BRITISH STANDARD

BS EN 14042:2003

Workplace atmospheres — Guide for the application and use of procedures for the assessment of exposure to chemical and biological agents

The European Standard EN 14042:2003 has the status of a British Standard

ICS 13.040.30

British Standards

National foreword

This British Standard is the official English language version of EN 14042:2003.

The UK participation in its preparation was entrusted by Technical Committee EH/2, Air Quality, to Subcommittee EH/2/2, Workspace atmospheres,which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 24 April 2003

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 40, an inside back cover and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

ISBN 0 580 41625 9

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 14042

April 2003

ICS 13.040.30

English version

Workplace atmospheres - Guide for the application and use of procedures for the assessment of exposure to chemical and biological agents

Atmosphères des lieux de travail - Guide pour l'application et l'utilisation de procédures permettant d'évaluer l'exposition aux agents chimiques et biologiques

Arbeitsplatzatmosphäre - Leitfaden für die Anwendung und den Einsatz von Verfahren und Geräten zur Ermittlung chemischer und biologischer Arbeitsstoffe

This European Standard was approved by CEN on 23 September 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Contents

Foreword

This document (EN 14042:2003) has been prepared by Technical Committee CEN/TC 137 “Assessment of workplace exposure”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2003, and conflicting national standards shall be withdrawn at the latest by October 2003.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

This document includes a Bibliography.

Introduction

Marking EN 14042 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of relevant European standards. The accuracy of the claim is therefore the responsibility of the person making the claim.

1 Scope

This European Standard provides guidance on the selection of procedures, and the installation, use and maintenance of devices for the determination of concentrations of chemical or biological agents in workplace atmospheres.

This European Standard is based on the guidance given in EN 689 and the requirements of EN 482.

Where appropriate, this European Standard specifies additional requirements specific to particular procedures or devices, or classes thereof.

It is the user's primary responsibility to choose appropriate procedures or devices that meet the requirements of relevant European Standards. One way of doing this is to obtain information or confirmation from the manufacturer. Type testing, or more generally, the assessment of performance criteria of procedures or devices, can be undertaken by the manufacturer, user, test house or research and development laboratory, as is most appropriate.

Although this Standard specifically addresses workplace air, many of the procedures or devices are also relevant to the assessment of air quality in ambient or indoor air.

Specific guides exist for electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours in workplace atmospheres (EN 45544-4) and for diffusive samplers for the determination of gases and vapours in ambient air (prEN 13528-3).

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 482:1994, *Workplace atmospheres — General requirements for the performance of procedures for the measurement of chemical agents.*

EN 689, *Workplace atmospheres — Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy.*

EN 838:1995, *Workplace atmospheres — Diffusive samplers for the determination of gases and vapours — Requirements and test methods.*

EN 1076:1997, *Workplace atmospheres — Pumped sorbent tubes for the determination of gases and vapours — Requirements and test methods.*

EN 1231:1996, *Workplace atmospheres — Short term detector tube measurement systems —* Requirements and test methods.

EN 1232, *Workplace atmospheres — Pumps for personal sampling of chemical agents — Requirements and test methods.*

EN 12919, *Workplace atmospheres — Pumps for sampling of chemical agents with a volume flow rate of over 5 l/min — Requirements and test methods.*

EN 13098, *Workplace atmospheres — Guidelines for measurement of airborne micro-organisms and endotoxin.*

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

prEN 13528-3, *Ambient air quality — Diffusive samplers for the determination of concentration of gases and vapours — Part 3: Guide to selection, use and maintenance.*

EN 13890, *Workplace atmospheres — Procedures for measuring metals and metalloids in airborne particles — Requirements and test methods.*

ENV 13936:2001, *Workplace atmospheres — Measurement of chemical agents present as mixtures of airborne particles and vapour — Requirements and test methods.*

EN 45544-4, *Workplace atmospheres — Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours — Part 4: Guide for selection, installation, use and maintenance.*

3 Terms and definitions

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

3.1
accuracy
closeness of agreement between a test result and the accepted reference value

[ISO 3534-1:1993]

3.2
averaging time
period of time for which the measuring procedure yields a single value

[EN 482:1994]

3.3
bias
consistent deviation of the measured value from the value of the air quality characteristic itself or the accepted reference value

[ISO 6879:1995]

NOTE In this European Standard “air quality characteristic” means the concentration of the pollutant in workplace air.

3.4
biological agent
micro-organisms, including those which have been genetically modified, cell cultures and human endoparasites which can cause any infection, allergy or toxicity or otherwise create a risk to human health

[EN 1540:1998]

3.5
chemical agent
any chemical element or compound, on its own or admixed as it occurs in the natural state or as produced by any work activity, whether or not it is produced intentionally and whether or not placed on the market

[EN 1540:1998]

3.6
desorption efficiency
ratio of the mass of analyte desorbed from a sampling device to that applied

[EN 838:1995]

3.7
detector tube measurement system
complete measurement system consisting of a detector tube and a detector tube pump

[EN 1231:1996]

3.8
diffusive sampler
device which is capable of taking samples of gases or vapours from the atmosphere at a rate controlled by a physical process such as gaseous diffusion through a static air layer or a porous material and/or permeation through a membrane, but which does not involve the active movement of air through the sampler

NOTE 1 Adapted from EN 838:1995.

NOTE 2 Active normally refers to the pumped movement of air.

3.9
diffusive uptake rate
rate at which the diffusive sampler collects a particular gas or vapour from the atmosphere, expressed in nanograms per parts per million1) per minute (ng ppm^{-1} min^{-1}) or cubic centimetres per minute (cm^{3} min^{-1})

[EN 838:1995]

3.10
inhalable fraction
mass fraction of total airborne particles which is inhaled through the nose and mouth

[EN 481:1993]

3.11
length of stain detector tube (in the following called "detector tube")
glass tube containing chemical reagents in which a colour change can be produced when a sample of the atmosphere is drawn through it

NOTE The length of stain, relative to a graduated scale, provides a measure of the concentration of the specified chemical agent in air.

3.12
limit value (LV)
reference figure for the concentration of a chemical or biological agent in air

[EN 1540:1998]

3.13
measuring procedure
procedure for sampling and analysing one or more chemical or biological agents in the air and including storage and transportation of the sample

[EN 1540:1998]

---

1) ppm is volume fraction, ( )=10^{-6}.

3.14

overall uncertainty (OU) (of a measuring procedure or of an instrument)

quantity used to characterise as a whole the uncertainty of the result given by an apparatus or a measuring procedure. It is expressed, as a percentage, by a combination of bias and precision usually according to the formula:

$$\frac{\left| \bar{x} \quad x_{ref} \right| + 2s}{x_{ref}} \tag{1}$$

where

$\bar{x}$ is the mean value of results of a number (*n*) of repeated measurements;

x_{ref} is the true or accepted reference value of concentration;

s is the standard deviation of measurements.

[EN 1540:1998]

3.15

particle/ vapour mixture

aerosol consisting of airborne particles and vapour

[ENV 13936:2001]

3.16

precision

the closeness of agreement between independent test results obtained under stipulated conditions

[ISO 3534-1:1993]

3.17

pumped sampler

device which is capable of taking samples of gases, vapours or particulates from the atmosphere and consisting of a sampling medium, such as a sorbent tube or filter, and an air sampling pump

3.18

respirable fraction

mass fraction of inhaled particles penetrating to the inciliated airways

[EN 481:1993]

3.19

selectivity

degree of independence from interferents

[EN 482:1994]

3.20

sorbent tube

tube, usually made of metal or glass, containing an active sorbent or reagent-impregnated support, through which sampled atmosphere is passed at a rate controlled by an air sampling pump

[EN 1076:1997]

3.21

specified measuring range

set of values of the concentration for which the overall uncertainty of a measurement procedure is intended to lie within specified limits

[EN 482:1994]

3.22
suspended matter
particles that remain airborne long enough to be detected by any physical means

[EN 1540:1998]

3.23
total airborne particles
all particles surrounded by air in a given volume of air

[EN 481:1993]

3.24
true value
value which characterises a quantity perfectly defined in the conditions which exist when that quantity is considered (or is the subject of a determination)

[ISO 3534-1:1993]

NOTE It is an ideal value which could be arrived at only if all causes of measurement error were eliminated and the population was infinite.

4 Measurement objectives and strategy

4.1 General

There are an extensive number of industrial processes and chemical and/or biological agents. An individual manufacturing stage can apply a number of conditions and a number of job functions can be necessary, each of which can result in different exposure conditions. Distance from an emission source and physical parameters (release rate, environmental conditions, ventilation) can also have a significant influence. Rapid fluctuations in concentration or large variations over small distances are commonplace; therefore the siting, timing and duration of sampling or direct measurement are of great importance.

