BS ISO 15202-1:2012

BSI Standards Publication

Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry

Part 1: Sampling

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 15202-1:2012. It supersedes BS ISO 15202-1:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/2/2, Work place atmospheres.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry —

Part 1:
Sampling

Air des lieux de travail — Détermination des métaux et métalloïdes dans les particules en suspension dans l'air par spectrométrie d'émission atomique avec plasma à couplage inductif —

Partie 1: Échantillonnage

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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 15202-1 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 2, *Workplace atmospheres*.

This second edition cancels and replaces the first edition (ISO 15202-1:2000), which has been technically revised. The major changes in the second edition are as follows:

- definitions have been updated;
- a new Annex A has been added to provide guidance regarding sampler wall deposits.

ISO 15202 consists of the following parts, under the general title *Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry*:

- *Part 1: Sampling*
- *Part 2: Sample preparation*
- *Part 3: Analysis*

Introduction

The health of workers in many industries is at risk through exposure by inhalation of toxic metals and metalloids. Industrial hygienists and other public health professionals need to determine the effectiveness of measures taken to control workers' exposure, and this is generally achieved by taking workplace air measurements. This part of ISO 15202 has been published in order to make available a method for making valid exposure measurements for a wide range of metals and metalloids in use in industry. It will be of benefit to: agencies concerned with health and safety at work; industrial hygienists and other public health professionals; analytical laboratories; industrial users of metals and metalloids and their workers, etc.

This part of ISO 15202 specifies a generic sampling method for subsequent determination of the mass concentration of metals and metalloids in workplace air using inductively coupled plasma atomic emission spectrometry (ICP-AES). Samples obtained using the method described herein can also be subsequently analysed by other instrumental methods, such as atomic absorption spectrometry (AAS) or inductively coupled plasma mass spectrometry (ICP-MS).

This part of ISO 15202 gives details of relevant International, European and National Standards which specify characteristics, performance requirements and test methods relating to sampling equipment. It augments guidance provided elsewhere on assessment strategy and measurement strategy, and specifies a method for collecting samples of airborne particulate matter for subsequent chemical analysis.

Part 2 of ISO 15202 describes a number of procedures for preparing sample solutions for analysis by ICP-AES.

Part 3 of ISO 15202 gives requirements and test methods for analysis of sample solutions by ICP-AES.

It has been assumed in the drafting of this part of ISO 15202 that the execution of its provisions, and the interpretation of the results obtained, is entrusted to appropriately qualified and experienced people.

Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry —

Part 1: **Sampling**

1 Scope

1.1 This part of ISO 15202 specifies a method for collecting samples of airborne particulate matter for subsequent determination of metals and metalloids using inductively coupled plasma — atomic emission spectrometry (ICP-AES). Samples obtained using the method described herein can also be subsequently analysed for elemental composition by other instrumental methods, such as atomic absorption spectrometry (AAS) or inductively coupled plasma mass spectrometry (ICP-MS).

1.2 The method is not applicable to the sampling of mercury, which is present in air in the vapour phase at ambient temperatures; inorganic compounds of metals and metalloids that are permanent gases, e.g. arsine (AsH_3); or inorganic compounds of metals and metalloids that are present in the vapour phase at ambient temperatures, e.g. arsenic trioxide (As_2O_3).

NOTE Although the method does not describe a means of collecting inorganic compounds of metals and metalloids that are present in the vapour phase, in most instances this is relatively easily achieved by using a back-up filter which has been pre-treated to trap the compound(s) of interest, e.g. a back-up paper pad impregnated with sodium carbonate is suitable for collecting arsenic trioxide (see ISO 11041[2]).

1.3 The method is applicable to personal sampling of the inhalable or respirable fraction of airborne particles, as defined in ISO 7708, and to static sampling.

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 7708:1995, *Air quality — Particle size fraction definitions for health-related sampling*

ISO 15202-2, *Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry — Part 2: Sample preparation*

ISO 15202-3, *Workplace air — Determination of metals and metalloids in airborne particulate matter by inductively coupled plasma atomic emission spectrometry — Part 3: Analysis*

EN 13205, *Workplace atmospheres — Assessment of performance of instruments for measurement of airborne particle concentrations*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General definitions

3.1.1
breathing zone
<general> space around the worker's face from which breath is taken

3.1.2
breathing zone
<technical> hemisphere (generally accepted to be 0,3 m in radius) extending in front of the human face, centred on the midpoint of a line joining the ears; the base of the hemisphere is a plane through this line, the top of the head and the larynx

NOTE 1 The definition is not applicable when respiratory protective equipment is used.

NOTE 2 Adapted from EN 1540:2011[6].

3.1.3
chemical agent
any chemical element or compound, on its own or admixed as it occurs in the natural state or as produced, used, or released including release as waste, by any work activity, whether or not produced intentionally and whether or not placed on the market

[Council Directive 98/24/EC[13], Art. 2(a)]

3.1.4
exposure
exposure by inhalation
situation in which a chemical agent is present in air which is inhaled by a person

NOTE Adapted from EN 1540:2011[6].

