenced, and also during the period of air sampling;

b) so far as it is practical, activities in the building should continue in their usual manner during the air sampling period.

6.3.3 Background sampling

Background sampling is carried out to establish the short-term asbestos fibre concentration in an occupied space in order to provide a basis for comparison after an activity is carried out. The activity may or may not involve disturbance of asbestos. Collect the samples immediately prior to the activity.

6.3.4 Procedure validation and investigative sampling

Measurements to determine the impact of a single event within a building can be difficult to make, because sources of asbestos fibres can be highly localized and this will result in inhomogeneous aerosols. Since the asbestos fibre concentration observed at a distance from a localized source of airborne asbestos fibres can be diluted to the point that no increase is detected by a single measurement, a large number of samples can be required in order to characterize the situation if no supplementary information as to the sources of the airborne asbestos fibres is available. In other situations, an activity, by its nature, can occur for only a short time, thus limiting the air volume that can be collected during the activity. This can result in an inadequate analytical sensitivity, and it can then be necessary to accumulate the asbestos fibres from a number of repetitions of the activity on to each of the filters being exposed. Consideration of measurement sensitivity is crucial in the experimental design for the study of short-term activities.

6.3.5 Clearance sampling

Mandatory national regulations for clearance sampling should be applied if they exist. In general, post-abatement clearance air monitoring following asbestos abatement activities shall be performed only after the following:

a) all surfaces have been cleaned after completion of the asbestos abatement work;

b) a thorough visual inspection shows that no asbestos residue or visible dust remains in the rooms; if any residue is observed, the criteria for the cleaning procedures have not been met and additional cleaning shall be performed;

c) all surfaces are dry; residual water will result in temporary adhesion of asbestos fibres to surfaces and lead to lower air concentrations than would occur if the surfaces were completely dry;

d) if any sealant has been applied by spraying to adhere residual dust to the surfaces, a sufficient period of time has elapsed to ensure that residual airborne sprayed sealant is no longer present.

Provided that no regulations state otherwise, during clearance sampling inside an asbestos abatement containment area, the negative pressure ventilation units, if installed, shall be turned off.

NOTE Some government regulations can require that the negative pressure ventilation units remain on during the clearance test. Air samples collected under these conditions generally contain suspended particulate material originating from outside the asbestos abatement containment area.

6.3.6 Leakage sampling

Leakage sampling is used to augment frequent, thorough, visual inspections of the containment barrier. A number of sample locations should be considered: for example, near an air-lock (the entry and exit for workers, near a bag-lock (the exit used to remove bags from the containment area), and near the exhausts of negative pressure ventilation units. For this type of testing, it may only be possible to sample for a few minutes, in which case a high flow-rate should be used in order to provide adequate analytical sensitivity for the measurement. The origin of any asbestos fibres resulting in a measurement that is confidently above background levels should be investigated.

6.3.7 Personal sampling

The breathing zone of a worker consists of a hemisphere of 0,3 m radius extending in front of the face, and measured from the mid-point of a line bisecting the ears. The filter holder should point downwards and be fixed to the upper lapel or shoulder of the worker's clothing, as close to the mouth and nose as practicable, and preferably within 0,2 m. Due regard shall be given to localized concentrations: in such cases, the sampling head should be positioned on the side expected to give the higher result. If a respirator is worn, the sampling head should be positioned away from the clean air exhaust.

6.3.8 Ambient sampling

Results from air samples collected outside of buildings under study are often used to provide a baseline against which the results from inside the buildings are compared. Weather conditions often restrict the ability to collect satisfactory air samples in the outdoor environment, and whenever possible, sampling should be carried out in low-wind, low-humidity conditions. Detailed records of the weather conditions, wind-speed and direction during the sampling period should be made. All available information concerning local topography and the types and positions of potential sources of asbestos fibres should be recorded. In studies of air-conditioned buildings in urban locations, the total suspended particulate concentration outside the building can limit the air volume that can be sampled, leading to higher values for the analytical sensitivity than those which can be achieved inside the building. This situation requires careful interpretation if only low numbers of asbestos fibres are observed in the measurements.

6.4 Calculation of results

6.4.1 General

In the interpretation of results, it is important to recognize the limits of detection and the limitations of precision for measurements made by PCM, SEM or TEM.

6.4.2 Limit of detection for PCM analyses

The limit of detection for PCM analyses on lightly-loaded filters is controlled by the background fibre count, which shall be obtained by examination of representative filters from each batch. The limit of detection will increase with an increase of particulate density on the filter, but no firm data on this effect are available.