A workplace monitoring strategy will involve various measuring procedures. The European Committee for Standardization (CEN), has introduced two standards dealing with "assessment of workers exposure". The first, EN 689, gives guidance for the assessment of workers exposure to chemical agents in workplace atmospheres including measurement strategy. The second, EN 482, specifies general performance requirements for procedures for determining the concentration of chemical agents in workplace atmospheres. The following clauses give a brief outline of the content of these two European Standards.

4.2 EN 689

4.2.1 General

The workers exposure assessment is based on an occupational exposure assessment and, if necessary, periodic measurements to check that the exposure conditions are unchanged. If the conditions are changed, a re-assessment is necessary.

4.2.2 Occupational exposure assessment

The occupational exposure assessment is used to identify potential exposure situations and assess the level of exposure through a sequence of stages with increasing sophistication (initial appraisal, basic survey, detailed survey). The assessment can be concluded at any stage. If a conclusion cannot be reached, the next stage of the assessment is undertaken.

The initial appraisal will indicate the likelihood of exposure. It is based on the list of chemical agents that are likely to be present in the workplace atmospheres and on several workplace factors likely to have an influence on the exposure level (e. g. tasks, work pattern and techniques, ventilation, emission sources). If the initial appraisal shows that the presence of an agent in the air at the workplace cannot for certain be ruled out, this agent needs to be considered in the next stage. In practice this means that if an agent is introduced in the factory even as an impurity or is produced in the factory even as a side product or waste, it has to be considered in the basic survey.

The basic survey provides quantitative information about exposure. This information is based on earlier measurements, measurements from comparable installations or reliable calculations on relevant quantitative data. If the information obtained is insufficient to enable valid comparison to be made with the limit value, it has to be supplemented by workplace measurements. If the basic survey shows that the exposure is above the limit value, EN 689 requires that immediate action be taken to remedy the situation and a new assessment be conducted. If the basic survey shows that the exposure is well below the limit value and is expected to remain so on a long term basis taking in account the stability of conditions at the workplace and the arrangement of the workplace process, the assessment procedure may be stopped. In EN 689 no figure is associated with the concept 'well below the limit value'.

NOTE What is considered as “well below limit value” can be regulated by national law, but it is generally admitted that it concerns time weighted average concentrations less than 0,1 LV.

The detailed survey will provide validated and reliable information on exposure when the exposure is close to the limit value. The information is based on workplace measurements and will lead to the conclusion of the occupational exposure assessment.

According to EN 689 the occupational exposure assessment phase will be concluded with one of the three actions listed below:

a) When the exposure exceeds the limit value, control measure are taken to reduce the exposure and the exposure re-assessed.

b) When the exposure is well below the limit value, a re-assessment of the exposure level will be done at periodic intervals. The time interval between assessments will depend on how long the exposure level is likely to remain low.

c) When the exposure is between a) and b), a periodic measurement scheme should be established to monitor the exposure level.

4.2.3 Periodic measurements

The emphasis of periodic measurement is on longer term objectives such as checking that control measures remain effective. Information is likely to be obtained on trends or changes in pattern of exposure so that action can be taken before excessive exposure occurs. In this respect it is important to use a measurement method and strategy that makes it possible to detect trends at a sufficiently early stage.

4.2.4 Reassessment

At any time during the assessment and monitoring process, changes in the process or control measures could have a major impact on the exposure level. Therefore, such changes will require a re-assessment of the exposure.

4.2.5 Measurement strategy

The measurement strategy described is based on an approach which enables the efficient use of resources.

The measurement strategy gives instructions on the selection of the measurement task and procedure, the selection of the workers for the exposure measurements, the selection of the measurement conditions and patterns and gives some examples of data treatment.

EN 689 refers to the basic measurement tasks described in EN 482.

4.3 EN 482

4.3.1 The general requirements referred to in EN 482 apply to all measuring procedures, irrespective of the chemical nature or physical form of the agent, and irrespective of the sampling method or analytical method used. EN 482 is applicable to measuring procedures with separate sampling and analysis stages and to direct reading instruments. The performance requirements include unambiguity, selectivity and overall uncertainty (a combination of bias and precision) for minimum specified measuring ranges and averaging times. EN 482 is a basis for forthcoming standards for specific procedures and devices for workplace measurements (see clauses 5 and 6).

4.3.2 Five basic measurement tasks have been defined in the standard. These are:

a) Screening measurements of time weighted average concentration to provide relatively crude quantitative information on the exposure level in order to determine whether an exposure problem exists at all. These measurements can also be used to determine if the exposure is well below or well above the limit values.

b) Screening measurements of variation of concentration in time and/or space to provide information of the likely pattern of exposure and to identify locations and periods of "high" exposure. They can also be used to set the duration and frequency of sampling for measurements for comparison with limit values.

c) Measurements near an emission source to provide information on the location and the intensity of the source. In association with other information they can allow the elimination of a suspected source as a significant contributor to exposure.

d) Measurements for comparison with limit value to provide accurate and reliable information on the time-weighted average concentration of a specific agent in the air which can be inhaled.

e) Periodic measurements to check if the exposure conditions have changed since the last comparison with limit values, or whether the control measure remain effective.

4.3.3 EN 482:1994, annex A gives a list of measurement task referred to in EN 689 and involving a combination of the basic measurement tasks:

a) Worst case measurements

Screening measurements in time and space can clearly identify episodes where higher exposure occur, e.g. high emissions due to certain work activities. Sampling periods can be selected containing these episodes. This approach is called worst case sampling. Subsequently, monitoring can be required either as a screening measurement of time-weighted average concentration or for comparison with limit values.

This approach can allow a low cost exposure assessment when the results of a few worst case measurements are still below the limit value.

b) Fixed point measurements

Fixed point measurements can be used for comparison with limit values if the results are representative for the exposure concentration. In other uses, the initial measurement task is the same as for emission sources and any subsequent monitoring will be a screening measurement of time-weighted average concentration or a periodic measurement.

c) Short term peak measurements

Screening measurements of variation in time can find short term peaks. These measurements can be followed by screening measurements of time- weighted average concentration. Where the measurements are exposure concentration, these can be compared with limit values. Short term limit values can be important in these cases.

4.4 Other tasks

In addition, measuring procedures and devices can be used for other measurements tasks not included in EN 482 or EN 689. These include:

a) area monitoring including the use of fixed instruments to provide continuous information on the concentration of hazardous substances over a site;

b) measurements for comparison with the short term exposure limit;

c) spot reading measurements;

d) hazard alarm measurements;

e) measurements in confined space;

f) visualisation of personal exposure. This provides visual information on the correlation between exposure and the work process through a combination of a fast response personal monitor and simultaneous video filming of the work activity.

5 Selection of the measurement procedure or device

5.1 General

There are frequently many alternative measuring procedures or devices appropriate for particular applications, and the best one will depend on the circumstances.

First step is to establish the requirements for the measurement according to EN 482 and specific standards relevant to the intended measurement. Factors which will need to be taken into account include:

a) the measurement task;

b) the nature of the chemical or biological agent;

c) the range of concentration which can be encountered;

d) the time resolution required;

e) selectivity to the target chemical agent and sensitivity to interfering chemical agents;

f) overall uncertainty required;

g) susceptibility of the sampler to environmental factors;

h) fitness for purpose, e.g. weight, size, durability;

i) training requirements for the reliable operation, maintenance and calibration;

j) the total cost of purchase and operation, including calibration and maintenance;

k) compliance with the performance requirements of appropriate national regulations;

l) conformity to the user's quality system.

Having established the requirements, the next step in the selection of a measuring procedure and the devices to run it is to search the available literature. Primary sources are:

¾ compendia of methods recommended by the regulatory authorities or governmental agencies in Europe (see bibliography);

¾ national and International Standards;

¾ recommended methods of other countries.

Secondary sources are published literature references in scientific journals or books. In any case, procedures shall be validated before application.

Choosing the equipment (sampling and analysis) to run the procedure, important information can be obtained from:

1) the manufacturer's instructions for use;

2) published commercial technical information;

3) technical and research publications.

The final stage is to review the performance characteristics of the available methods and the devices against the selection criteria established and requirements of relevant specific standards (see 5.2.2).

