SLOVENSKI STANDARD
SIST EN 14412:2004

01-december-2004

Kakovost notranjega zraka - Difuzijski vzorļ evalniki za doloļ evanje koncentracije plinov in par ï Vodilo za izbiro, uporabo in vzdrģevanje

Indoor air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Guide for selection, use and maintenance

Innenraumluftqualität - Passivsammler zur Bestimmung der Konzentrationen von Gasen und Dämpfen - Anleitung zur Auswahl, Anwendung und Handhabung

Qualité de l'air intérieur - Echantillonnage par diffusion pour la détermination de la concentration des gaz et des vapeurs - Guide pour la sélection, l'utilisation et la maintenance

Ta slovenski standard je istoveten z: **EN 14412:2004**

ICS:

13.040.20	Kakovost okoljskega zraka	Ambient atmospheres

SIST EN 14412:2004 **en**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 14412

September 2004

ICS 13.040.20

English version

Indoor air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Guide for selection, use and maintenance

Qualité de l'air intérieur - Echantillonneurs par diffusion pour la détermination de la concentration des gaz et des vapeurs - Guide pour la sélection, l'utilisation et la maintenance

Innenraumluftqualität - Passivsammler zur Bestimmung der Konzentrationen von Gasen und Dämpfen - Anleitung zur Auswahl, Anwendung und Handhabung

This European Standard was approved by CEN on 9 July 2004.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, 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

Ref. No. EN 14412:2004: E

Contents

Foreword

This document (EN 14412:2004) has been prepared by Technical Committee CEN/TC 264 “Air Quality”, 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 March 2005, and conflicting national standards shall be withdrawn at the latest by March 2005.

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

Introduction

European Standard EN 13528 specifies requirements and test methods for the determination of performance characteristics of diffusive samplers used for the determination of concentrations of gases and vapours in ambient and indoor atmospheres. Additionally this document provides a guidance for the user when selecting an appropriate type of sampler, measurement strategy and maintenance procedure.

EN 13528 is a multi-part standard having the following parts:

- Part 1 (Ambient air quality – Diffusive samplers for the determination of concentrations of gases and vapours – Requirements and test methods): General requirements.
- Part 2 (Ambient air quality – Diffusive samplers for the determination of concentrations of gases and vapours – Requirements and test methods): Specific requirements and test methods.
- Part 3 (Ambient air quality – Diffusive samplers for the determination of concentrations of gases and vapours – Requirements and test methods): Guide to selection, use and maintenance.

Because of the importance of these samplers in the process of monitoring, diffusive samplers used to measure indoor air quality have to fulfil some general requirements related to the sampling objective. These requirements are given in EN 13528-1 for measuring ambient air quality. The same principles apply to measuring indoor air although the target values have yet to be set by the Regulatory Authorities at either National, European or International level.

These requirements include unambiguity, selectivity and data quality objectives, including uncertainty.

In addition, diffusive samplers used to measure ambient and indoor air quality have to also fulfil some specific requirements in addition to those specified in EN 13528-1. These specific requirements are given in EN 13528-2 for measuring ambient air quality. The same principles apply to measuring indoor air. These requirements include desorption efficiency, diffusive uptake rate and sensitivity to air velocity.

Such general and specific requirements may also be appropriate for other measuring objectives used in the assessment of indoor air quality.

It is the user's primary responsibility to choose appropriate procedures or devices that meet the requirements of this document. 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, may be undertaken by the manufacturer, user, test house or research and development laboratory, as is most appropriate.

EN 13528-3 gives guidance on the selection, use and maintenance of diffusive samplers used to measure ambient air quality.

For the special tasks of sampling workplace air, the regulations of the European Standard EN 482 [1] and EN 838 apply. This document on the use of diffusive samplers for indoor air has been created in addition to those for workplace air because the measurement strategies, the underlying European Directives for ambient air [2], limit and guideline values and the consequent definitions and practical applications of the estimation of the uncertainty of measurements are different.

1 Scope

This document gives guidelines for the selection, use and maintenance of diffusive samplers used to analyse gaseous pollutants in indoor air including measurement strategy and planning.

