INTERNATIONAL STANDARD

**ISO 16000-2**

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# Indoor air —

## Part 2: **Sampling strategy for formaldehyde**

*Air intérieur —*

*Partie 2: Stratégie d'échantillonnage du formaldéhyde*

Reference number
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# Foreword

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

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

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

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

ISO 16000-2 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 6, *Indoor air*.

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

— *Part 1: General aspects of sampling strategy*

— *Part 2: Sampling strategy for formaldehyde*

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

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

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

The following parts of ISO 16000 are under preparation:

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

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

— *Part 8: Ventilation rate measurement*

— *Part 9: Determination of the emission of volatile organic compounds — Emission test chamber method*

— *Part 10: Determination of the emission of volatile organic compounds — Emission test cell method*

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

# Introduction

This part of ISO 16000 describes basic aspects to be considered when working out a sampling strategy for the analysis of formaldehyde in indoor air.

NOTE The term "formaldehyde" is used in this International Standard instead of the term "methanal", as specified by IUPAC regulations.

It is intended to be a link between Part 1 of ISO 16000, which describes a measurement strategy, and Parts 3 and 4 of ISO 16000, which describe the analytical procedures dealing with active or diffusive sampling of formaldehyde respectively. This part of ISO 16000 presupposes knowledge of Part 1 of ISO 16000.

The sampling strategy procedure is based on VDI 4300, Part 3[1].

VOC measurements in different fields of air pollution are described in ISO 16017, *Indoor, ambient and workplace air — Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography*

— *Part 1: Pumped sampling*

— *Part 2: Diffusive sampling*

# Indoor air —

# Part 2: Sampling strategy for formaldehyde

## 1 Scope

This part of ISO 16000 is intended as an aid to planning formaldehyde indoor pollution measurements. In the case of indoor air measurements[1) ], the careful planning of sampling and the entire measurement strategy are of particular significance, since the result of the measurement can have far-reaching consequences, for example, with regard to the need for remedial action or the success of such an action.

## 2 Normative references

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

*ISO Guide to the expression of uncertainty in measurement (GUM),* published jointly by BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML, first edition 1995

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

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds — Active sampling method*

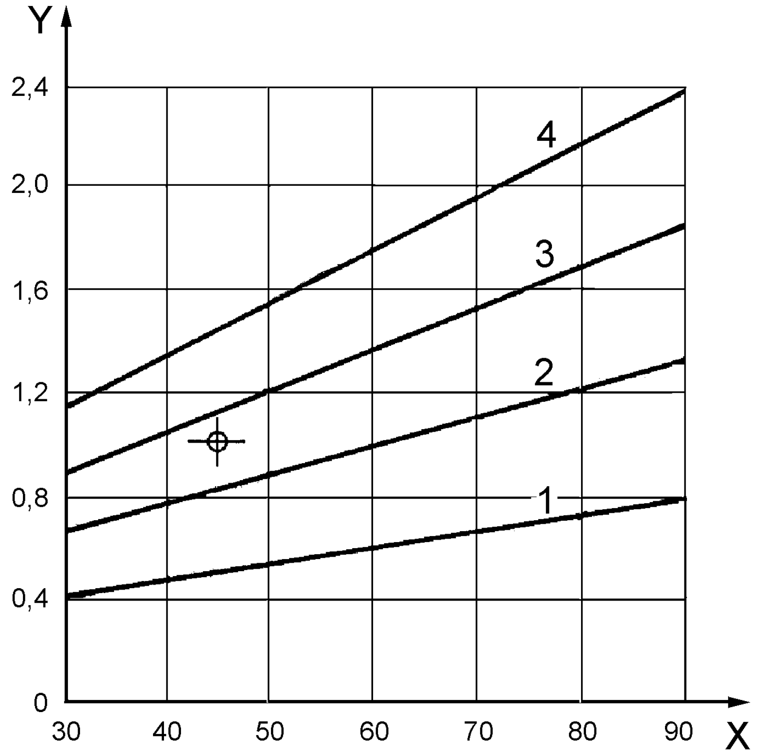
ISO 16000-4, *Indoor air — Part 4: Determination of formaldehyde — Diffusive sampling method*

## 3 Sources and occurrence of formaldehyde

The occurrence of formaldehyde in indoor air is often due to the use of certain wood-based board material for construction and for work on the interior and furnishing of a room. Increased concentrations may also be caused by other products, including use of certain disinfectants and paints. Tobacco smoke is an additional important intermittent source of formaldehyde. Details are given in Table B.1.