3.1.5
occupational exposure limit value
limit value
limit of the time-weighted average of the concentration of a chemical agent in the air within the breathing zone of a worker in relation to a specified reference period

[Council Directive 98/24/EC[13], Art. 2(d)]

EXAMPLES Threshold Limit Values® (TLVs) established by the ACGIH[14], Indicative Occupational Exposure Limit Values (IOELVs) promulgated by the European Commission[12] and national limit values. Information on national limit values is available from the International Labour Organization (ILO)[15] and on the GESTIS database[16].

3.1.6
measuring procedure
measurement procedure
set of operations, described specifically, for the sampling and analysis of chemical agents in air

NOTE 1 A measuring procedure usually includes preparation for sampling, sampling, transportation and storage, preparation of samples for analysis and analysis.

NOTE 2 Adapted from EN 1540:2011[6].

3.1.7
operating time
period during which a sampling pump can be operated at specified flow rate and back pressure without recharging or replacing the battery

[EN 1232][5]

3.1.8
reference period
specified period of time for which the occupational exposure limit value of a chemical agent applies

NOTE 1 The reference period is usually 8 h for long-term measurements and 15 min for short-term measurements.

NOTE 2 Examples for different reference periods are short-term and long-term limit values, such as those established by the ACGIH[14].

NOTE 3 Adapted from EN 1540:2011[6].

3.1.9
time-weighted average concentration
TWA concentration
concentration of a chemical agent in the atmosphere, averaged over the reference period

NOTE A more detailed discussion of TWA concentrations and their use can be found in Reference [14].

3.1.10
workplace
designated area or areas in which the work activities are carried out

[EN 1540:2011][6]

3.2 Particle size fraction definitions

3.2.1
inhalable convention
target specification for sampling instruments when the inhalable fraction is of interest

[ISO 7708:1995]

3.2.2
inhalable fraction
mass fraction of total airborne particles that is inhaled through the nose and mouth

[ISO 7708:1995]

NOTE The inhalable fraction depends on the speed and direction of air movement, on breathing rate and other factors.

3.2.3
respirable convention
target specification for sampling instruments when the respirable fraction is of interest

[ISO 7708:1995]

3.2.4
respirable fraction
mass fraction of inhaled particles penetrating to the unciliated airways

[ISO 7708:1995]

3.2.5
total airborne particles
all particles surrounded by air in a given volume of air

[ISO 7708:1995]

NOTE Because all measuring instruments are size-selective to some extent, it is often impossible to measure the total concentration of airborne particles.

3.3 Sampling definitions

3.3.1
personal sampler
sampler, attached to a person, that collects airborne particles in the breathing zone to determine exposure to chemical agents

NOTE Adapted from EN 1540:2011[6].

3.3.2
personal sampling
process of sampling carried out using a personal sampler

[EN 1540:2011][6]

3.3.3
air sampler
sampler
device for separating chemical agents from the surrounding air

NOTE 1 Air samplers are generally designed for a particular purpose, e.g. for sampling airborne particles.

NOTE 2 Adapted from EN 1540:2011[6].

3.3.4
static sampler
area sampler
sampler, not attached to a person, that collects airborne particles at a particular location

NOTE Adapted from EN 1540:2011[6].

3.3.5
static sampling
area sampling
process of (air) sampling carried out using a static sampler

[EN 1540:2011][6]

4 Principle

4.1 Airborne particles containing metals and metalloids are collected by drawing a measured volume of air through a filter mounted in a sampler designed to collect an appropriate size fraction of airborne particles (see 8.1.1.1).

4.2 The filter and collected sample are then treated to dissolve the metals and metalloids of interest using one or more of the sample preparation methods prescribed in ISO 15202-2.

4.3 The resultant solution is subsequently analysed for the metals and metalloids of interest using inductively coupled plasma-atomic emission spectrometry, as described in ISO 15202-3.

5 Requirement

The measuring procedure as a whole (covered by ISO 15202-1, ISO 15202-2 and ISO 15202-3) shall comply with any relevant International, European or National Standard that specifies performance requirements for procedures for measuring chemical agents in workplace air (e.g. EN 482[3] and EN 13890[8]).

6 Sampling equipment

6.1 Samplers

6.1.1 Inhalable samplers, designed to collect the inhalable fraction of airborne particles, complying with the provisions of EN 13205, for use when the limit value(s) for metals and metalloids of interest apply to the inhalable fraction of airborne particles.

NOTE 1 In general, personal samplers for collection of the inhalable fraction of airborne particles do not exhibit the same size selective characteristics if used for static sampling.

NOTE 2 Some inhalable samplers are designed to collect the inhalable fraction of airborne particles on the filter, and any particulate matter deposited on the internal surfaces of the sampler is not of interest. Other inhalable samplers are designed such that airborne particles which pass through the entry orifice(s) match the inhalable convention, in which case particulate matter deposited on the internal surfaces of the sampler does form part of the sample. For many samplers, particulate matter deposited on the internal surfaces of the sampler or insert is included as part of the sample. For more information on the issue of internal wall deposits, see Annex A.