6.4.3 Limits of detection for SEM and TEM analyses

For measurements made by SEM or TEM, the limit of detection is defined in this sampling strategy as the numerical asbestos fibre concentration below which, with 95 % probability, the real concentration shall lie when no asbestos fibres are detected during the analysis.

The limit of detection depends on

a) the sampled volume which passes through the filter during the sampling period, and

b) the area of filter examined.

The limit of detection is defined as that concentration corresponding to the detection of 2,99 asbestos fibres in the analysis. For example, for an SEM measurement in which an air volume of 1 m^3 was collected per square centimetre (cm^2) of filter area, and an area of 1 mm^2 of the filter surface was examined, the defined limit of detection would be 300 fibres/m^3.

Any asbestos fibre background that may be present on unused filters is not taken into account in the specification of the above limit of detection. Experience, however, has shown that background is negligible for both SEM and TEM measurements of asbestos fibres longer than 5 µm. The presence of low numbers of background asbestos fibres may need to be considered when measurements of all asbestos fibres longer than 0,5 µm are made by TEM.

6.4.4 Interpretation of results and compliance with a fixed concentration value

6.4.4.1 Interpretation of PCM measurements

The coefficient of variation for PCM analyses is a combination of the Poisson variability, errors in the measurement of air volume, and a subjective component. The subjective component is the largest of these effects, and each analytical laboratory can derive a value for its group of analysts. Studies have shown that, for a random group of laboratories, the interlaboratory 90 % confidence interval can be estimated by combining the Poisson variability with a subjective component of 0,45 [7][8][9]. In order to demonstrate compliance with a fixed concentration value, it is necessary to take account of the overall variability. The lower and upper 95 % confidence limits are given by the empirical equations:

$$L_{\text{LCL}} = \frac{2x + 4 - \left[(4 + 2x)^2 - 4(1 - 4s_R^2)x^2 \right]^{1/2}}{2x(1 - 4s_R^2)} \qquad (2)$$

$$L_{\text{UCL}} = \frac{2x + 2{,}25 + \left[(2{,}25 + 2x)^2 - 4(1 - 2{,}25s_R^2)x^2 \right]^{1/2}}{2x(1 - 2{,}25s_R^2)} \qquad (3)$$

where

L_{LCL} is the multiplication factor to obtain the lower 95 % confidence limit;

L_{UCL} is the multiplication factor to obtain the upper 95 % confidence limit;

s_R is the subjective component of the interlaboratory coefficient of variation;

x is the total number of fibres counted.

Equation (2) is not valid for values of $s_R \geqslant 0{,}50$. Equation (3) is not valid for values of $s_R \geqslant 0{,}66$.

A group of laboratories or analysts that has collected sufficient data to derive its own value of s_R can use these formulae to derive 95 % confidence limit curves for use by the group. The user of the laboratory data should obtain the value of s_R from the laboratory, or should assume a value of 0,45 for the interpretation of PCM data.

For example, assuming an s_R of 0,45, in order to demonstrate compliance with a 0,01 fibre/ml standard using a single sample on which 100 fibres have been counted, Equation (3) indicates that the measured airborne fibre concentration shall be a factor of 3,13 lower than the 0,01 fibre/ml standard. The measured airborne fibre concentration, therefore, shall not be higher than 0,003 fibre/ml (100 fibres counted) in order to demonstrate compliance with the 0,01 fibre/ml standard at 95 % confidence.

6.4.4.2 Interpretation of SEM and TEM measurements

Background contamination by asbestos fibres longer than 5 µm in either SEM or TEM analyses is generally negligible, but a low background may need to be accounted for if measurements are based on asbestos fibres longer than 0,5 µm.

The precision of SEM and TEM analyses is not usually compromised by subjective effects, and, provided that the overall aerosol deposition on the sample collection filter is uniform, a Poisson distribution of asbestos fibres can be assumed. The 95 % confidence interval of a measurement, as a function of the number of asbestos fibres counted, can be obtained either from Equations (4) and (5) or from Table 3. Equations (4) and (5) are approximations that produce upper and lower 95 % confidence limits correct to within two digits in the second decimal place.

For an asbestos structure or asbestos fibre count of x, the lower 95 % confidence limit is

$$x_{LCL} = x[1-(1/9x)-z(1/9x)^{1/2}]^3 \tag{4}$$

The upper 95 % confidence limit is

$$x_{UCL} = d[1-(1/9d)+z(1/9d)^{1/2}]^3 \tag{5}$$

where $d = (x + 1)$, and $z = 1{,}960$, the standard normal deviate for two-sided limits at the 95 % probability level.