Whereas an intermittent emission source (e.g. the use for a limited period of time of disinfectant spray containing formaldehyde) will cause an increased formaldehyde concentration in indoor air for only a short period of time during and after use, a continuous emission source (e. g. a particleboard used for indoor furnishings) will contribute to the formaldehyde concentration over a longer period. Figure 1 shows the influence of humidity and temperature on the emission rate of formaldehyde from particleboard; by increasing humidity and temperature, formaldehyde emission increases considerably.

1) This part of ISO 16000 uses the definition for indoor environment [2], [3] defined in ISO 16000-1.




**Key**

X relative humidity, $H$, in percent
Y factor $K$

1 temperature = 15 °C
2 temperature = 20 °C
3 temperature = 25 °C
4 temperature = 30 °C

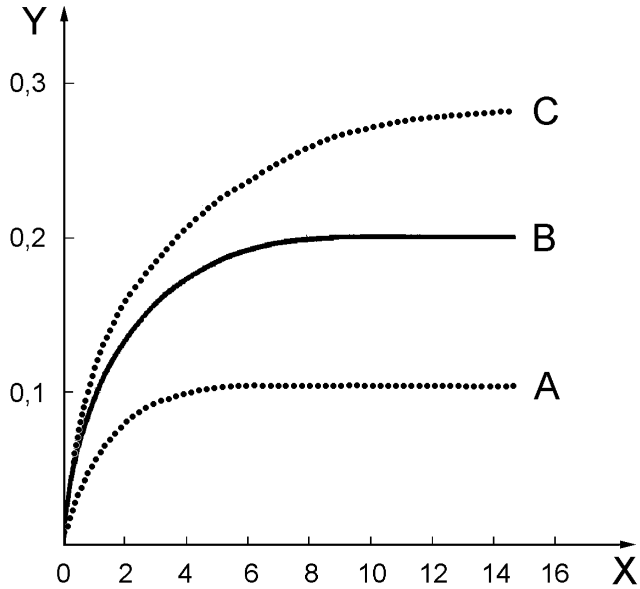
NOTE 1 Parameter for $K = 1$: temperature, 23 °C; relative humidity, 45 %; air exchange rate, 1 $h^{-1}$; loading, 1 $m^2/m^3$.

NOTE 2 $C_{t/H} = C_{23/45} \cdot K$, expressed in millilitres per cubic metre (ppm).

**Figure 1 — Plot of rate of emission of formaldehyde from particleboards in relation to temperature and relative humidity[1], [4]**

Figure 2 presents the formaldehyde equilibration concentration as a function of the air exchange rate after placing a 23-$m^2$ particleboard emitting 2,3 mg/h formaldehyde into a room of 23 $m^3$[1], [5]. Curves A, B and C show the outcome with ventilation rates of > 0,5 $h^{-1}$, 0,5 $h^{-1}$ and < 0,5 $h^{-1}$, respectively.

The recommended World Health Organization (WHO) guideline value for formaldehyde for indoor/ambient air quality is 0,1 $mg/m^3$, expressed as the 30 min average concentration[6].




**Key**

X time, expressed in hours

Y formaldehyde concentration, expressed in milligrams per cubic metre

A ventilation rate > 0,5 $h^{-1}$

B ventilation rate = 0,5 $h^{-1}$

C ventilation rate < 0,5 $h^{-1}$

**Figure 2 — Formaldehyde equilibration concentration in relation to the ventilation rate**

Generally, outdoor sources of formaldehyde are not significant sources of formaldehyde in indoor air. Outdoor air may be contributory only if strong formaldehyde sources (e.g. heavy road traffic) are nearby.