6.1.2 Respirable samplers, designed to collect the respirable fraction of airborne particles, complying with the provisions of EN 13205, for use when the limit values for the metals and metalloids of interest apply to the respirable fraction of airborne particles.

NOTE 1 Cyclone-type samplers are typically used for personal sampling. Cascade impactors are often used to characterize the particle size distribution in static sampling.

NOTE 2 For many samplers, internal wall deposits are included as part of the sample.

6.1.3 Multi-fraction samplers, designed to collect airborne particles and fractionate them so as to enable two or more particle size fractions to be separately determined, complying with the provisions of EN 13205, for use as an alternative to collecting multiple samples when limit values for the metals and metalloids of interest apply to more than one particle size fraction.

Multi-fraction samplers sometimes use polyurethane foam to collect larger particles. In such cases, the foam should be compatible with the selected sample preparation method (see ISO 15202-2) and should have the same low metal content specified for filters in 6.2.

6.2 Filters

The filters shall be of a diameter suitable for use with the samplers (6.1), have a collection efficiency of not less than 99,5 % for particles with a 0,3 µm diffusion diameter (see 2.2 of ISO 7708:1995), have a very low metal content (typically less than 0,1 µg of each metal or metalloid of interest per filter) and be compatible with the selected sample preparation method (see ISO 15202-2).

NOTE 1 See Annex B for guidance on filter selection.

NOTE 2 Besides filters, other types of collection substrates can be suitable, such as foams.

NOTE 3 Commercial products are available[1] that combine a filter and an associated ‘shell’ that are heat-sealed together to form a sampler insert that primarily collects airborne particles on the filter but also collects on the shell particles that would otherwise be deposited on the internal walls of the sampler.

6.3 Sampling pumps

The sampling pumps shall have an adjustable flow rate and be capable of maintaining the selected flow rate (between 1 l/min and 5 l/min for personal sampling pumps, and between 5 l/min and 400 l/min for high-volume

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[1] A sampler insert of this type is available from SKC Inc and this is referred to as an Accu-Cap™. At the time when this International Standard was developed the Accu-Cap™ was the only known commercially available product. This information is given for the convenience of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

sampling pumps) to within ± 5 % of the nominal value throughout the sampling period (see 8.1.2). For personal sampling, the pumps shall be capable of being worn by the worker without impeding normal work activity.

The pump should have, as a minimum, the following features:

— an automatic control that keeps the volumetric flow rate constant in the case of a changing back pressure;

— either a malfunction indicator that, following completion of sampling, indicates that the air flow has been reduced or interrupted during sampling; or an automatic cut-out that stops the pump if the flow rate is reduced or interrupted;

— a facility for the adjustment of flow rate, such that it can only be actuated with the aid of a tool (e.g. screwdriver) or requires special knowledge for operation (e.g. via software), so as to preclude inadvertent readjustment of the flow rate during use.

An integral timer is a highly desirable additional feature.

NOTE 1 A flow-stabilized pump may be required to maintain the flow rate within the specified limits.

NOTE 2 EN 1232[5] and EN 12919[7] require that the performance of the pumps is such that:

— the pulsation of the flow rate does not exceed 10 %;

— a flow rate set within the nominal range does not deviate by more than ± 5 % from the initial value under increasing back pressure;

— within the range of ambient temperatures from 5 °C to 40 °C, the flow rate measured under operating conditions does not deviate by more than ± 5 % from the flow rate at 20 °C;

— the operating time is at least 2 h, and preferably 8 h;

— the flow rate does not deviate by more than ± 5 % from the initial value during the operating time.

If the sampling pump is used outside the range of conditions specified in EN 1232[5] and/or EN 12919[7], appropriate action should be taken to ensure that the performance requirements are met. For instance, at sub-zero temperatures it might be necessary to keep the pump warm.

6.4 Flowmeter

The flowmeter shall be portable and have an accuracy that is sufficient to enable the volumetric flow rate (see 8.1.1.2) to be measured to within ± 5 %.

The calibration of the flowmeter shall be checked against a primary standard, i.e. a flowmeter whose accuracy is traceable to national standards. If appropriate (see 8.1.3), record the atmospheric temperature and pressure at which the calibration of the flowmeter was checked.

It is advisable that the flowmeter used is capable of measuring the volumetric flow rate to within ± 2 % or better.

6.5 Ancillary equipment

6.5.1 Flexible tubing, of a diameter suitable for making a leakproof connection from the samplers (6.1) to the sampling pumps (6.3).

6.5.2 Belts or harnesses, to which the sampling pumps can conveniently be fixed for personal sampling (except where the sampling pumps are small enough to fit in workers' pockets).

6.5.3 Flat-tipped forceps, non-metallic (e.g. plastic or plastic-coated) for loading and unloading filters from samplers or from filter transport cassettes.

6.5.4 Filter transport cassettes or similar, if required (see 8.5.1), in which to transport samples to the laboratory.

6.5.5 Thermometer, 0 °C to 50 °C, graduated in divisions of 1 °C or less, for measurement of atmospheric temperature, if required (see 8.1.3).