5.2 Selection flow chart

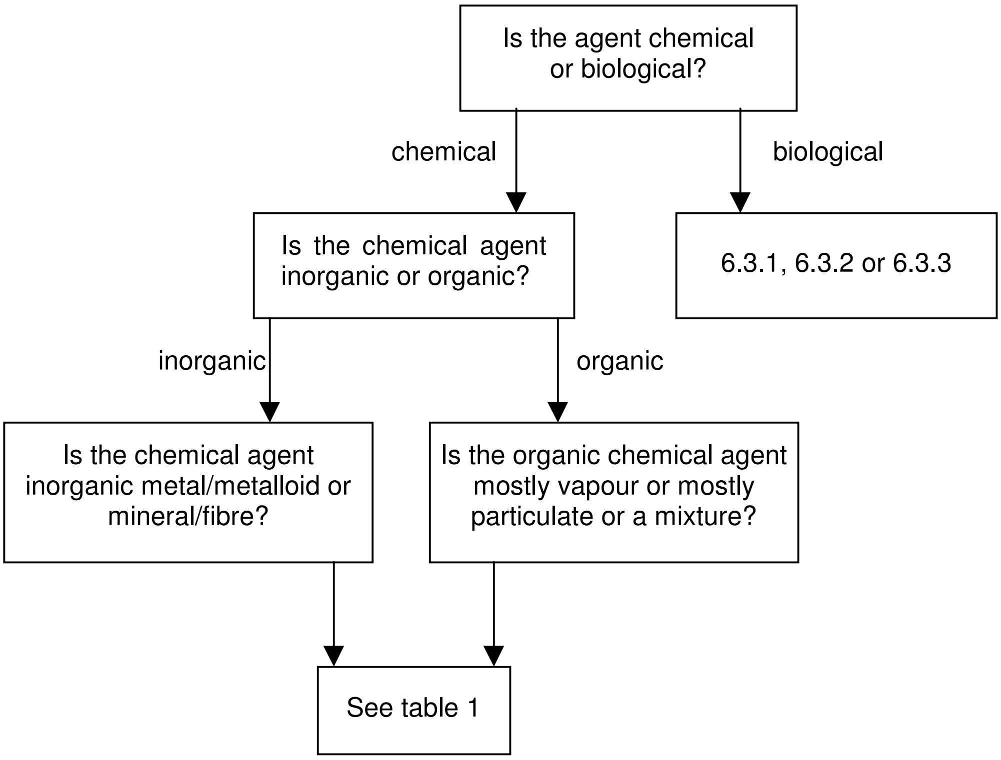

Table 1 — Selection of a suitable measurement procedure or device

	Inorganic gas	Metal / metalloid	Mineral / Fibre	Organic vapour	Organic particulate	Particle/ vapour mixture	Micro-organisms
Short-term measurement	6.2.1, 6.2.2, 6.2.3	—	—	6.2.1, 6.2.2, 6.2.3	—	—	6.3.1, 6.3.2, 6.3.3
Continuous/ Instrumental	EN 45544-4	6.2.4	6.2.4	EN 45544-4	6.2.4	6.2.5	—
Time-weighted-average concentration	6.2.2, 6,2,3, 6.2.4, 6.2.6, 6.2.7	6.2.4, 6.2.6, 6.2.8	6.2.4	6.2.3, 6.2.6, 6.2.7, 6.2.9	6.2.2, 6.2.4	6.2.5	6.3.1, 6.3.2, 6.3.3

5.2.1 The performance requirements in the European Standard are related to the general requirements of EN 482. The table relating the specification of performance requirements with the measurement task in EN 482 is reproduced in table 2.

Table 2 — Specification of performance requirements depending on the measurement task

Measurement task	Relative overall uncertainty	Minimum specified measuring range	Averaging time
Screening measurement of time-weighted-average concentration	50%	0,1 LV to 5 LV	Less than or equal to the limit value reference period
Screening measurement of variation of concentration a) in time	20%	dynamic range 10:1 (see note 1)	5 min
b) in space	40%	dynamic range 10:1 (see note 1)	15 min
Measurement near an emission source	50%	0,5 LV to 10 LV	source dependent
Measurements for comparison with limit values	50%	0,1 LV to 0,5 LV	Less than or equal to the limit value reference period
Measurements for comparison with limit values	30%	0,5 LV to 2 LV	Less than or equal to the limit value reference period
Periodic measurements	50%	0,1 LV to 0,5 LV	Less than or equal to the limit value reference period
Periodic measurements	30%	0,5 LV to 2 LV	Less than or equal to the limit value reference period

NOTE 1 A minimum measuring range is not specified. The required measuring range of the concentration can be decided for each particular application. Nevertheless, a minimum span between the upper and lower limits of the measuring range of concentration is specified.

NOTE 2 If the requirements contained in table 2 cannot be met with a single device or procedure, it is acceptable to use two different devices or procedures with complementary and overlapping measurement ranges that together span the range required.

NOTE 3 Occasionally, measurement tasks have to be performed which do not fall into any of the above categories. An important example is measurements performed to investigate components without existing Limit Values. In these cases, the user of the method should document the anticipated measuring range and the overall uncertainty determined within this range.

5.2.2 Performance of the procedure can imply one stage and one device or several stages and several devices.

EN 482 (see 4.3) establishes the requirements for the whole procedure in relation with the measurement task regardless of the number of devices or stages. Specific standards (see table 3) give requirements that are more detailed for specific devices used in some sampling systems and for direct measurement system. Therefore, it can be convenient to group the procedures considering these aspects as:

¾ one stage procedures (chemical agents). They use a device that gives the result of the field measurements without further actions, for example, short-term detector tubes (see 6.2.1 and EN 1231).

¾ procedures with separate stages for sampling and analysis (chemical agents). They use a sampling system with one or several devices. Further actions and equipment are required to obtain the result of the measurement. They can use:

  ¾ pumped sampling: one or several samplers to retain the chemical agents plus a personal pump (EN 1232 and clause 9). Devices used are: impingers (6.2.2), denuders (6.2.3), particle selectors (EN 13205 and 6.2.4), sorbent tubes (EN 1076 and 6.2.6), filters (6.2.8), bags (6.2.9)

  ¾ diffusive sampling: diffusive samplers (EN 838 and 6.2.7).

The relevant standards giving specific requirements are given in table 3.

Table 3 — Specific standards and requirements

Specific measuring procedures or devices	Relevant standard	Requirements
Diffusive samplers for the determination of gases and vapours	EN 838	Desorption efficiency Storage Overall uncertainty Blank value Sampler leak test Uptake rate value Air velocity/ sampler orientation Shelf life Mechanical strength Instructions for use Sample identification
Pumped sorbent tubes for the determination of gases and vapours	EN 1076	Desorption efficiency Storage Overall uncertainty Blank value Sampler leak test Flow resistance Instructions for use Sample identification
Short term detector tubes	EN 1231	Overall uncertainty Specified measuring range Reusable tubes Scale Evaluation of the stain Shelf life mechanical strength Temperature stability Packing of the detector tubes Interferences Overloading Climatic influences Instructions for use
Personal sampling pumps	EN 1232	Mass Mechanical strength Pulsation of flow rate Design safety Flow rate stability Required back pressure Operating time Start-up and long term performance Short term interruption of air flow Temperature dependence Orientation Timer accuracy Instructions for use Electromagnetic compatibility Explosion hazard

Specific measuring procedures or devices	Relevant standard	Requirements
Pumps with a flow rate over 5 l/min	EN 12919	Features Mechanical strength Pulsation of flow rate Design safety Flow rate stability Nominal volume flow rate Operating time Start-up and long term performance Short term interruption of air flow Temperature dependence Orientation Timer accuracy Instructions for use Electromagnetic compatibility Explosion hazard
Measurement of airborne micro-organisms and endotoxin	EN 13098	Guidelines only
Instruments for the measurement of airborne particle concentrations	EN 13205	Accuracy Specimen variability Air flow stability Transportation and handling Sample identification Instructions for use Design safety Electrical safety Temperature stability Time stability
Measurement of chemical agents present as mixtures of particles and vapour	ENV 13936	For particles: Fraction to be sampled Accuracy For vapours: Concentration and loading Temperature and humidity Shelf life Maximum capacity of sampler For combined system: Overall uncertainty Recovery efficiency Storage Blank value Dimension of result
Metals and metalloids in airborne particles	EN 13890	General requirements Quantification limit Analytical recovery Overall uncertainty

5.3 Selectivity requirements

Many types of measuring procedures and devices are not sensitive to a specific chemical or biological agent. The presence of other chemical or biological agents can influence the measurement value. A lower measurement value is unacceptable. A significantly higher measurement value is also not desirable, but can be acceptable in some cases. Where a measuring procedure or device is to measure more than one chemical or biological agent, it should be calibrated accordingly.

Selectivity requirements will vary from case to case, depending on what is known in advance about the air composition.

a) If the air composition is not fully known in advance then the measuring procedure or device should have a high selectivity taking into account the overall uncertainty or precision and the likely interferences.

b) If the composition of the atmosphere is qualitatively known, prior to the measurement, then the selectivity requirement will be low. Assuming that the measured value recorded is counted as applying to the chemical agent being measured and provided that the result is not lowered by the presence of other compounds.

The manufacturer of the measuring device should indicate in the instruction manual known interferences likely to affect the measurement. In particular, the manufacturer should specify those interferents that lead to a lower measurement value. If these interfering agents are present during the measurement, then the suitability of the measuring device should be questioned. The user should note that the manufacturer of a measuring device can not be fully aware of all potential interfering agents in each individual case.