In a study of 300 typical households in Germany during 1985/86, the median level of formaldehyde in indoor air was found to be 55 µg/m$^3$[7]. In a few per cent of the cases, concentrations were above 100 µg/m$^3$. Other, more recent studies in the UK, Sweden and Australia found median formaldehyde concentrations of about 25 µg/m$^3$ (see Table B.2). Table B.2 compares the median and the range of concentrations measured indoors with concentrations observed in outdoor air.

## 4 Measurement techniques

### 4.1 General

There are several methods for measuring formaldehyde. Basically, they meet different demands and can be divided into short-term measurements with active sampling, long-term measurements with active or diffusive samplers, continuous measurements, and screening tests with direct-reading detection tubes. High concentrations of interfering gases (in special cases ozone, $NO_2$ etc.) shall be taken into account.

Analytical methods for the determination of formaldehyde in the air that can be used to determine compliance with the WHO guideline are described in ISO 16000-3.

### 4.2 Short-term monitoring

Short-term monitoring is generally conducted for less than one hour.

The method described in ISO 16000-3 is considered to be a multicomponent measurement technique. After formaldehyde reacts with 2,4-dinitrophenylhydrazine to form a hydrazone, it can be determined by HPLC. In addition to formaldehyde, other aldehydes and ketones can also be analysed by this method. This method can be used for checking compliance with the WHO guideline value.

### 4.3 Long-term monitoring

Long-term monitoring is preferably done with diffusive samplers, described in ISO 16000-4. Sampling relies on the principle of gaseous diffusion into a reactive adsorbent[8], [9], [10], [11], [12]. With diffusive samplers, formaldehyde concentrations are measured over a time period of several hours to a few days. Results are obtained as mean values. If measurement results are necessary for a longer period, repeated measurements shall be performed. The active measurement described in 4.2 is applicable for sampling periods of 24 h or less.

### 4.4 Methods for screening tests

Screening tests provide an immediate, although not necessarily sufficient, indication of the formaldehyde concentration. Commercially available test tubes and direct-reading diffusive samplers are available that are relatively simple to use and give results that can inform decisions about the need for further measurements. The results of screening tests facilitate the determination on to the extent of further measurements required. In certain cases the screening tests may result that no further measurements are required (see Annex E). A formaldehyde concentration near or above a given guideline value would make it necessary to determine, with the help of measurement techniques described in ISO 16000-3, whether there is compliance with the guideline value, or by how much the value is exceeded.

When using methods for screening tests, the requirements for design of an appropriate strategy shall be considered. Subclause 5.2 refers to the required conditions. Examples of screening tests are given in Annex E.

## 5 Sampling strategy

### 5.1 General

The air-measurement technique selected depends on the problem to be solved as well as the nature of the source. Since long-term and continuously emitting surface-area sources are most important, the methods discussed in this International Standard are confined only to these kinds of sources. If intermittent sources, e.g., tobacco smoke, are or have been recently present, they shall be removed before sampling and formaldehyde emitted by them is to be removed by intensive ventilation.

### 5.2 Objectives of the measurement and conditions

#### 5.2.1 General

Before an indoor air measurement can be carried out, its objective has to be defined clearly. The measurement is usually required because of one of the following objectives:

a) to check compliance with the guideline value;

b) to determine maximum concentrations;

c) to check the efficiency of remediation;

d) to determine the average concentration over a longer period of time.

### 5.2.2 To check compliance with the guideline value

For the indoor air, the WHO guideline value on formaldehyde published in 1987 sets no special sampling conditions.

Because formaldehyde is an acute irritant, compliance with the guideline value shall be determined by short-term measurements in accordance with the following conditions and with the aid of one of the measurement techniques outlined in 4.2.

Before sampling, naturally ventilated rooms are intensively ventilated for 15 min and after this are kept closed for at least 8 h (preferably overnight). The doors and windows are kept closed during this period, without taking additional measures such as sealing of windows or doorframes. Sampling is then performed over a period of 30 min with the doors and windows still closed.