This document gives guidelines for the selection, use and maintenance of diffusive samplers used to measure indoor air quality and personal exposure. This document is applicable to indoor air quality assessment because crucial differences to ambient air measurement have to be taken into account concerning environmental parameters, measurement strategy, as well as the nature, number, source and abundance of indoor air pollutants.

In contrast to typical ambient air measurements the appearance of unexpected compounds in indoor air environments is quite common. Procedures to calculate specific uptake rates of these compounds are needed more often as there is only a limited number of uptake rates validated by experiments (see EN 13528-2 and EN 13528-3) to assess the respective concentration values. In addition to the general calculation procedure of the individual uptake rate as given in EN 13528-2 and EN 13528-3 detailed procedures to calculate diffusion coefficients and the uptake rate are given in annex C of this document.

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.

EN 13528-2:2002, *Ambient air quality – Diffusive samplers for the determination of concentrations of gases and vapours – Requirements and test methods – Part 2: Specific requirements and test methods.*

ISO 16000-1, Indoor air – Part 1: General aspects of sampling strategy.

3 Terms and definitions

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

3.1
ambient air
outdoor air in the troposphere, excluding indoor air and workplaces

[EN 13528-1:2002]

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

[EN 13528-1:2002]

3.3
cross-sectional area of the diffusion path
cross-sectional area of the space inside the diffusive sampler, which is available for the diffusion process, expressed in square centimetres. This cross-sectional area may be identical to the intake opening

3.4
diffusive sampler
a 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 pumped air through the device

[EN 13528-1:2002]

NOTE Active normally refers to the pumped movement of air.

3.5
diffusive uptake rate
rate at which the diffusive sampler collects a particular gas or vapour from the atmosphere, expressed in cubic centimetres per minute (cm^3 min^{-1})

3.6
indoor air
air in indoor environment, i.e. dwellings having living rooms, bedrooms, DIY (do-it-yourself) rooms, recreation rooms and cellars, kitchens and bathrooms; workrooms or work places in buildings which are not subject to health and safety inspections in regard to air pollutants (for example, offices, sales premises); public buildings (for example hospitals, schools, kindergartens, sports halls, libraries, restaurants and bars, theatres, cinemas and other function rooms), and also cabins of vehicles

NOTE In some countries workplaces like offices and sales premises are subject to health and safety inspections with regard to air pollutants.

3.7
measuring procedure
procedure for sampling and analysing one or more pollutants in air and including storage and transportation of the sample

[EN 13528-1:2002]

3.8
personal sampler
a device attached to a person that samples air in the breathing zone

[EN 689:1995]

3.9
personal sampling
the process of air sampling carried out using a personal sampler

[EN 1540:1998]

NOTE In the German language the term 'personenbezogene Probenahme' is used for the sampling with a personal sampler as well as with static sampler under the condition that the sample is taken in the breathing zone of the person.

3.10
reference value
reference value of a compound in a specified environment, e.g. indoor air, is a statistically determined value (95 percentile per convention) on the basis of a representative study at the time of its assessment. This value is descriptive and has no toxicological significance

3.11
sampling capacity

maximum mass of analyte, which can be sorbed by the diffusive sampler during time of exposure with the diffusive uptake rate remaining constant

NOTE The actual sorbed mass is calculated according to:

$$m = u \times t \times \rho \qquad (1)$$

where

m is the mass (ng);

u is the uptake rate (ml/min);

t is the time of exposure (min);

ρ is the concentration of analyte (µg/m³).

3.12
sorbent medium

part of the diffusive sampler which sorbs the analyte to be collected either by a physical process (adsorption, absorption) or by a chemical reaction (chemisorption)

3.13
selectivity

degree of independence from interferents

3.14
guideline value

recommended concentration which serves as a target and which shall be complied with as much as possible but is not legally binding

3.15
uncertainty (of measurement)

parameter, associated with the results of a measurement, that characterises the dispersion of values that could reasonably be attributed to the measurand

NOTE 1 The parameter may be, for example, a standard deviation (or given multiple of it), or the half width of an interval having a stated level of confidence.

NOTE 2 Uncertainty of measurement comprises, in general, of many components. Some of these components may be evaluated from the statistical distribution of the results of a series of measurements and can be characterised by experimental standard deviations. The other components, which can also be characterised by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

NOTE 3 It is understood that the result of a measurement is the best estimate of the value of a measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to this dispersion.