The user has a particular responsibility to attempt to identify in advance the mixtures of chemical agents likely to be present in the workplace atmosphere. This information will assist in selecting the appropriate measuring device.

5.4 The influence of environmental parameters

Environmental conditions in workplaces will vary widely. The measuring procedure or device selected should comply with the performance requirements detailed in the relevant standards when the environmental conditions are within the following typical ranges:

a)	temperature	5 °C to 40 °C
b)	pressure	95 kPa to 110 kPa
c)	humidity	20 % to 90 % relative humidity
d)	air speed	0,01 m/s to 4 m/s

While a great proportion of workplace measurements will be performed within these environmental ranges, some measurements will not. In the latter case, the measuring procedure or device might not comply with the performance requirements, particularly with regard to the overall uncertainty requirement.

Nevertheless, the measuring procedure or device may still be used, provided that the user is able to identify, on the basis of the information available, what influence the environmental conditions outside these ranges will have on the measurement value and be able to take the appropriate action. For further specific information, see tables 4 to 15.

5.5 Fitness for purpose

The measuring procedure or device should be easy to operate, robust, reliable and be designed to minimise operator errors.

6 Operating principles and characteristics

6.1 General

This clause gives a brief description of the operating principles and general response parameters of the common measuring procedures and devices' technologies. The information should only be used as a guide. Developments in instrument technologies are advancing all the time and new advances can make some of the information obsolete. The user should check the current operation parameters with the instrument manufacturer. The list is not in order of recommendation. The flow chart in 5.2 indicates the variety of possible approaches.

6.2 Measurement of chemical agents

6.2.1 Short term detector tubes

Table 4 — Short term detector tubes

Characteristics	Comments
Operating principles	A short term detector tube measurement system consists of a detector tube connected to a compatible detector tube pump. When workplace air containing a particular chemical agent is drawn through the tube, a colour change, corresponding to the concentration, takes place.
Typical measurement tasks	Screening measurements of time-weighted average concentrations; measurements near an emission source; periodic measurements
Typical measurement range	A dynamic range of about 15:1 within the range 0,1 mg/m^3 to 1000 mg/m^3. Usually several tubes are available with different ranges
Averaging time	10 s to 15 min, depending on the number of strokes
Selectivity	Generally poor, but detailed information available from the manufacturer
Influence of environmental parameters:	
Pressure	Small in comparison with overall error
Temperature	Small in comparison with overall error
Humidity	Generally , some humidity required for tube reaction
Air speed	No
Vibration	No
Calibration	Each batch of tubes should be calibrated. This is normally done by the manufacturer
Limitations	Relatively inaccurate Interferences by other substances
NOTE Long term detector tubes are also available that are suitable for other measurement tasks.	

6.2.2 Procedures using an impinger/bubbler as sampler

Table 5 — Procedures using an impinger/bubbler as sampler

Characteristics	Comments
Operating principles	A measured volume of sample air is drawn through one (or more) impingers in series using a pump; an appropriate liquid being selected for the compound or mixture to be sampled. Provided suitable liquids are chosen, volatile organic components are retained by the impinger and thus are removed from the flowing air stream. An aliquot of the liquid containing the collected vapour is injected by means of a syringe into a gas chromatograph, where it is transferred by inert carrier gas into a suitable capillary column. The organic compounds are detected by a flame ionization or other suitable detector The method is also appropriate for some inorganic vapours with an appropriate spectrographic or chromatographic analyser. The method can also be used for reactive agents by introducing a reagent onto the impinger. It is then more usual to use high pressure liquid chromatography for the analysis.
Typical measurement tasks	Screening measurement of time-weighted-average concentration; measurements for comparison with limit values; periodic measurements
Typical measurement range	1 mg/m^3 to 1000 mg/m^3
Response time/ Averaging time	15 min to 8 h
Selectivity	The gas or liquid chromatographic separation gives high selectivity
Influence of environmental parameters:	
Pressure	No;
Temperature	Sorption capacity is inversely proportional to temperature;
Humidity	No;
Air speed	No;
Vibration	No;
Calibration	Calibrate the analyser and the pumps
Limitations	Not convenient for personal measurements; particulates will be collected, depending on inlet velocity

6.2.3 Procedures using a denuder as sampler

Table 6 — Procedures using a denuder as sampler

Characteristics	Comments
Operating principles	The simplest form of a denuder is a long glass tube coated at the inside. If the measured air flow drawn through the tube by a pump is laminar, airborne substances move at right angle to the air flow to the walls, where they are retained by a coating material. If the latter is chosen specifically, a selective sampling is possible, while any other substance passes trough the denuder. An annular denuder combines several concentrically arranged glass tubes. The compact design is a big advantage in handling of this type of denuder. The method can be normally used for organic and inorganic gases which reacts with the wall coating. For analysis the coating is washed from the denuder walls. After the clean up different analytical techniques (GC, HPLC, etc.) can be used.
Typical measurement tasks	Screening measurements of time-weighted average concentration; measurement for comparison with limit values
Typical measurement range	1 µg/m³ to 100 mg/m³
Response time / Averaging time	15 min to 8 h
Selectivity	The gas or liquid chromatographic separation gives high selectivity
Influence of environmental parameters:	
Pressure	No
Temperature	No
Humidity	High, depends on the coating
Air speed	Laminar flow conditions are necessary for the denuder principle
Vibration	Glass denuders are highly fragile
Calibration	Calibrate the analyzer and the pump
Limitations	Sampling efficiency data need particulates will pass the denuder

6.2.4 Procedures using a particle selector to sample size fractions

Table 7 — Procedures using a particle selector to sample size fractions

Characteristics	Comments
Operating principles	A measured volume of air is drawn through a defined inlet of an aerodynamic particle selector by a pump, such that the airborne particles are selected into predefined fractions. The particles in the size range of interest are deposited into a collection substrate, which may be either a filter, porous foam, impaction surface, or combination of these elements. The collected particles can be quantified either by weighing the collection substrates, or by other analytical methods.
Typical measurement tasks	Measurements near an emission source; personal sampling; periodic measurements
Typical measurement range	0,1 mg/m^3 to 20 mg/m^3
Response time / Averaging time	15 min to 8 h
Selectivity	Dependent on subsequent analysis
Influence of environmental parameters:	
Pressure	No
Temperature	No
Humidity	Not under normal circumstances
Wind velocity/direction	Affects some types of instruments
Vibration	Affects the integrity of samples by causing unwanted movement of deposits
Calibration	Calibrate the pump and the analyser
Limitations	Many – refer to the manufacturer’s literature for known limitations on the use of specific instruments

6.2.5 Procedures to measure chemical agents present as mixtures of particles and vapour

Table 8 — Procedures to measure chemical agents present as mixtures of particles and vapour

Characteristics	Comments
Operating principles	A measured volume of air is drawn through a defined inlet of an aerodynamic particle selector by a pump, such that the inhalable fraction of total airborne particles is selected. The sampled particles and vapour are collected onto substrates, which can be combinations of filters, porous foams, sorbents, or other elements. The methods of analysis depend strongly on the substances to be quantified and the choice of substrates.
Typical measurement tasks	Measurements near an emission source; personal sampling; periodic measurements
Typical measurement range	Not well defined – most methods are in the developmental stage
Typical response time	Intended for 15 min to 8 h sampling
Selectivity	Dependent on subsequent analysis
Influence of environmental parameters: Pressure Temperature Humidity Air speed Vibration	Not well defined at present
Calibration	Calibrate inlet air flow rate or speed and the analyser
Limitations	Particle and vapour fractions under initial sampling conditions cannot easily be quantified separately. Hence, measurement is usually directed at the sum of the inhalable particle fraction and the vapour. There can be severe limitations on the measuring range for certain chemical agents. Is not applicable for short-term measurement.