6.5.6 Barometer, suitable for measurement of atmospheric pressure, if required (see 8.1.3).

7 Occupational exposure assessment

7.1 General

The scope of this part of ISO 15202 pertains to the taking of personal and static samples. Refer to relevant International, European or National Standards (e.g. EN 689[4], ASTM E 1370[10]) for guidance on how to develop an appropriate assessment strategy and for general guidance on measurement strategy.

7.2 Personal sampling

Exposure of workers to metals and metalloids shall normally be determined by personal sampling, since the concentration of metals and metalloids in the breathing zone is usually higher than their background levels in the workplace.

7.3 Static sampling

Static sampling may be carried out, if appropriate, to assess the exposure of workers in a situation where personal sampling is not possible (see Note in 8.1.2.1 for an example of such a situation); to characterize the background levels of metals and metalloids in the workplace in order to give an indication of the efficiency of ventilation; or to provide information on the location and intensity of an emission source.

7.4 Selection of measurement conditions and measurement pattern

7.4.1 General

7.4.1.1 Sampling shall be carried out in such a way as to cause the least possible interference with the worker and the normal performance of the job, and to provide samples that are representative of normal working conditions and that are compatible with the analytical method (see ISO 15202-2 and ISO 15202-3).

7.4.1.2 The pattern of sampling shall take into consideration practical issues, such as the nature of the measurement task and the frequency and duration of particular work activities.

7.4.2 Screening measurements of variation of concentration in time/and or space

Screening measurements of variation of concentration in time and/or space may be performed to provide information on the likely pattern of concentration of chemical agents. They can be used to identify locations and periods of elevated exposure and to set the duration and frequency of sampling for measurements for comparison with limit values. Emission sources can be located and the effectiveness of ventilation or other technical measures can be estimated (see EN 482[3]).

7.4.3 Screening measurements of time-weighted average concentration and worst-case measurements

7.4.3.1 Screening measurements of time-weighted average concentration may be performed to obtain relatively crude information on the exposure level in order to decide whether an exposure problem exists at all, and, if so, to appraise its possible seriousness. They can also be used to determine if the exposure is well below or well above the limit value (see EN 482[3]).

7.4.3.2 Screening measurements of time-weighted average concentration are typically carried out in the initial stages of a survey to assess the effectiveness of control measures. Sampling may be carried out during representative work episodes to obtain clear information about the level and pattern of exposure, or worst case measurements may be made.

NOTE Screening measurements of time-weighted average concentration made to clearly identify work episodes during which highest exposure occurs are typically referred to as “worst-case measurements” (see EN 689[4]).

7.4.4 Measurements near an emission source

Measurements may be performed near an emission source to provide information on the location and intensity of the source. In association with other information, they can allow the elimination of a suspected source as a significant contributor to exposure (see EN 482[3]).

7.4.5 Measurements for comparison with limit values and periodic measurements

7.4.5.1 Measurements for comparison with limit values

7.4.5.1.1 Measurements for comparison with limit values are performed to provide accurate and reliable information on, or allow the prediction of, the time-weighted average concentration of a specific chemical agent in the air that could be inhaled (see EN 482[3]).

7.4.5.1.2 For metals and metalloids with short-term limit values, the sampling time shall be as close as possible to the reference period, which is typically 15 min, but can be anything between 5 min and 30 min.

7.4.5.1.3 For metals and metalloids with long-term limit values, samples shall be collected for the entire working period, if possible, or during a number of representative work episodes (see 8.1.2.1 for the minimum sampling time).

NOTE The best estimate of long-term exposure is obtained by taking samples for the entire working period, but this is often not practicable (e.g. because of the possibility of overloading the filter).

7.4.5.2 Periodic measurements

Periodic measurements are performed to determine whether exposure conditions have changed since measurements for comparison with limit values were made, or whether control measures remain effective (see EN 482[3]).

8 Sampling method

8.1 Preliminary considerations

8.1.1 Selection and use of samplers

8.1.1.1 Select samplers (6.1) designed to collect the inhalable or the respirable fraction of airborne particles, as defined in ISO 7708, according to which particle size fraction is applicable to the limit values for the metals and metalloids of interest. If more than one particle size fraction is of interest, collect multiple samples or use a multi-fraction sampler.

Limit values for individual metals and metalloids can apply to either the inhalable or the respirable fraction of airborne particles, or both. The samplers used should therefore be selected to meet national requirements.

If possible, the samplers selected should be manufactured from conducting material, since samplers manufactured in non-conducting material have electrostatic properties that can influence representative sampling.

8.1.1.2 Use the samplers at their design flow rate, and in accordance with the instructions provided by the manufacturer, so that they collect the intended fraction of airborne particles. See Reference [9] for further guidance.