Alternatively, it is possible to compute precisely the values for the upper and lower 95 % confidence limits in a software spreadsheet if the spreadsheet can calculate the χ^2 distribution, and the confidence limits are given by:

$$x_{LCL} = 1/2D_1 \tag{6}$$

$$x_{UCL} = 1/2D_2 \tag{7}$$

where

D_1 is the value of χ^2 with 2× degrees of freedom and a significance level of $(1 - \alpha/2)$;

D_2 is the value of χ^2 with 2(× + 1) degrees of freedom and a significance level of $\alpha/2$.

For 95 % confidence intervals, use $\alpha/2 = 0{,}025$.

In some cases, the asbestos fibres collected on the filter can be present as clusters and matrices, and the asbestos fibre counting criteria used can cause the distribution to deviate from the Poisson distribution. If the deviation from the Poisson distribution is significant, and if a sufficient number of asbestos fibres has been detected, it is a more conservative approach to assume another distribution such as the Gaussian, in which the mean and standard deviation are independent variables.

In general, the distribution of asbestos fibres on the microscope specimen prepared by the indirect-transfer TEM method more closely approaches the Poisson distribution than is the case for the direct-transfer TEM method.

The statistical interpretation of results is common to all of the electron microscopy methods, and is illustrated by the following examples.

EXAMPLE 1 There is an ambient asbestos fibre concentration of 50 fibres/m^3, and measurements of air concentration in a building are made with an analytical sensitivity of 100 fibres/m^3. If the mean asbestos fibre count is $\bar{x}$, the probability of detecting x asbestos fibres during examination can be described using the Poisson distribution:

$$P(x,\bar{x}) = \frac{\bar{x}^{x}\exp(-\bar{x})}{x!} \tag{8}$$

In this example, since $\bar{x} = 0{,}5$, the probability of detecting two asbestos fibres during the sample examination is approximately 15 %. Therefore, although observation of two asbestos fibres in the count would correspond to an asbestos fibre concentration of 200 fibres/m^3, if it were concluded that this concentration was elevated above ambient, there would be a 15 % probability that this conclusion would be incorrect.

This ambiguous situation can often be resolved by increasing the area of the sample examined, i.e. by improving the analytical sensitivity of the measurement. If the area of sample examined were doubled, the analytical sensitivity would be 50 fibres/m^3, and on average four asbestos fibres should be detected. Table 3 shows that the lower 95 % confidence limit for four asbestos fibres is 1,090 asbestos fibres, thus yielding a value of 54,5 fibres/m^3 for the lower 95 % confidence limit of concentration. Doubling of the area of sample examined, in this case, allows a statement, at 97,5 % confidence, that the measured concentration is elevated with respect to the ambient concentration.

EXAMPLE 2 If a concentration was measured as 100 fibres/m^3, and the measurements were made at an analytical sensitivity of 100 fibres/m^3, one asbestos fibre would be detected. In order to demonstrate, with 97,5 % confidence, that the measurement is elevated with respect to an ambient concentration of 50 fibres/m^3, it would be necessary to increase the area examined by a factor of 12. This would yield an analytical sensitivity of 8,333 fibres/m^3 and twelve asbestos fibres would be detected. The lower 95 % confidence limit for a mean of twelve asbestos fibres is found in Table 3 to be 6,201 asbestos fibres, giving a lower 95 % confidence limit for the concentration of 51,7 fibres/m^3, slightly higher than the ambient concentration of 50 fibres/m^3.

Table 3 — Upper and lower limits of the Poisson 95 % confidence interval of a count