6.2.6 Procedures using pumped samplers for gases and vapours

Table 9 — Procedures using pumped samplers for gases and vapours

Characteristics	Comments
Operating principles	A measured volume of sample air is drawn through one (or more) sorbent tubes in series by a pump; an appropriate sorbent (or sorbents) being selected for the compound or mixture to be sampled. Provided suitable sorbents are chosen, volatile organic components are retained by the sorbent tube and thus are removed from the flowing air stream. The collected vapour (on each tube) is either a) desorbed by solvent and injected by means of a syringe or, b) desorbed by heat and transferred under inert carrier gas into a gas chromatograph equipped with a suitable capillary column and a flame ionization or other suitable detector, where it is analysed. The method is also appropriate for some inorganic vapours with an appropriate spectrometric or chromatographic analyser. The method can also be used for reactive agents by introducing a reagent onto the sorbent or onto a filter. It is then more usual to use high pressure liquid chromatography for the analysis.
Typical measurement tasks	Screening measurement of time-weighted-average concentration; measurements for comparison with limit values; periodic measurements
Typical measurement range	0,02 mg/m^3 to 100 mg/m^3 (thermal desorption) 1 mg/m^3 to 1000 mg/m^3 (solvent desorption)
Averaging time	15 min to 8 h
Selectivity	The gas or liquid chromatographic separation gives high selectivity
Influence of environmental parameters:	
Pressure	No;
Temperature	Sorption capacity is inversely proportional to temperature;
Humidity	Carbon-based sorbents affected
Air speed	No;
Vibration	No;
Calibration	Calibrate the analyser with each batch of samples
Limitations	Particulates will be collected and analysed only if volatile (thermal desorption) or extractable (solvent desorption)

6.2.7 Procedures using diffusive samplers

Table 10 — Procedures using diffusive samplers

Characteristics	Comments
Operating principles	An appropriate sampler type - badge, tube, radial - is selected, depending on the sampling rate desired. An appropriate sorbent is selected for the compound or mixture to be sampled. The rate of sampling is determined by prior calibration in a standard atmosphere, or from manufacturer’s data. The diffusive sampler is exposed to air for a measured time period. The organic compound vapour(s) migrate into the sampler by diffusion and are collected on the sorbent. The collected vapour is either a) desorbed by solvent and injected by means of a syringe or, b) desorbed by heat and transferred by inert carrier gas into a suitable capillary column of a gas chromatograph. The organic compounds are detected by a flame ionization or other suitable detector. The method is also appropriate for some inorganic vapours with an appropriate spectrometric or chromatographic analyser. The method can also be used for reactive agents by introducing a reagent onto the sorbent or onto a filter. It is then more usual to use high pressure liquid chromatography for the analysis.
Typical measurement tasks	Screening measurement of time-weighted-average concentration; measurements for comparison with limit values; periodic measurements
Typical measurement range	0,04 mg/m^3 to 100 mg/m^3 (thermal desorption) 1 mg/m^3 to 1000 mg/m^3 (solvent desorption)
Averaging time	30 min to 8 h
Selectivity	The gas or liquid chromatographic separation gives high selectivity
Influence of environmental parameters:	
Pressure	Small effect on sampling rate
Temperature	Small effect on sampling rate
Humidity	Carbon-based sorbents affected
Air speed	Minimum air velocity required for ‘badge’ designs
Vibration	No
Calibration	Determine the uptake rate (once for sorbent/ analyte combination); Calibrate the analyser
Limitations	No

6.2.8 Procedures to measure metals and metalloids in airborne particles

Table 11 — Procedures to measure metals and metalloids in airborne particles

Characteristics	Comments
Operating principles	Samples are collected by drawing by a pump a measured volume of air through a filter mounted in a sampler designed to collect either the respirable or the inhalable fraction of airborne particles, depending on which particle size fraction is applicable to the exposure limits for the metals and metalloids of interest. Depending on the sampler, the collected sample consists of the material collected on the filter or on all parts of the sampler (filter and walls). Samples (filters) are analysed using a suitable analytical technique, e.g. X-ray fluorescence Spectrometry (XRFS), inductively coupled plasma atomic emission spectrometry (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS) or atomic absorption spectrometry (AAS).
Typical measurement tasks	Screening measurement of time-weighted-average concentration; measurements for comparison with limit values; periodic measurements.
Typical measurement range	0,001 mg/m^3 to 10 mg/m^3
Averaging time	15 min to 8 h
Selectivity	The analytical techniques used are element specific
Influence of environmental parameters:	
Pressure	No
Temperature	No
Humidity	No
Air speed	Can affect the sampling process
Vibration	No
Calibration	The analytical instrument and pump is calibrated with each batch of samples (ICP-AES, ICP-MS, AAS) or a 'ratio monitor standard' is used to correct for instrument drift (XRFS).
Limitations	Does not measure metals or metalloids present in the vapour phase, e.g. mercury, arsenic trioxide. Some analytical techniques might not have adequate sensitivity for short-term measurements to be made for certain elements. In the case of gravimetric analyses, some samplers do not allow to take into account particulate matter deposited on the sampler walls.

6.2.9 Procedures using bags and canisters for sampling

Table 12 — Procedures using bags and canisters for sampling

Characteristics	Comments
Operating principles	Sample air collection for both bags and canisters are performed using several approaches. The most common approach involves the use of a pump to push a positive flow of sample air into the bag or canister system. Typically a measured volume of sample air is directed into the container over an integrated time period. Since bags are flexible containers, usually prepared from 2 m Tedlar or 2 m and 5 m Teflon film, sample air flow rates are readily maintained throughout the collection process. It is recommended that total collected sample volumes should not exceed 75 % to 80 % capacity of the bag to prevent damage to the bag seams. Canisters are fixed volume containers constructed from stainless steel. For inertness, canisters surfaces are conditioned by either a mild electro-oxidization process (referred to as SUMMA™ polishing) or coated with a thin silica like layer (referred to as Silicosteel™ process). Canisters are commercially available in sizes ranging from 0,5 l to 32 l volumes. Bags are commercially available in sizes from 10 l and larger. Because of the rigid surface, canisters require the use of mass flow controllers to be filled with integrated sample volumes. Canisters are usually evacuated to high vacuum prior to collecting sample air. Due to the necessity of reduced pressure, air samples are sometimes into canisters under reduced pressure using critical flow orifices.
Typical measurement tasks	Both type of containers are used to collect ambient, indoor, workplace, or source air samples. Sometime these containers are used to prepare standard mixtures. Both container types are convenient for collecting field samples and returning and/or shipping to a central laboratory for analysis.
Typical measurement range	0,1 µg/m^3 to 1000 µg/m^3 concentration ranges are typical.
Averaging time	Grab sample (< 5 min) to 24-h integrated samples are collected with these containers.
Selectivity	These containers are generally used for VOCs with a vapour pressure greater than 20 Pa.
Influence of environmental parameters:	
Pressure	Air samples can be collected in canisters, with little difficulty, at sub-ambient to four atmospheres pressure. Bags require that the sample be collected at ambient pressure.
Temperature	Canisters can be maintained at ambient temperatures ranging from 0 °C to 50 °C. Bag temperatures are not recommended to exceed 35 °C to 40 °C. Canisters are often cleaned for sampling using temperatures of approximately 150 °C.
Humidity	Samples are collected and prepared in both types of containers at relative humidities ranging from 10 % to nearly 100 % at ambient temperatures. When high relative humidity samples are collected in canisters to pressures above ambient, water condensation on the interior canister surfaces will occur. As a result, water-soluble VOCs can be lost because of surface absorption.
Particulates	Airborne particulate matter should be removed with a stainless-steel filter during the sample collection process to prevent surface deposition inside the canister and bag containers.
Calibration	Calibrate the pump
Limitations	See above limitations with respect to VOC vapour pressure requirements for quantitative sample collection, storage and analysis. Bag containers seals usually tear with usage and require frequent replacement. Canisters are durable, but require adequate cleaning between sample collection. Memory effects can be a limitation for reusable items

6.3 Measurement of airborne micro-organisms and endotoxin

6.3.1 Methods using an impactor as sampler

Table 13 — Methods using an impactor as sampler

Characteristics	Comments
Operating principles	A measured volume of air is drawn through a sampler such that airborne micro-organisms are caused to leave the air stream and impact onto a semi solid (typically an agar culture medium) or solid surface. Semi solid media thus directly inoculated are incubated to develop colonies from viable, culturable micro-organisms.
Typical measurement tasks	Measurements near an emission source; periodic measurements
Typical measurement range	10^1 to 10^5 colony forming units per m^3 air
Response time/ Averaging time	1 min to 30 min depending on bioaerosol concentration
Selectivity	Dependent on subsequent analysis
Influence of environmental parameters:	
Pressure	No
Temperature and humidity	Both can affect viability/culturability of bioaerosol; could cause dehydration of semisolid collection substrates leading to reduction in collection efficiency
Air speed	Effect on inlet efficiency
Vibration	No
Calibration	Calibrate inlet air flow rate before each sampling
Limitations	Short sampling time for high bioaerosol concentrations to avoid overloading. In general can only be used for culturable analysis. High sampler costs. Static (area) sampling only. Many samplers available poorly characterised for inlet efficiency compared to ISO/CEN convention.