8.1.2 Sampling period

8.1.2.1 Select a sampling period that is appropriate for the measurement task (see 7.4), but ensure that it is long enough to enable the metals and metalloids of interest to be determined with acceptable uncertainty at levels of industrial hygiene significance. For example, consider the metal or metalloid of interest with the lowest limit value, and estimate the minimum sampling time required to ensure that the amount collected is above the lower limit of the working range of the analytical method when the metal or metalloid concerned is present in the test atmosphere at an appropriate multiple of its limit value, using the following equation:

$$t_{\mathrm{min}} = \frac{m_{\mathrm{min}}}{q_V \times F \times \rho_{\mathrm{LV}}}$$

where

t_{min} is the minimum sampling time, in minutes;

m_{min} is the lower limit of the analytical range, in micrograms, for the metal or metalloid interest with the lowest limit value;

q_V is the design flow rate of the sampler, in litres per minute;

F is an appropriate multiple of the limit value (e.g. 0,1 times for an 8 h time-weighted average limit value or 0,5 times for a short-term limit value);

ρ_{LV} is the limit value, in milligrams per cubic metre, for the metal or metalloid of interest with the lowest limit value.

NOTE If the minimum sampling time is too long, consider the possibility of using a sampler designed to be used at a higher flow rate or of using an alternative more sensitive analytical technique (e.g. ICP-MS).

8.1.2.2 When high concentrations of airborne particles are anticipated, select a sampling period that is not so long as to risk overloading the filter with particulate matter.

8.1.3 Temperature and pressure effects

Refer to the manufacturer’s instructions to determine if the indicated volumetric flow rate of the flowmeter (6.4) is dependent upon temperature and pressure. Consider whether the difference between the atmospheric temperature and pressure at the time of calibration of the flowmeter and during sampling is likely to be great enough to justify making a correction to take this into account, e.g. if the error could be greater than ± 5 %. If a correction is necessary, measure and record the atmospheric temperature and pressure at which the calibration of the flowmeter was checked (see 6.4) and measure and record the atmospheric temperature and pressure at the start and at the end of the sampling period (see 8.4.1 and 8.4.2).

NOTE An example of temperature and pressure correction for the indicated volumetric flow rate is given in Annex C for a constant pressure drop, variable area flowmeter.

8.1.4 Handling of filters

To minimize the risk of damage or contamination, only handle filters using flat-tipped forceps (6.5.3), in a clean area, where the concentration of airborne particles is as low as possible.

8.2 Preparation for sampling

8.2.1 Cleaning of samplers

Unless disposable filter cassettes are used, clean the samplers (6.1) before use. Disassemble the samplers, soak in detergent solution, rinse thoroughly with water, wipe with absorptive tissue and allow to dry before reassembly. Alternatively, use a laboratory washing machine to clean the samplers.

8.2.2 Loading the samplers with filters

Load clean samplers (see 8.2.1) with filters (6.2), label each sampler so that it can be uniquely identified, and seal with its protective cover or plug to prevent contamination.

NOTE Alternatively, commercially available pre-loaded filter cassettes can be used.

8.2.3 Setting the volumetric flow rate

Perform the following in a clean area, where the concentration of airborne particles is low.

Connect each loaded sampler (see 8.2.2) to a sampling pump (6.3) using flexible tubing (6.5.1), ensuring that no leaks can occur. Remove the protective cover or plug from each sampler, switch on the sampling pump, attach the flowmeter (6.4) to the sampler so that it measures the flow through the sampler inlet orifice(s), and set the required volumetric flow rate (see 8.1.1.2). Switch off the sampling pump and seal the sampler with its protective cover or plug to prevent contamination during transport to the sampling position.

If necessary, allow the sampling pump operating conditions to stabilize before setting the volumetric flow rate.

8.2.4 Blanks

Retain as blanks one unused loaded sampler from each batch of ten prepared, subject to a minimum of three. Treat these in the same manner as those used for sampling with respect to storage and transport to and from the sampling position, but draw no air through the filters.

8.3 Sampling position

8.3.1 Personal sampling

8.3.1.1 The sampler shall be positioned in the worker's breathing zone, as close to the mouth and nose as is reasonably practicable, e.g. fastened to the worker's lapel. Attach the sampling pump to the worker in a manner that causes minimum inconvenience, e.g. to a belt (6.5.2) around the waist, or place it in a convenient pocket.

8.3.1.2 Give consideration to whether the nature of the process is likely to result in a significant difference between the actual exposure of the worker and the concentration of metals and metalloids measured by a sampler mounted on the lapel. If this is the case, make special arrangements to mount the sampler as close as possible to the worker's nose and mouth.

NOTE Examples of the need to make special arrangements to mount the sampler as close as possible to the worker's nose and mouth are:

- in welding and allied processes, when the use of a welder's face shield provides a degree of protection by physically deflecting the plume of welding fume away from the breathing zone, and sampling on the lapel could overestimate exposure (see ISO 10882-1[1]); and
- in soldering, when sampling on the lapel could significantly underestimate exposure because the characteristic plume of solder fume rises up past the nose and mouth.

8.3.2 Static sampling

8.3.2.1 If static sampling is carried out to assess the exposure of a worker in a situation where personal sampling is not possible (e.g. due to the need to sample at a volumetric flow rate higher than the design flow rate of available personal samplers), the sampling position shall be in the immediate vicinity of the worker and at breathing height. If in doubt, the sampling position shall be taken as the point where the risk of exposure is considered to be greatest.