To gather information on the possibility of reducing the concentration by ventilation, the room is ventilated for 5 min after sampling by opening the doors and windows. Then doors and windows are closed again and after a waiting time of 1 h, another sample is taken.

If the rooms have a forced air heating, ventilation and air conditioning (HVAC) system, the system shall be operated under normal conditions for 3 h before monitoring.

If there are regulations for ventilation in special cases (e. g. schools, kindergartens), sampling is performed after a cycle of use (e. g. after the first class).

If specific occupant complaints are reported under differing conditions, sampling should also be taken under these conditions.

If pressed-wood products (manufactured with adhesives and resins) are the main source of formaldehyde in the room air, the concentration of formaldehyde will depend to a large extent on the room temperature and relative humidity. With otherwise constant conditions, an increase of the room temperature by 1 °C causes an increase of the formaldehyde concentration of several per cent (see Figure 1).

Conduct the measurement under the indoor climate conditions that usually exist in these rooms. Nevertheless, these conditions should still be within the range of comfort.

The measurements can be performed when the occupants are present.

### 5.2.3 To determine the maximum concentrations

In certain situations, it may be of interest also to acquire information on the levels of formaldehyde under extreme conditions. This might be of interest if a room is used under unfavourable indoor climate conditions, e.g. at temperatures or relative humidities above the normal comfort range (for instance in summer with sunny weather conditions). Another example of such an extreme situation is the emission of formaldehyde from intermittent sources, such as the use of disinfectants. As a consequence, there should be a short-term measurement (30 min) made under those conditions that lead to the higher formaldehyde concentrations.

### 5.2.4 To check the efficiency of remediation

To check the efficiency of remediation measures, the sampling conditions shall be the same as before the remediation.

### 5.2.5 To determine the average concentration over a longer period of time

The sampling duration is normally $\geqslant$ 24 h. Normal occupancy of the building should be maintained.

Normal indoor activities should be recorded before the start of the investigation. Any deviations during sampling shall be documented.

## 5.3 Time of sampling

The time of sampling depends on the objective. Different concentrations that occur over longer periods of time (e.g. seasonal fluctuations caused by differences in temperatures and humidity; see also Clause 3), as well as changes in concentration levels that are caused by short-term interferences (e.g. changing of source strength or ventilation), play an important role. If pressed-wood products are the main source in naturally ventilated buildings, which is especially common in practice, the time necessary to reach the equilibrium formaldehyde concentration can be estimated with the help of the diagram of different air exchange rates shown in Figure 2.

Figure C.1 shows that a period of 2 h is generally not sufficient to achieve an equilibrium after intensive ventilation, especially at higher formaldehyde concentrations.

## 5.4 Duration of sampling and frequency of measurement

The duration of a sampling is determined both by the objective of the measurement and by the limit of quantification of the analytical method for a given air sampling volume. In order to observe compliance with the guideline value, the sampling time should be 30 min.

The decision on the frequency of sampling depends on both the objectives of the sampling strategy and the uncertainty of measurement (see 5.6).

## 5.5 Sampling location

In larger buildings, it shall be decided beforehand in which rooms the formaldehyde measurements are to be carried out. Room selection typically depends either on complaints by the occupants or on the use of the room. Generally in larger buildings, but also in private dwellings, not all rooms are tested at once. When selecting a room, its use is the primary consideration. Rooms where people dwell for longer periods of time (e.g. living rooms, bedrooms, classrooms, nursery school rooms and office rooms) are of special interest. A decision may be made after a screening test (see 4.4).

The position of the sampler within a room can decisively influence the result. Sampling in the vicinity of a suspected emission source, e.g. furniture made of particleboard, can often result in higher concentrations than those obtained at other locations in the same room. To find the emission source, it can thus be useful to measure twice in one room: once “close” to the source and a second time at a greater distance from the source. However, it is important to note that the results of measurements inside cabinets which sometimes are carried out to identify a potential source, shall not be used to check compliance with a guideline value.