6.3.2 Procedures using impingers as samplers

Table 14 — Procedures using impingers as samplers

Characteristics	Comments
Operating principles	Using a pump a measured volume of air is drawn through a sampler containing a measured volume of aqueous collection fluid, such that airborne micro-organisms are trapped in the liquid. The resulting suspension is analysed for the presence of micro-organisms or their products.
Typical measurement tasks	Measurements near an emission source; periodic measurements
Typical measurement range	10^2 to 10^{10} total micro-organisms per m^3 air; 10^2 to 10^8 colony forming units per m^3 air
Response time/ Averaging time	15 min to 2 h
Selectivity	Dependent on subsequent analysis
Influence of environmental parameters:	
Pressure	No
Temperature and humidity	Both can affect viability/culturability of bioaerosol; could cause evaporation losses of collection fluid leading to reduction in collection efficiency
Air speed	Effect on inlet efficiency
Vibration	No
Calibration	Calibrate inlet air flow rate before each sampling
Limitations	Possible collection losses through re-entrainment into air stream or with evaporative losses of collection fluid. Mainly static (area) sampling only. Many samplers available poorly characterised for inlet efficiency compared to ISO/CEN convention.

6.3.3 Procedures using filtration samplers

Table 15 — Procedures using filtration samplers

Characteristics	Comments
Operating principles	A measured volume of air is drawn through a filter membrane housed in a sampler with a defined inlet, such that airborne micro-organisms are trapped on the filter. The trapped micro-organisms can be cultured directly by placing the filter directly onto nutrient medium or washed from the surface of the filter into suspension using an aqueous wash fluid. Micro-organisms are trapped in the liquid. The resulting suspension is analysed for the presence of micro-organisms or their products.
Typical measurement tasks	Measurements near an emission source; personal sampling; periodic measurements
Typical measurement range	10^2 to 10^{10} total micro-organisms per m^3 air; 10^2 to 10^8 colony forming units per m^3 air
Response time/ Averaging time	15 min to 8 h
Selectivity	Dependent on subsequent analysis
Influence of environmental parameters:	
Pressure	No
Temperature and humidity	Both can affect viability/culturability of bioaerosol
Air speed	Effect on inlet efficiency
Vibration	No
Calibration	Calibrate inlet air flow rate before each sampling
Limitations	Dehydration effects on sampling culturable bioaerosol

7 Operation of the measuring devices

7.1 Guidance for use of measuring procedures and personal, portable and transportable measuring devices

7.1.1 General

When measuring devices for the detection and measurement of chemical agents are purchased it is important that the user should read the manufacturer's instruction manual thoroughly and follow the instructions on testing, calibration and maintenance. Most measuring devices are complex and can require function tests, maintenance, calibration and/or recalibration to be carried out at regular intervals by a competent person. Calibration can require specialist equipment and reliable methods for generating known concentrations of gases and vapours or aerosols. If the user is unable to carry out any of these tests the manufacturer or other competent persons or organisations will be able to advise on what actions to take.

Personnel required to use such measuring devices should be properly trained and have ready access to the manufacturer's instruction and operating manuals.

For measuring devices to give reliable measurements for a long useful life they have to be handled with care. Avoid dropping the measuring device and subjecting it to unnecessary vibrations or extremes of temperature. If the measuring device is dropped it will be necessary to carry out the function checks before the measuring device is used further.

7.1.2 Transportation

Measuring devices can be complex and require care when transporting to and from the workplace. It is good practice to protect the measuring device from:

a) large temperature changes, particularly outside the range 0 °C to 40 °C;

b) large humidity changes;

c) unnecessary vibrations and mechanical shock;

d) direct sunlight;

e) low pressure, e.g. less than 50 kPa, and rapid changes of pressure;

f) precipitation and dust.

When travelling to a field site it is important that the measuring device is kept at a temperature similar to the temperature of the site. It would be bad practice to transport the apparatus in the boot of a car at a temperature of around 0 ^{o}C when intending to use it in a factory having an ambient temperature of 30 °C.

7.1.3 Storage conditions and shelf life

Where a measuring device is not used on a regular basis it is important that it is stored in appropriate conditions. Factors to consider include:

a) the cleanliness of the storage environment;

b) the temperature and humidity of the storage environment;

c) the possibility of parts of the measuring device deteriorating with age, e.g. sensors or batteries;

d) the testing of the measuring device on a planned regular basis;

e) the charging of the batteries, if appropriate.

After prolonged storage it can be appropriate to carry out a full maintenance check and recalibration.

The manufacturer's instruction manual should recommend storage conditions.

7.1.4 Field measurements

Certain precautions have to be observed when making field measurements. These are:

a) Avoid water vapour condensation on the measuring device. This can easily occur when taking a measuring device from a cool to a warm 'wet' environment, e.g. transporting the measuring device by car in the cold winter months and immediately using it in a warm workplace with high relative humidity. It is important to allow the measuring device to reach a temperature equilibrium without condensation before use in some cases this can take several hours.

b) Avoid accidental exposure to very high concentrations of gases and vapours. This can effect the reliable operation of the measuring device for a short or long time. If accidental exposure occurs remove the measuring device and place in a clean air environment. Allow a reasonable time for the measuring device to recover and then carry out the function checks and, if possible, a calibration check. The manufacturers instruction manual will contain information on the action to take in the event of exposure to a concentration above the measuring range.

c) Climatic conditions. Users should ensure that the measuring device is suitable for use in the expected environmental conditions, e.g. temperature and humidity.

d) Precipitation and dust. The measuring device should be protected from precipitation, e.g. rain, and dusts.

e) Sampling pumps. Where sampling pumps are used, it is good practice to use water filters or traps to avoid the intake of water.

f) Radio interference. Avoid the use of mobile telephones and radio communicators since they can cause interference with the reliable operation of electrical apparatus.

7.1.5 Inspection and field check

Immediately before use, all measuring devices should be subjected to routine inspection and function tests. In general, the user should:

a) check that the measuring device is within its calibration period;

b) visually inspect all accessories, e.g. cables, sample lines, sample probe, are in good condition and free from contamination;

c) for aspirated measuring devices check that the flow rate is within the flow rate recommended by the manufacturer in the instruction manual;

d) check that any batteries are fully charged. The batteries should be charged in accordance with the manufacturers recommendations in the instruction manual. Some types of batteries, e.g. nickel hydride, can discharge fully without use within two weeks. These types of batteries should be recharged prior to use.

e) in measuring devices fitted with alarms, check the alarm, audio and/or visual, are operating correctly.

7.2 Guidance for use of fixed measuring devices

7.2.1 General

Fixed measuring devices are used for area monitoring to provide continuous information on the concentration of chemical agents over a site. Two types of fixed systems are commonly used:

a) Systems consisting of remote sensors or other devices which can be connected to central control equipment. These systems are the most suitable for the majority of industrial site monitoring applications. The siting and connection to control equipment should adhere to national regulations for installation of electrical equipment and be certified for the intended zone of use.

b) Systems consisting of tube sampling measuring devices and central measurement and control equipment. These systems are used where comparatively static process conditions are found. The response time of the system is related to the sampling flow rate and the sampling line length. Where time sequential sampling systems are used the time interval between successive samples at one of the sampling points should not compromise the overall response of the system.

c) When using a measuring device with an associated sampling line, two methods can be practicable to obtain time weighted average results from the measured concentrations:

    1) a multi-channel switching system;

    2) a multi-channel mixing system.

Multi-channel switching systems have the advantage of measuring the concentration at each sample point at close time intervals; depending on the time interval between successive samples high concentrations peaks of short duration can not be detected. On the other hand, it is not possible to have a continuous record of the concentration at a single sample point. Using a multi-channel mixing system, the measured value is the average concentration of all sample points. High concentration peaks at a single sample point can not be detected.

For the reliable operation of a fixed detection system each instrument or sampling point should be placed in a suitable location according to its individual application. Inspection and maintenance including recalibration should be carried out periodically by trained personnel. If the user is not able to address these points the work should be carried out by the manufacturer or other competent person.

It is important that the manufacturer's installation manual be read thoroughly and the instructions followed.

Many factors need to be considered when specifying the monitoring site and determining the number of sensors required, including industry standards and/or regulatory authority requirements.

7.2.2 Installation

A fixed system should be installed such that it is capable of monitoring those parts of a plant or processes where the chemical agent(s) can accidentally accumulate. The system should be capable of:

a) giving early alarm warning of a significant release of chemical agent and the general location of the release in order to initiate one or more of the following actions, either automatically or under manual control:

   1) increase ventilation;

   2) remove the hazard;

   3) shut down the plant process;

   4) safely evacuate the premises.

b) providing screening measurements of variation of concentration in time, (see 4.3);

c) providing screening measurements of time weighted average concentration, (see 4.3);

d) providing periodic measurements, (see 4.3).

The length of any sampling line should be as short as is reasonably practicable. Adequate drainage and/or heating should be incorporated into the system design to minimise moisture and water condensation in the measuring device and any interconnecting cable/conduit system. Any toxic gas introduced into the sampling systems should be vented in a safe manner.

In general a fixed system should be installed such that failure of individual elements of the system or their temporary removal for maintenance does not compromise the safety of the premises being protected.

Breakdown or fault of the main power supply should be detectable since the safety of the monitored area has to be preserved.

Appropriate precautions, for example the use of screened cables, should be incorporated when installing the complete cabling system to ensure that the total system is immune from the effects of radio interference.