8.3.2.2 If static sampling is carried out to characterize the background level of metals and metalloids in the workplace, select a sampling position that is sufficiently remote from the work processes, such that results will not be directly affected by airborne particles from emission sources.

8.4 Collection of samples

8.4.1 When ready to begin sampling, remove the protective cover or plug from the sampler and switch on the sampling pump. Record the time and volumetric flow rate at the start of the sampling period. If the sampling pump is fitted with an integral timer, check that this is reset to zero. If appropriate (see 8.1.3), measure the atmospheric temperature and pressure at the start of the sampling period using the thermometer (6.5.5) and barometer (6.5.6), and record the measured values.

NOTE If the temperature or pressure at the sampling position is different from that where the volumetric flow rate was set (see 8.2.3), the volumetric flow rate could change and it might need to be re-adjusted before sampling.

8.4.2 At the end of the sampling period (see 8.1.2), record the time and calculate the duration of the sampling period. Check the malfunction indicator and/or the reading on the integral timer, if fitted, and consider the sample to be invalid if there is evidence that the sampling pump was not operating properly throughout the sampling period. Measure the volumetric flow rate at the end of the sampling period using the flowmeter (6.4), and record the measured value. If appropriate (see 8.1.3), measure the atmospheric temperature and pressure at the end of the sampling period using the thermometer (6.5.5) and barometer (6.5.6), and record the measured values.

8.4.3 Carefully record the sample identity and all relevant sampling data (see 9.1). Calculate the mean volumetric flow rate by averaging the volumetric flow rates at the start and at the end of the sampling period and, if appropriate (see 8.1.3), calculate the mean atmospheric temperature and pressure. Calculate the volume of air sampled, in litres, at atmospheric temperature and pressure, by multiplying the mean flow rate in litres per minute by the duration of the sampling period in minutes.

8.5 Transportation

8.5.1 For samplers that collect airborne particles on the filter (see Note 2 in 6.1.1), remove the filter from each sampler, place it in a labelled filter transport cassette (6.5.4) and close with a lid. Take particular care to prevent the collected sample from becoming dislodged from heavily loaded filters. Alternatively, transport samples to the laboratory in the samplers in which they were collected.

8.5.2 For samplers that have an internal filter cassette (see Note 2 in 6.1.1), remove the filter cassette from each sampler and fasten with its lid or transport clip.

8.5.3 For samplers of the disposable cassette type, transport samples (collected on filters or by using inserts) to the laboratory in the samplers in which they were collected.

8.5.4 Transport the samples (8.5.1 to 8.5.3) to the laboratory in a container which has been designed to prevent damage to the samples in transit and which has been labelled to ensure proper handling.

8.5.5 Ensure that the documentation which accompanies the samples is suitable for a “chain of custody” to be established (see, for example, ASTM D 4840[11]).

9 Documentation

9.1 Sampling information

The following information shall be recorded by the person carrying out the sampling. It shall be passed to the person responsible for completing the test report, if this is someone different:

a) a statement to indicate the confidentiality of the information supplied, if appropriate;

b) a complete identification of the air sample, including the date of sampling, the place of sampling, the type of sample (personal or static), either the identity of the individual whose breathing zone was sampled (or other personal identifier) or the location at which the general occupational environment was sampled (for a static sample), a brief description of the work activities that were carried out during the sampling period, and a unique sample identification code;

c) the make, type and diameter of filter used;

d) the make and type of sampler used, including information about the target size fraction of airborne particles that the sampler is designed to collect;

e) the make and type of sampling pump used, and its identification;

f) the make and type of flowmeter used, the primary standard against which the calibration of the flowmeter was checked, the range of flow rates over which the calibration of the flowmeter was checked, and the atmospheric temperature and pressure at which the calibration of the flowmeter was checked, if appropriate (see 8.1.3);

g) the time at the start and at the end of the sampling period, and the duration of the sampling period in minutes;

h) the mean flow rate during the sampling period, in litres per minute;

i) the mean atmospheric temperature and pressure during the sampling period, if appropriate (see 8.1.3);

j) the volume of air sampled, in litres, at ambient conditions;

k) the name of the person who collected the sample.

9.2 Information to accompany the request for analytical services

The following information shall be supplied to the laboratory analysing the sample(s):

a) the unique sample identification code(s);

b) the type(s) of filter or sampler insert used;

c) a list(s) of the metals to be determined and the associated data quality objectives;

d) details of the person to whom the results shall be returned;

e) any special requirements (e.g. quality control protocols to be followed).

Annex A
(informative)

Sampler wall deposits

A.1 Samplers

Samplers for aerosols typically consist of a filter supported in a holder, though other collection substrates are also used, e.g. impaction plates and foams. The entire device is considered to be an aerosol sampler. The sampling efficiency of an aerosol sampler is considered to be the air concentration calculated from the particles collected by the sampler compared to their concentration in undisturbed air. All aerosol samplers exhibit a decrease in sampling efficiency with increasing particulate aerodynamic diameter. Size-selective samplers are designed for a specific sampling efficiency over a range of aerodynamic diameters, known as a sampling convention (see ISO 7708), and the sampling efficiency of the sampler is considered with reference to the relevant sampling convention. In some sampler designs, e.g. cyclones, there is an internal separator to achieve the required size selection.