3.16
validation

process of evaluating the performance of a measuring procedure and checking that the performance meets certain pre-set criteria

4 Symbols and abbreviations

A	cross-sectional area of the diffusion path, or equivalent sorption surface, in square centimetres
D	diffusion coefficient of analyte, in square centimetres per minute
k	correction factor for non-ideal behaviour
l	length of static air layer in sampler (or equivalent for permeation types), in centimetres
M	molar mass of analyte, in grams per mol
m_s	mass of the analyte which is sorbed by diffusion, in picograms
P	pressure of the sampled atmosphere during sampling, in kilopascals
t	exposure time, in minutes
T	temperature of the atmosphere sampled, in Kelvin
U	diffusive uptake rate, in cubic centimetres per minute
ρ	delivered concentration, in micrograms per cubic meter
ρ_1	the concentration of the given analyte at the beginning of the diffusion layer (l = 0), in micrograms per cubic meter
ρ_2	the concentration of the given analyte at the end of the diffusion layer, in micrograms per cubic meter
τ	the time constant of the diffusive sampler, in seconds

5 Operating principles

5.1 Principle of diffusive sampling

The mass of the analyte which can diffuse to a suitable sorbent within a certain time is determined by the equation which is derived from Fick's first law of diffusion:

$$m_s = \frac{A \times D \times (\rho_1 - \rho_2) \times t}{l} \qquad (2)$$

This equation differs from equation (4) in EN 13528-2:2002, because it refers to the more general situation where ρ_2 may be non-zero. Ideally ρ_1 is equal to the concentration of the given analyte in the air outside the diffusive sampler (ρ), and ρ_2 equals zero ("zero sink"-condition). In that case the magnitude of the diffusive uptake rate, $D \cdot A/l$, is dependent only on the diffusion coefficient of the given analyte and on the geometry of the diffusive sampler used.

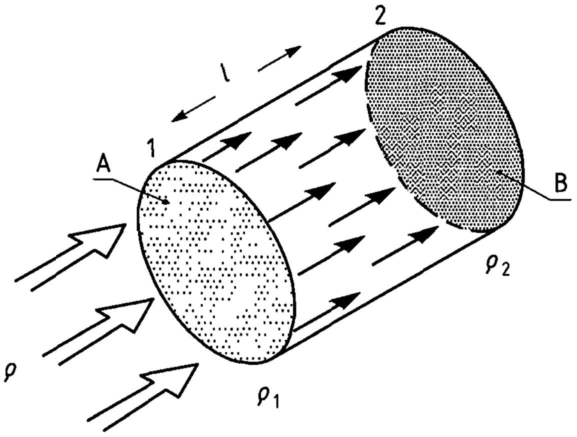

Figure 1 – Diagram of diffusion process

The inlet of a sampler with cross-section *A* at position 1 defines the beginning of the diffusion path of an analyte with a concentration of ρ_1. A sorbent at position 2, which will reduce the concentration of the analyte, ρ_2, to zero (ideally) due to sorption or chemical reaction, serves as the driving force for the diffusion along *l*.

In practice, there are a number of factors that can give rise to non-ideal behaviour, so that:

$$m_s = \frac{A \times D \times \rho \times t \times k}{l} \tag{3}$$

NOTE The correction factor *k* can be a function of concentration and time of exposure (see 5.3).

A general overview of the principles of diffusive sampling is given in [3].

5.2 Dimensions of diffusive uptake rate

For a given concentration ρ in micrograms per cubic metre of gas or vapour, the diffusive uptake rate is given by:

$$U = \frac{m_s}{\rho \times t} \tag{4}$$

NOTE Although the uptake rate, *U*, has dimensions of volume per unit time, this does not indicate a real volumetric flow of (analyte in) air.

5.3 Bias due to the selection of a non-ideal sorbent

The performance of a diffusive sampler depends critically on the selection and use of a sorbent or collection medium. If the sorbent has a high sorption efficiency, the residual vapour pressure and the respective concentration (ρ_2) of the sampled compound at the sorbent surface will then be very small in comparison to the ambient concentration, and the observed uptake rate will be close to its ideal steady-state value, which can usually be calculated from the geometry of the sampler and the diffusion coefficient of the analyte in air.