Detection devices should be installed and used in such a way that only authorised personnel have access to functional controls of the device.

7.2.3 Location

Instruments should be placed such that accumulations of chemical agents are detected before they create a significant hazard. The placement of the instruments should be determined following the advice of experts having specialist knowledge of gas dispersion, experts having a knowledge of the process plant system and equipment involved, and safety/hygiene and engineering personnel. The agreement reached on the location of instruments should be recorded.

Fixed sensors should be installed in locations such that they are not vulnerable to mechanical damage or water damage from normal operations in the area. Sensors should be readily accessible to permit regular calibration, maintenance and electrical safety inspection. If it is impossible to achieve regular direct access to the instrument then, as a minimum requirement, some form of automatic remote calibration facility should be provided.

The location of fixed instruments requires a detailed knowledge of many factors. The following are some, but not all, of the important factors to consider:

a) site design, e.g. position of plant and equipment, and whether it is an indoor or outdoor site;

b) the potential sources of release, the location and nature of the potential sources (e.g. high pressure pipelines, pipelines containing liquids, storage vessels, quantity of chemicals used or stored, source temperature, density and distances);

c) type of release, e.g. high pressure gas, slow leakage from pipeline joints, liquid spillage;

d) chemical and physical data on the chemicals used, e.g. volatility, density;

e) topography of the site;

f) localised ventilation equipment;

g) outdoor environmental conditions, e.g. wind speed, direction, rainfall;

h) local environment outside plant boundaries;

i) number and position of plant employees;

j) considerations on inspection and maintenance of fixed sensors;

k) siting to limit the chance of tampering;

l) structural arrangements (e.g. walls, troughs, partitions) which could allow releases of chemical agents to accumulate.

7.2.4 Inspection and field check

After the initial calibration, fixed systems should work automatically without further adjustment. However to ensure correct operation it is essential to carry out both inspection and recalibration periodically. The work required to maintain the integrity and reliability of a fixed instrument system is extensive. Routine tests of the detection system is an extremely important factor affecting the reliability of the units. Optimum system performance and reliable operation is only achieved through a defined program of tests.

It is essential that safety is maintained by appropriate measures when the detection system or a part of it becomes inoperative during calibration or if it is removed from service.

Appropriate measures can be:

a) use of a duplicate system;

b) use of portable or transportable measuring devices;

c) increasing ventilation.

The complete detection system including all ancillary equipment should be inspected prior to use to ensure that the design and installation has been carried out in a satisfactory manner. A check should be made to confirm that a full set of operating instructions, plans and records for the complete system have been supplied. The instructions should include details on use, testing, calibration and operation.

For maintenance and record purposes, plans of the installation should be provided that show the locations of all parts of the system (control units, sensors, sampling points etc.) together with the routes and sizes of all cables. The records should be updated when any changes are made to the installation.

Alarm set points should be as low as possible taking into consideration the need to avoid false alarms. Adjustments should be carried out in accordance with the manufacturers instructions.

After installation on site, each instrument should be calibrated according to the manufacturers instructions. Calibration should only be carried out by a competent person.

The detection system should be frequently inspected by a competent person. The inspection should be in accordance with the manufacturers instructions and the specific requirements of the application. The intervals can be specified by the manufacturer or by regulations of the regulatory authorities. If different intervals are defined the shortest period should be taken.

The inspection should include the following:

a) a check that the measuring device is within its calibration period;

b) a visual inspection of all accessories, e.g. cables, sample lines, sample probe, to ensure that they are in good condition and free from contamination;

c) a visual inspection of the control and alarm panel to ensure that the system is fully operational; e.g. inspection of the fault signals and alarm status of all the remote sensors;

d) a function check of the control and alarm system, e.g. checks to ensure that all lights, alarms, and electronics are operating normally;

e) a full calibration and system test. This involves calibrating each fixed instrument with the calibration standard and complete maintenance check on the system. The time period between full instrument calibration and system tests will depend on many factors, e.g. sensor drift, temperature, dust, poisoning, corrosive atmospheres, site location, etc.

The manufacturers instructions should be followed with regard to:

f) periodic cleaning of filters, windows etc.;

g) assembly of required materials, e.g. auxiliary gas for some measuring devices;

h) safe operation of the system.

Full documented records of all the above tests should be kept.

8 Recommendations on the use of sampling pumps

8.1 General

Pumps claimed by the manufacturer to comply with EN 1232 or EN 12919 should be used. Although many manufacturers specify a maximum flow rate deviation of 5 %, this should not be taken for granted, since the factory specifications are valid for:

a) type testing;

b) laboratory conditions;

c) newly manufactured pumps.

Older pumps can be less reliable and can not always meet the manufacturer specifications, especially when used under severe conditions.

8.2 Factors influencing the flow rate stability of a pump

a) temperature difference between storage and use;

b) duration of apparatus warm-up;

c) environmental conditions, especially temperature; special attention is required when the pumps are used under conditions outside or near the limits of the ranges claimed by the manufacturer;

d) important variations in environmental conditions (e.g. temperature) for subsequent samplings, for example operation under standard conditions followed by extreme conditions;

e) quality of the battery and the pump components;

f) variation of the pressure drop during sampling (due for example to the sampler loading);

g) provision (or otherwise) of electronic flow control.

8.3 Flow rate calibration

To avoid as much as possible these problems the following general procedure is recommended, whenever possible:

a) before going on site a preliminary adjustment of the pump flow rate to the desired value can be done using a pressure drop similar to field conditions;

b) store the apparatus before use at a temperature as close as possible to the sampling temperature;

c) when feasible (and if necessary), sampling should be started after preliminary operation of the pump to allow stabilisation of the flow rate (the minimum duration for flow rate stabilisation at a given temperature can be determined by recording the flow rate against time);

d) before starting sampling measure the flow rate and readjust it to the desired value if necessary. If relevant, a flow resistance or a sampling device equivalent to the one used for site sampling should be applied, to ensure a similar pressure drop;

e) the initial flow rate shall be the mean value of at least three successive measurements;

f) position the pump and the sampler (do not turn the pump off); record the time when sampling is started;

g) whenever possible, during sampling visually check that the pump operates correctly by observing the rotameter or other indicating device;

h) an intermediate check of the flow rate during sampling can be decided. Record the flow rate value and the time. If a flow rate adjustment is made, record the new value. If the flow rate deviation exceeds the maximum deviation required by the procedure in use stop sampling (see note 4);

i) determine the final flow rate by calculating the mean value of at least three successive measurements;

j) when there is a drastic change in environmental conditions between two sampling operations (e.g. sampling at high or low temperature after sampling at 20 °C), all the previous steps shall be repeated.

NOTE 1 The applicability of some of these steps will strongly depend on the type of pumping system used. For pumps whose flow rate can be kept constant (by an automatic controller) during sampling all of the above steps are normally applicable. For some other types of pumping systems (pumps with rotating cups, air movers, venturi, etc.) only part of the above recommendations will be appropriate; in these cases the user should check the instructions for use to determine the steps which cannot be applied.

NOTE 2 When the sampling duration exceeds 3 h, the initial and final flow rates can be measured during the first and last sampling hour respectively.

NOTE 3 Note any unusual features (e. g. temperature, humidity).

NOTE 4 If the final flow rate deviation exceeds the maximum deviation required by the procedure in use, it is the operator's responsibility to keep or discard the sample. If the sample is retained, it has to be recorded that the recommended deviation was exceeded and the result is for indication only.

8.4 Calculation of flow rates and sampling volumes

8.4.1 Mean volumetric flow rate

Generally, the mean value of the volumetric flow rate (F_{m}) is used for calculation of the sampling volume.

$$F_{\mathrm{m}} = \frac{F_{\mathrm{s}} + F_{\mathrm{f}}}{2} \tag{2}$$

where

F_{m} is the mean volumetric flow rate in litres per minute;

F_{s} is the initial volumetric flow rate in litres per minute;

F_{f} is the final volumetric flow rate in litres per minute.

If an intermediate flow rate measurement and readjustment is made, take into account the intermediate flow rates F_{i} :

$$F_{\mathrm{m1}} = \frac{F_{\mathrm{s}} + F_{\mathrm{i1}}}{2} \tag{3a}$$

and

$$F_{\mathrm{m2}} = \frac{F_{\mathrm{i2}} + F_{\mathrm{f}}}{2} \tag{3b}$$

where

F_{m1} is the mean volumetric flow rate in litres per minute, over the time period before readjustment;

F_{m2} is the mean volumetric flow rate in litres per minute, over the time period after readjustment;

F_{s} is the initial volumetric flow rate in litres per minute;

F_{i1} is the intermediate volumetric flow rate in litres per minute, before readjustment;

F_{i2} is the intermediate volumetric flow rate in litres per minute, after readjustment;

F_{f} is the final volumetric flow rate in litres per minute.