A.2 Collection efficiency

The collection efficiency of an aerosol sampler has four components:

- the aspiration efficiency;
- the transfer efficiency within the sampler (either from sampler inlet to the collection substrate or, if an internal separator is present, both from the sampler inlet to the internal separator and from the internal separator to the collection substrate);
- the penetration efficiency (through the internal separator, if present); and
- the capture efficiency of the collection substrate (e.g. filtration efficiency, when the collection substrate is a filter).

For any given sampler design, the various components depend on the particle aerodynamic size and air flow rate through the sampler. The aspiration efficiency also depends on wind speed and direction, while the sampler's angle to the vertical influences both aspiration and transport efficiency. Part of the sample will deposit on internal surfaces of the sampler as a result of losses during passage within the sampler. In addition, if the sampler is transported after sampling, particles deposited on the substrate can become dislodged and add to deposits already on the internal surfaces of the sampler (although this is likely of lesser importance, except when the collection substrate is overloaded with sample). If the design specification for the sampler is to include all aspirated particles, these losses need to be taken into account. Table A.1 provides examples of median values of deposits on the walls for two commercially available samplers in common use, taken from data in References [17], [18], [19] and [20]. No pattern can be discerned from these data that would allow the use of correction factors.

For some samplers, the sample deposited on the collection substrate is considered to be the entire sample, i.e. wall deposits are not considered to be part of the sample. For other samplers, it is recommended that the wall deposits are evaluated.

A.3 Contribution to the uncertainty budget

Where an air sampling and analytical method includes a specific procedure for recovering and analysing wall deposits, this needs to be taken into account when estimating the expanded uncertainty of the method.

Table A.1 — Median wall deposits for closed-face cassette (CFC) and Institute of Occupational Medicine (IOM) samplers

Industry	Analyte	CFC samplers		IOM samplers	
		Median wall deposit (%)	*n*	**Median wall deposit** (%)	*n*
Copper smelter	Cu	21	18	16	17
Lead ore mill	Pb	19	9	19	8
Solder manufacture	Pb	29	30		
Battery production	Pb	28	16	8	11
Welding	Cr (VI)	5	10		
Welding	Al			3	18
Plating	Cr (VI)	12	12		
Paint spray	Cr (VI)	7	29		
Foundry	Zn	53	9		
Zinc plating	Zn	27	18		
Cast iron foundry	Fe	22	18	8	18
Grey iron foundry	Fe	24	18	5	18
Bronze foundry	Cu, Pb, Sn, Zn	19, 13, 0, 15	6	0, 0, 0, 3	6
Cuproberyllium	Cu, Be	31, 12	4		

Annex B
(informative)

Guidance on filter selection

NOTE The following guidance is intended to help the user choose the most suitable filter or sampler insert for a particular application. It is not an exhaustive treatise on the subject, and covers only the basics of those matters that merit consideration. In many instances, similar considerations apply to the selection of other sampling substrates, such as polyurethane foams.

B.1 Collection efficiency

B.1.1 Most filters that are typically used for sampling airborne particulate matter have the required collection efficiency (see 6.2) for sampling both the respirable and the inhalable fractions of airborne particles. Such filters include depth filters (e.g. glass or quartz fibre filters) and membrane filters [e.g. mixed cellulose ester membrane filters and membrane filters made from polymers such as polyvinyl chloride (PVC) or polytetrafluoroethylene (PTFE)].

B.1.2 Cellulose (paper) filters can have a collection efficiency below 99 %, and are generally unsuitable for sampling airborne particles. However, they are sometimes treated with a reagent, e.g. sodium carbonate, and used as a secondary medium to collect inorganic gases or vapours, e.g. arsenic trioxide.

B.1.3 Certain processes carried out at elevated temperatures can produce ultrafine airborne particles condensed from the vapour phase, known as fume. Filters used to sample airborne particulate matter can have a reduced collection efficiency for these very small particles, which are significantly less than 1 µm in diameter. However, the particles usually agglomerate soon after formation to produce larger particles that are efficiently collected. In general, filters that have a collection efficiency that meets the specification given in 6.2 are therefore suitable for sampling fume.

B.2 Dust-loading capacity

B.2.1 Membrane filters are manufactured from a variety of polymeric materials by a number of different processes. In each case, the result is a thin, flexible disc of microporous material, with well-defined pore-size, pore structure, pore density etc. Retention of particles takes place on the surface of membrane filters, which results in them having a relatively low dust-loading capacity in comparison with depth filters. If an excessive amount of dust is collected on a membrane filter, this can result in blockage of the pores, and failure of the sampling pump. In addition, sample can be lost from the filter during handling or in transport. Sampling times should therefore be kept reasonably short when sampling with membrane filters in a dusty environment, or depth filters should be used.