Asbestos fibre or structure count	Lower	Upper	Asbestos fibre or structure count	Lower	Upper	Asbestos fibre or structure count	Lower	Upper
0	0	3,689[a]	46	33,678	61,358	92	74,164	112,83
1	0,025	5,572	47	34,534	62,501	93	75,061	113,94
2	0,242	7,225	48	35,392	63,642	94	75,959	115,04
3	0,619	8,767	49	36,251	64,781	95	76,858	116,14
4	1,090	10,242	50	37,112	65,919	96	77,757	117,24
5	1,624	11,669	51	37,973	67,056	97	78,657	118,34
6	2,202	13,060	52	38,837	68,192	98	79,557	119,44
7	2,814	14,423	53	39,701	69,326	99	80,458	120,53
8	3,454	15,764	54	40,567	70,459	100	81,360	121,66
9	4,115	17,085	55	41,433	71,591	110	90,400	132,61
10	4,795	18,391	56	42,301	72,721	120	99,490	143,52
11	5,491	19,683	57	43,171	73,851	130	108,61	154,39
12	6,201	20,962	58	44,041	74,979	140	117,77	165,23
13	6,922	22,231	59	44,912	76,106	150	126,96	176,04
14	7,654	23,490	60	45,785	77,232	160	136,17	186,83
15	8,396	24,741	61	46,658	78,357	170	145,41	197,59
16	9,146	25,983	62	47,533	79,482	180	154,66	208,33
17	9,904	27,219	63	48,409	80,605	190	163,94	219,05
18	10,668	28,448	64	49,286	81,727	200	173,24	229,75
19	11,440	29,671	65	50,164	82,848	210	182,56	240,43
20	12,217	30,889	66	51,042	83,969	220	191,89	251,10
21	13,000	32,101	67	51,922	85,088	230	201,24	261,75
22	13,788	33,309	68	52,803	86,207	240	210,60	272,39
23	14,581	34,512	69	53,685	87,324	250	219,97	283,01
24	15,378	35,711	70	54,567	88,441	260	229,36	293,62
25	16,178	36,905	71	55,451	89,557	270	238,75	304,23
26	16,983	38,097	72	56,335	90,673	280	248,16	314,82
27	17,793	39,284	73	57,220	91,787	290	257,58	325,39
28	18,606	40,468	74	58,106	92,901	300	267,01	335,96
29	19,422	41,649	75	58,993	94,014	310	276,45	346,52
30	20,241	42,827	76	59,880	95,126	320	285,90	357,08
31	21,063	44,002	77	60,768	96,237	330	295,36	367,62
32	21,888	45,175	78	61,657	97,348	340	304,82	378,15
33	22,715	46,345	79	62,547	98,458	350	314,29	388,68
34	23,545	47,512	80	63,437	99,567	360	323,77	399,20
35	24,378	48,677	81	64,328	100,68	370	333,26	409,71
36	25,213	49,840	82	65,219	101,79	380	342,75	420,22
37	26,050	51,000	83	66,111	102,90	390	352,25	430,72
38	26,890	52,158	84	67,003	104,00	400	361,76	441,21
39	27,732	53,315	85	67,897	105,11	410	371,27	451,69
40	28,575	54,469	86	68,790	106,21	420	380,79	462,18
41	29,421	55,622	87	69,684	107,32	430	390,32	472,65
42	30,269	56,772	88	70,579	108,42	440	399,85	483,12
43	31,119	57,921	89	71,474	109,53	450	409,38	493,58
44	31,970	59,068	90	72,370	110,63	460	418,92	504,04
45	32,823	60,214	91	73,267	111,73	470	428,47	514,50

[a] The one-sided upper 95% confidence limit for zero structures is 2,99.

6.4.5 Calculation of volume-weighted mean values

For special applications (e.g. calculation of long-term mean values), the combination of several measured values to calculate a mean value for the asbestos fibre concentration, C, is desired in order to reduce, for example, the variability of the measured result.

If the mean value is to be calculated for a series of measured results that are based on low numbers of counted asbestos fibres, the following mathematical procedure shall be applied in order to obtain a volume-weighted average. The usual calculation of the arithmetic mean would yield a value of the asbestos fibre concentration that does not take the relationship between asbestos fibre count and sampled volume into account.

The measured value is completely determined by two parameters: the evaluation result for the number of asbestos fibres, x, and the evaluated sample air volume, V_p. The evaluated sample air volume, V_p, alone determines the limit of detection.

Correspondingly, several individual measured values are combined by summation of the number of asbestos fibres, x_i, and the evaluated sample air volumes, V_p. Hence:

$$C = \frac{\sum x_i}{\sum V_\mathrm{p}} \tag{9}$$

and for the limit of detection, E:

$$E = \frac{2{,}99}{\sum V_\mathrm{p}} \tag{10}$$

The 95 % confidence interval due to the random sample-related deviation is calculated analogously on the basis of Σx_i and ΣV_p.

In order to make the results traceable, the presentation of the measurements for each sample shall include both the number of asbestos fibres counted and the data to allow calculation of the volume of sampled air examined by the analyst. It is essential that all samples be taken at the same flow-rate.

6.5 Reporting

An example of a summary report form is shown in Annex D, which may be used for any of the measurement objectives, and for measurements made by PCM, SEM, direct-transfer TEM or indirect-transfer TEM.

7 Quality assurance

7.1 General

This clause gives practical information to the user of this standard in order to improve the quality of the measurements. The information provided here relates only to the sampling strategy, and not to the analytical methods themselves, each of which contains quality assurance procedures as an integral component of the method. For evaluation of laboratory performance, refer to ISO/IEC 17025.