NOTE If the intermediate flow rate deviation is within the required range and if no readjustment is decided, the intermediate flow rate F_{i} can nevertheless be used to calculate the mean volumetric flow rates F_{m}, in order to obtain a better accuracy of the sampling volume (see 8.4.2). In this case $F_{\mathrm{i1}} = F_{\mathrm{i2}}$.

8.4.2 Sampling volume

$$V = F_{\mathrm{m}} \quad t \tag{4}$$

where

V is the volume of air sampled in litres;

F_{m} is the mean volumetric flow rate in litres per minute;

t is the sampling time in minutes.

If an intermediate flow rate adjustment is made:

$$V = \left(F_{\mathrm{m1}} \quad t_1\right) + \left(F_{\mathrm{m2}} \quad t_2\right) \tag{5}$$

where

V is the volume of air sampled in litres;

F_{m1} is the mean volumetric flow rate in litres per minute, over the time period before readjustment;

F_{m2} is the mean volumetric flow rate in litres per minute, over the time period after readjustment;

t_1 is the sampling time in minutes from the beginning of sampling to the intermediate readjustment;

t_2 is the sampling time in minutes from the intermediate readjustment to the end of sampling.

9 Maintenance and calibration

Maintenance and calibration should only be undertaken by trained personnel. If the user does not have a maintenance and calibration facility or trained personnel to carry out the work then the measuring device should be returned to the manufacturer or another qualified organization.

The manufacturer's instructions should be followed regarding the replacement of component parts. When components are replaced, the replacement components should meet the specifications and tolerances of the original.

Calibration should be done in accordance with the manufacturer's recommendations in the instruction manual. The recommended recalibration period will depend on many factors; the type of sensor used, the type of measuring device, the environmental conditions and experience of the user in similar situations.

The calibration of a measuring device involves often a highly skilled/technical operation requiring calibration equipment for the production of precise concentrations of calibrant gases or aerosols, detailed knowledge of the physical sorption properties of the calibrant and should only be done by a competent technician or organization. The manufacturer or supplier of the measuring device should either offer a calibration service for the measuring device or advise the user where the work could be carried out.

The calibration of certain measuring devices involves:

a) preparation of calibration mixture(s).

The preparation of gas mixtures in the occupational hygiene range of concentration is often a very difficult problem. There are many documented methods for the preparation of calibration gas mixtures (see ISO 6141 to ISO 6147). The particular method chosen will depend on many factors. One method which avoids many of the problems is to use a gas cylinder with a certified gas concentration.

The preparation of test aerosols (usually a surrogate of the actual chemical agent) is a specialist activity, see EN 13205 for guidance.

b) exposing the measuring device to the calibration mixtures using a calibration mask or exposure chamber.

When a calibration mask is used, the design and operation of the mask should not inadmissibly influence the concentration measurement. Practically, in most cases, the use of a mask will have some effect. It is recommended that the user should consult with the manufacturer or supplier in determining the design and operation of the calibration mask. In some cases, the manufacturer will provide a suitable calibration mask as an optional accessory. Exposure chambers are expensive and are not universally suitable for calibration with gases and vapours that are difficult to produce or handle.

c) Adjusting the measuring device's zero point and gain (span) controls, if appropriate.

It is desirable that the adjustment of the gain should not effect the zero point. For the reliable operation of a measuring device, it is advisable that unauthorised interference with these controls, particularly the gain control, should be discouraged.

In the simplest case, where the instrument response is linear over the measuring range, the measuring device is calibrated in a two stage process. Firstly, the instrument is exposed to clean air and the zero adjusted to give a zero reading, and secondly, the instrument is exposed to the test concentration equal to the maximum value of the measuring range, or the concentration for which the most accurate measurement is required and the gain adjusted to give the concentration reading.

In cases where the instrument response is non-linear the calibration process can involve exposing the instrument to a number of test concentrations. Linearisation of the response can then be done using analogue or digital electronics.

10 Disposal of measuring devices

Care should be taken with the disposal of the measuring device at the end of its useful life. Many measuring devices contain toxic materials, e.g. radioactive sources or batteries. In these cases special disposal procedures should be taken in accordance with local statutory requirements.

11 Requirements for training

For most measuring devices, specialist training is required for both the operator and those responsible for the maintenance and calibration. Diffusive samplers, however, do not require a specialist operator for their deployment, provided that clear and unambiguous instructions for use are available and due note is taken of this guidance.

Maintenance and calibration, however, are important for all devices, and particular attention should be made to the following:

a) for re-usable devices, ensure that the collection element is intact, clean, or replaced as necessary;

b) ensure that all component parts are free from contamination;

c) ensure that the devices are calibrated for typical exposure regimes of concentration, time of exposure, humidity and other significant variables;

d) ensure that devices are used within the manufacturer's recommended shelf-life.

12 Quality assurance

It is good practice to set up a quality assurance scheme for the maintenance and calibration of the samplers or other devices (e.g., associated pumps). This includes:

a) the establishment of a Standard Operating Procedure (SOP);

b) for re-usable devices, a log of usage;

c) keeping a record of the traceability of the calibration;

d) retaining the raw data as required by the quality or other system;

e) using a unique and durable sampler numbering system for re-usable devices;

f) depending on the measurement task, taking an appropriate number of field blank and replicate samples (e.g. 10%);

g) an appropriate level of internal and external quality assurance.

Bibliography

HYPERLINKEN 481:1993, *Workplace atmospheres — Size fraction definitions for measurement of airborne particles.*

EN 1540:1998, *Workplace atmospheres — Terminology.*

ISO 3534-1:1993, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms.*

ISO 6141, *Gas analysis — Requirements for certificates for calibration gases and gas mixtures*.

ISO 6142, *Gas analysis — Preparation of calibration gas mixtures — Gravimetric method*.

ISO 6143, *Gas analysis — Comparison methods for determining and checking the composition of calibration gas mixtures.*

ISO 6144, *Gas analysis — Preparation of calibration gas mixtures —Static volumetric methods*.

ISO 6145-1, *Gas analysis — Preparation of calibration gas mixtures — Dynamic volumetric methods — Part 1: Methods of calibration*

ISO 6145-2, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 2: Volumetric pumps.*

ISO 6145-4, *Gas analysis — Preparation of calibration gas mixtures — Dynamic volumetric methods — Part 4: Continuous injection method.*

ISO 6145-5, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 5: Capillary calibration devices.*

ISO 6145-6, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 6: Critical orifices.*

ISO 6145-7, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 7: Thermal mass-flow controllers.*

ISO 6145-9, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 9: Saturation method*

ISO 6145-10, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 10: Permeation method.*

ISO 6147, *Gas analysis — Preparation of calibration gas mixtures — Saturation method*.

ISO 6879:1995*, Air quality – Performance characteristics and related concepts for air quality measuring methods.*

[1] Health and Safety Executive: Methods for the Determination of Hazardous Substances. HSE Occupational Medicine and Hygiene Laboratory, Sheffield, UK (in series, 1981-98).

[2] Deutsche Forschungsgemeinschaft: Analytische Methoden zur Prüfung Gesundheitsschädlicher Arbeitsstoffe. DFG. Verlag Chemie, Weinheim, FRG (1985).

[3] Vetenskaplig skriftserie Arbete och Hälsa 2000:23 Stockholm, Sweden (2001). Also available under www.niwl.se/ah/

[4] National Institute for Occupational Safety and Health: NIOSH Manual of Analytical Methods, 2nd ed. DHEW (NIOSH) Pub. No. 75-121 (1975); 3rd ed. DHEW (NIOSH) Pub. No. 84-100 (1984, revised 1990); 4th ed. DHHS (NIOSH) Pub. No. 94-113 (1994); (updated regularly).

[5] Occupational Safety and Health Administration: OSHA Analytical Methods Manual. OSHA Analytical Laboratories, Salt Lake City, UT. Available from ACGIH, Cincinnati, OH (various methods, 1979-1995, updated regularly).

[6] Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT): Méthodos de Toma de Muestra y Análisis, INSHT, Madrid, España (is series, 1989- 2000)

[7] Institut National de Recherche et de Sécurité (INRS): MétroPol (Métrologie des polluants) – Recueil des méthodes de prélèvement et d'analyse de l'air pour l'évaluation de l'exposition professionnelle aux agents chimiques — INRS, Paris, 2001 (http://www.inrs.fr/metropol/sommet.htm)

blank

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.
Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001.
Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre.
Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.
Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001.
Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsi-global.com/bsonline.

Further information about BSI is available on the BSI website at http://www.bsi-global.com.

Copyright

Details and advice can be obtained from the Copyright & Licensing Manager.
Tel: +44 (0)20 8996 7070. Fax: +44 (0)20 8996 7553.
Email: copyright@bsi-global.com.

BSI
389 Chiswick High Road
London
W4 4AL