B.2.2 Depth filters consist of fibres that have been pressed together to form an irregular three-dimensional mesh. Particles are not only retained at the surface, but also within the structure of the filter, in its depths. This gives them a significantly higher dust loading capacity than membrane filters. In this respect, depth filters are a better choice than membrane filters when sampling for long periods in a dusty environment. However, depth filters tend to have a higher metal content than membrane filters, particularly in the case of certain metals, and this also needs to be considered when selecting the filter to be used.

B.2.3 Sampler inserts consisting of plastic material with a filter attached usually have a higher dust load capacity than in cases B.2.1 and B.2.2 above.

NOTE Sampler inserts are also useful in case of collection of non-sticky particulates that could be lost while transferring the filter from the sampler to the transport and/or solubilisation device.

B.3 Metal content

B.3.1 The metal content of the filters should be as low as possible, since it can make a significant contribution to the blank, the variability of which determines in part the lower limit of the working range of the analytical method. Exactly how low the metal content of the filters should be depends upon the applicable limit value. For each metal of interest, the lower limit of the working range of the analytical method should be less than the amount of metal that would be collected when sampling air at 0,1 times the limit value over the selected sampling period (see 8.1.2.1) at the selected flow rate (see 8.1.1.2). If this condition is not met, and it is suspected that the metal content of the filters might be high, consideration should be given to using an alternative filter.

B.3.2 Membrane filters generally have a very low metal content, and in this respect are suitable for nearly all applications.

B.3.3 Glass fibre filters are unsuitable for use when sampling for certain metals (e.g. aluminium, calcium and zinc) for which they have a relatively high blank value. This is also true of quartz fibre filters, but to a lesser extent.

B.4 Weight stability

B.4.1 If the filters (or inserts) are to be weighed in order to determine the amount of dust collected, it is important that they be reasonably resistant to moisture retention, so that blank weight changes that can occur as a result of changes in atmospheric conditions (temperature, humidity) are as low and as repeatable as possible. For example, mixed cellulose ester filters are generally unsuitable for gravimetric analysis since they absorb significant moisture. PVC filters are widely used when gravimetric analysis is required.

B.4.2 If glass fibre filters or quartz fibre filters are used, it is important that these be not excessively friable, since this can introduce weighing errors due to loss of filter material. Quartz fibre filters can be more friable than glass fibre filters. However, this disadvantage is counterbalanced by their lower metal content.

B.5 Solubility

B.5.1 The filters (or inserts) should be either wholly soluble or wholly insoluble using the selected sample preparation method. Partially dissolved filters can make subsequent handling of the sample solutions difficult, and/or they can cause analytical error because of a matrix mismatch between sample solutions and calibration solutions.

B.5.2 If the sample preparation method selected (see ISO 15202-2) involves quantitative transfer of the sample solution to volumetric glassware (or appropriate vessel in case of use of hydrofluoric acid) prior to analysis, the filters (or inserts) used for sampling should preferably be soluble using the sample preparation method concerned. This reduces the chance of incomplete transfer of the sample solution. Mixed cellulose ester membrane filters of 0,8 µm mean pore diameter are soluble in nitric acid, and these are suitable for use when this acid is used in the selected sample preparation method. Quartz fibre filters are soluble in hydrofluoric acid, and are suitable for use when this acid is used. Other filters might be equally suitable.

B.5.3 If sample solutions are to be made to volume in the sample dissolution vessel (e.g. a graduated centrifuge tube), it is unimportant whether or not the filters are soluble using the selected sample preparation procedure.

B.6 Chemical compatibility

If chemical analysis of the sample is also to be carried out by a method not described in this part of ISO 15202, the filters shall not be of a type that can react with the chemical agent to be determined. For example, PTFE membrane filters are suitable for sampling alkaline dusts, for which determination of hydroxide and the associated alkali metal (lithium, sodium, potassium or caesium) could be required.

Annex C
(informative)

Temperature and pressure correction for the indicated volumetric flow rate

Bubble flowmeters are preferred for measuring the volumetric flow rate because the readings they give are independent of temperature and pressure. For other flowmeters, it might be necessary to apply a correction to the indicated volumetric flow rate if the temperature and pressure at the time of measurement are different to when the calibration of the flowmeter was checked (see 8.1.3).

A typical example of the need for a temperature and pressure correction is when a constant pressure drop, variable area, flowmeter is used to measure the volumetric flow rate. In this instance, the following expression should be used to calculate the air sample volume:

$$V_{\mathrm{corr}} = q_V \times t \times \sqrt{\frac{p_1 \times T_2}{p_2 \times T_1}}$$

where

V_{corr} is the corrected air sample volume, in litres;

q_V is the mean volumetric flow rate, in litres per minute;

t is the duration of the sampling period, in minutes;

p_1 is the atmospheric pressure, in kilopascals, during calibration of the flowmeter;

p_2 is the mean atmospheric pressure, in kilopascals, during the sampling period;

T_1 is the temperature, in kelvin, during calibration of the flowmeter;

T_2 is the mean temperature, in kelvin, during the sampling period.

Other flowmeters can also require correction for variation in temperature and pressure. The operating instructions provided by the manufacturer should be consulted for information about any necessary correction.

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