7.2 Laboratory quality assurance system

Prior to submission of samples to the analytical laboratory, ensure that the laboratory has a documented quality assurance system, and confirm that the laboratory appears to be applying that system.

7.3 Replicate measurements

It is recommended that approximately 10 % replicate samples be submitted to the laboratory as blind samples. The results obtained for pairs of replicate samples should be consistent, within the statistical limitations of the asbestos fibre sampling and counting procedures.

7.4 Submission of unused filters and field blanks as blind samples

Field blanks and unused filter cassettes should not be identified to the laboratory. Each field blank or unused filter cassette should be assigned an air volume and randomly included in the sequence of samples to be analyzed. This provides an independent control over laboratory and field contamination, and ensures that these control samples are analysed with the same degree of care as the actual samples.

7.5 Interlaboratory analyses

It is recommended that one filter cassette from each study be submitted to a second laboratory for analysis. This provides an independent control over laboratory bias. This may be omitted if the laboratory can provide documentation of consistent performance in an interlaboratory programme.

Annex A
(normative)

Simulation methods

A.1 General

The specified simulation methods are intended to be a practicable compromise between the requirement to re-suspend any dust present on surfaces in the area under study and the requirement that sample collection filters have loadings of particulate material such that they are suitable for analysis.

The basic methods used to re-suspend fibres from surfaces are

a) air movements,

b) vibrations,

c) use of a brush or broom,

d) a combination of a), b) and c).

These methods shall be used unless national standards or regulations specify otherwise. When determining the type of simulation to be used, internal instructions and internal organizational measures in connection with safety precautions shall be taken into consideration. It is also important to ensure that all equipment used in the simulation activities is carefully cleaned to avoid the inadvertent introduction of asbestos fibres into the area to be tested.

A.2 Disturbance of surfaces

With the methods described in this clause, settled asbestos fibres are re-suspended from surfaces and from niches, either using a brush or using a blower directed at the surface from a specified working distance.

In general, the disturbance activities should disturb a minimum of 5 % of the surface area under study. The time of disturbance will be related to the size of the area/enclosure (number of room units). For clearance sampling purposes, the simulated disturbance shall be designed to replicate a substantial disturbance inside the enclosure, and be used to disturb the areas from where the asbestos has been removed, the areas directly underneath where the removal took place and a proportion of the horizontal areas in each of the room units within a 3 m to 5 m radius around the sampling device. Disturbance should take place directly before or from the start of the sampling activity and can be repeated during the sampling period. Mechanical disturbance of dust by brushing the surfaces in a room using a broom or brush is an effective means of suspending dust into the air, when combined with air movements. The brush used shall be new, in order to avoid introducing asbestos fibres into the area originating from previous use of the brush. Fans can be used in the area to disperse the re-suspended dust throughout the volume of the room. If brushes are used, brush the surfaces vigorously prior to sampling. Brushing may be repeated during the sampling period. If blowers are used, approximately 5 % of the surface area under study shall be swept one time with the exhaust of the blower, and at least 5 m^2 of each allocated room unit within a 3 m to 5 m radius around the corresponding sampling device. Aim the air stream directly at the surface.

A.3 Blower performance

The performance of the blower used for simulation of disturbances should be evaluated a minimum of once every three months. The air velocity at the working distance shall be 4 m/s ± 20 %. The velocity of the air stream can be measured by means of an anemometer.

A.4 Producing vibrations

A.4.1 Bouncing a ball

In order to simulate the typical conditions of usage in rooms such as gymnasiums or play-rooms, bounce a basketball 40 times against the floor and the walls within a radius of 5 m around each air sampling device during the sampling period. This activity should represent a minimum of 10 % of the sampling time.

A.4.2 Slamming a door

Asbestos fibres can be released from interior wall panels made of asbestos-containing materials through vibrations and the pumping effects from hollow walls. Slamming the door is an appropriate means to simulate typical conditions of usage and to cause re-suspension of deposited asbestos fibres possibly originating from the panels. Close the door from a right angle position in an accelerating manner so that it slams shut forcefully. Repeat this action five times during the sampling period. If slamming the door cannot simulate the pump effect, press strongly against the panels five times during the sampling period.

A.4.3 Dropping an object

In order to re-suspend asbestos fibres that have possibly been deposited on carpets and wall-to-wall carpeting, drop objects which are typical of the room, such as books or files, on to the carpet. Drop the objects from the height of 1 m such that the broadest side hits the floor within a 5 m radius of each sampling device. Repeat this action five times during the sampling period.