In the case where a weak sorbent is used, then ρ_2 in equation (2) is non-zero and m_s/t will decrease with the time of sampling. In the alternative expression, equation (3), k has a value significantly less than unity. Hence U in equation (4) will also decrease with the time of sampling. The concentration of the sampled pollutant can also have a (lesser) effect on m_s/t and hence on U. The magnitude of these effects is dependent on the adsorption isotherm of the analyte and sorbent concerned, and may be calculated with the aid of computer models [4,5].

Another manifestation of the same effect is back-diffusion, sometimes called reverse diffusion. This can happen where, some time after sampling has started, the vapour pressure of the analyte at the sorbent surface, ρ_2, is greater than the external concentration, ρ_1, for example if a sampler is first exposed to a high concentration and then to a much lower or even zero concentration. This type of exposure profile can occur in certain applications, and the magnitude of any error introduced will depend on whether the period of high concentration occurs at the beginning, middle, or end of the sampling period. The phenomenon has been discussed in detail by Bartley and others [6-8] and a simple test is proposed [9] to give an estimate of the maximum bias to be expected between a pulsed exposure and an exposure to a constant concentration, which latter normally provides the basis for the sampler calibration. This test is 30 min exposure to a high concentration, followed by 7,5 h of clean air, and has been adopted in EN 838. For ambient air applications (EN 13528-2:2002, 7.3.1), however, it is considered that an exposure profile of alternate equal periods of high and low exposure for a 24h cycle is more typical of the intended application, where diurnal variations in concentration are common. Generally in indoor environments both types of exposure profiles may occur. The extent of back-diffusion can also be modelled theoretically [5,10].

To reduce these effects as much as possible, it is desirable to choose a sorbent with high sorption capacity and low vapour pressure of the sorbed analyte or of the reaction product formed by a reactive sorbent.

5.4 Environmental factors affecting sampler performance

5.4.1 Temperature and pressure

For an ideal diffusive sampler, the dependence of U on absolute temperature and pressure is governed by that of the diffusion coefficient of the analyte. The latter dependence is given by:

$$D = \mathrm{f}(T^{n+1}, P^{-1}) \qquad (5)$$

with $0{,}5 < n < 1{,}0$ [11].

Hence, the dependence of U, expressed in units of $\mathrm{cm}^3 \cdot \mathrm{min}^{-1}$ or equivalent is:

$$U = \mathrm{f}(T^{n+1}, P^{-1}) \qquad (6)$$

Accurate knowledge of the average temperature and pressure during the sampling period is important for a correct application of equation 5.

5.4.2 Humidity

High humidity can impair the sorption capacity of hydrophilic and strong sorbents, such as molecular sieve and charcoal. Sampling becomes non-linear because of a significant ρ_2 term in equation 2. This effect will reduce the sampling time (at a given concentration) in which saturation of the sorbent occurs. High humidity can also alter the sorption behaviour of the exposed inner wall of tube-type samplers or draught screen, particularly if condensation occurs.

5.4.3 Transients

Simple derivations of Fick's Law assume steady state conditions, but in the practical use of diffusive samplers, the ambient level of pollutants is likely to vary widely. The question then arises whether a sampler will give a truly integrated response (ignoring sorbent effects, see 5.3) or will "miss" short-lived transients before they have had a chance to be trapped by the sorbent. The problem has been discussed theoretically [6, 13-15] and practically [13, 16-17] and shown not to be a problem provided the total sampling time is well in excess of (say 10 times) the time constant, τ, of the diffusive sampler, i.e. the time a molecule takes to diffuse into the sampler under steady-state conditions. The time constant is given by:

$$\tau = l^2/D \tag{7}$$

Most commercial samplers, as described in annex D, exhibit time constants with values between about 1 s and 10 s. When using these types of sampler at low concentrations and respective sampling duration (days and weeks) transients are of no concern.

5.4.4 The influence of air velocity

5.4.4.1 Effect of low and high wind speeds

Air face velocity and the way a diffusive sampler is oriented in a room can affect its performance because both parameters may influence the effective diffusion path length [18-21]. The diffusive mass uptake of a sampler (equation 2) is a function of the length, l, and the cross-sectional area, A, the diffusion gap within the sampler. The nominal diffusion path length is defined by the geometry of the sampler and is the distance between the sorbent surface and the external face of the sampler. The effective length is not necessarily the same as the nominal length, and may be greater or less, depending on circumstances. The cross-sectional area is also defined by the geometry of the sampler and if the cross-section of the diffusion gap is not constant along its length, is defined by the narrowest portion.

Under conditions of low wind speeds, the effective diffusion path length may be increased [20,21]. This is because a 'boundary layer' [18,19] exists between the stagnant air within the sampler and the moving air outside and contributes to the effective diffusion path length, l. In reality, there is a space outside the sampler where there is a transition between static air and moving air: this space defines an extra length (Δl) of static air which shall be included in the value of l. The value of Δl depends on the external geometry of the sampler. It also decreases with increasing air velocity. Its significance depends on the value of the nominal path length of the diffusive sampler. Thus a sampler with a small cross-section and long internal air gap will be relatively unaffected by air velocity, whilst a short, broad sampler will be significantly affected. This is borne out in practice, as has been demonstrated with samplers of varying length [20,21]. Low sampling rates are observed at low air velocities, but increase to a plateau value as the boundary layer effect becomes insignificant.

Under conditions of high wind speeds, the effective diffusion path length may be decreased [22-27]. This is because external high air flows disturb the static air layer within the sampler, which reduces the effective air gap by a (different) factor Δl. The value of Δl is small, provided the length to diameter ratio of the sampler air gap is greater than 2,5 to 3 [22], or it can be avoided, or greatly reduced, by incorporating a draught shield, e.g. a stainless steel screen or plastic membrane.

The overall effect is therefore an s-shaped curve (see EN 13528-2:2002, 7.4, Figure 1).

5.4.4.2 Consequence for different sampler geometries

Tube-type samplers are typically unaffected by low air velocities [13,28,29] but those without a draught shield may be affected by high air velocities.

Badge-type samplers generally have a large surface area and a reduced length of static air layer, so that they may be more affected by air velocity than tube designs and typically require a minimum face velocity of between 0,5 $m \cdot s^{-1}$ and 0,2 $m \cdot s^{-1}$ [30-33]. Some badges with an inadequate draught shield are also affected at high air velocities [29,31,34].

Radial diffusive samplers [35,36] require a minimum face velocity of about 0,25 $m \cdot s^{-1}$.

5.4.5 Transportation

Typically, samplers will require transportation between the sampling site and an analytical laboratory. To ascertain sample integrity during transportation, the following precautions are recommended:

- ensure that any seals are sufficiently tight to avoid ingress of contamination or loss of sample during transit: metal - plastic seals may become loose if a large temperature change takes place;

- place the samplers in inert closed containers to minimise the ingress of external contamination;

- if air-freighting samples, ensure that they are not subjected to negative pressure, e.g. in the baggage hold;

- avoid exposure to high temperatures during transit, e.g. in the boot of a car;

- if possible, keep the samplers at low temperature and away from contamination sources e.g. petroleum or aviation fuel, but avoiding condensation on the sample;

- ensure that adequate sample blanks are transported with the samples so that any of the above problems can be identified.

6 Measurement objectives

6.1 General

The primary objective of taking indoor air is to determine the quality of indoor air with the aim of assessing any risks to the health of the population and of individuals due to indoor air pollution. This may include personal sampling. In addition diffusive sampling is a cost effective way to gain knowledge of parameters influencing the indoor environment, e.g. ventilation rate.

6.2 Identification of causes of complaints about poor indoor air quality

In many cases investigations of the indoor air are carried out as a consequence of complaints, which are made by persons living or working indoors. Such complaints may be the perception of unknown or unpleasant odours, headache, irritation of the eyes, nose and throat, dryness of the skin or symptoms like tiredness, lack of concentration and unspecific hypersensitivity reactions. Investigations resulting from observed or suspected health problems of occupants are quite similar and require the same sampling strategy.

6.3 Determination of reference values for indoor air quality

Reference values describe the status of a defined set of rooms at a given period in terms of their expected level of indoor pollutants. These are useful to assess whether the levels of indoor pollutants are outside the normal range of occurrence.