When checking for compliance, the sampling device should be placed at least 1 m to 2 m from a wall and at a height of 1,50 m or 1 m to 1,2 m in case of offices, schools or kindergartens where the sitting position is normal. Under such circumstances one location per room will, as a rule, be enough for sampling. Places in the sun, close to heating systems, with noticeable draught or close to ventilation channels should be avoided, because this may influence the measurement results.

One study of the effect of the location of diffusive samplers in rooms of dwellings found that the position of the sampler in the room at heights of 1 m to 2 m did not influence the measurement, provided that locations close to strong sources of formaldehyde (such as unfaced particleboard) and sites near an open window area were avoided[14].

## 5.6 Reporting on results and uncertainties

Within the scope of the sampling strategy, it is essential to define what measurement parameters are to be used to report the results in the measurement report and how uncertainties are to be described. Apart from single values, other parameters (mean value, percentile) may be used to characterise the results.

Uncertainties in sampling and analysis are inevitable. They are caused by the fact that the number of measurements is always limited and there are uncertainties during the analytical determination. Furthermore, the available sampling locations might be or might not be representative of the room or building under investigation (for general information on the assessment of uncertainty, see also GUM).

To determine measurement uncertainties the following are useful:

— replicate measurements;

— standard deviation of measurements;

— measurement range.

An explanation of the relevant performance characteristics that are valid during the performance of the measurement shall be included in the measurement report. The most important parameters are:

— calibration function;

— detection limit and quantification limit (see ISO 6879:1995).

When diffusive samplers are used, the conversion equations used to calculate the results shall be documented.

The result should be reported with an accuracy appropriate to the level of uncertainty associated with the method used.

Uncertainties derived from the above-mentioned performance characteristics should allow an experienced laboratory to obtain measurement results (in milligrams per cubic metre) to three decimal places after the comma.

Table D.1 shows how the confidence interval changes with the number of measurements[13]. It also shows the confidence interval if two, three, five or ten measurements are carried out, assuming a formaldehyde concentration of 120 μg/m$^3$ (0,1 mg/m$^3$) and a standard deviation of 5 μg/m$^3$. Equation (1) is used to calculate the confidence interval [$I(n)$]:

$$I(n) = \pm\, t \cdot s \big/ \sqrt{n} \qquad (1)$$

where $t$ is the $t$-distribution value (95 %), $s$ is the standard deviation and $n$ the number of measurements.

## 5.7 Quality assurance

The quality demands of the client shall be defined in the measurement strategy.

To select and define the elements of quality assurance, the following questions should be addressed when preparing the sampling strategy.

— Does the measuring laboratory have a documented quality assurance system?

— What calibration procedures are used, how often and how extensively?

— Are collocated measurements necessary?

— How are the uncertainties defined (e.g., according to GUM)?

— Does the laboratory participate in interlaboratory tests?

# Annex A
(informative)

# Properties of formaldehyde

Formaldehyde (CAS-No. 50-00-0) is the simplest aldehyde with the formula HCHO (1 ml/m$^3$ = 1 ppm, which is equivalent to 1,2 mg/m$^3$ at 20 °C and 101,3 kPa). It is a colourless gas with a pungent odour and is highly reactive. Formaldehyde is readily soluble in polar solvents such as water and alcohol and is commercially available mainly as a 35 % to 40 % mass fraction aqueous solution containing 5 % to 15 % mass fraction methanol added as a stabilizer.

# Annex B
(informative)

# Overview of important sources and typical concentrations

**Table B.1 — Overview of the most important formaldehyde sources in the indoor environment**

| Source | Examples for use |
|---|---|
| particleboard and other pressed-wood products | walls (outdoors and indoors), ceilings, false ceilings, floors, baseboards, doors and doorframes, stairs, plywood panelling, furniture |
| urea-formaldehyde foams | wall cavity insulation, roof insulation |
| adhesives, glue | wallpaper pastes; gluing tiles, veneer, panelling, carpets and vinyl floor |
| wallpaper, lacquers, varnishes, paints | interior decoration |
| tobacco | tobacco smoke |
| disinfectants | sprays and solutions for surface disinfection |
| combustion processes | gas stove operation |
| treated textiles | furnishings |
| internal combustion engines[a] | transportation |

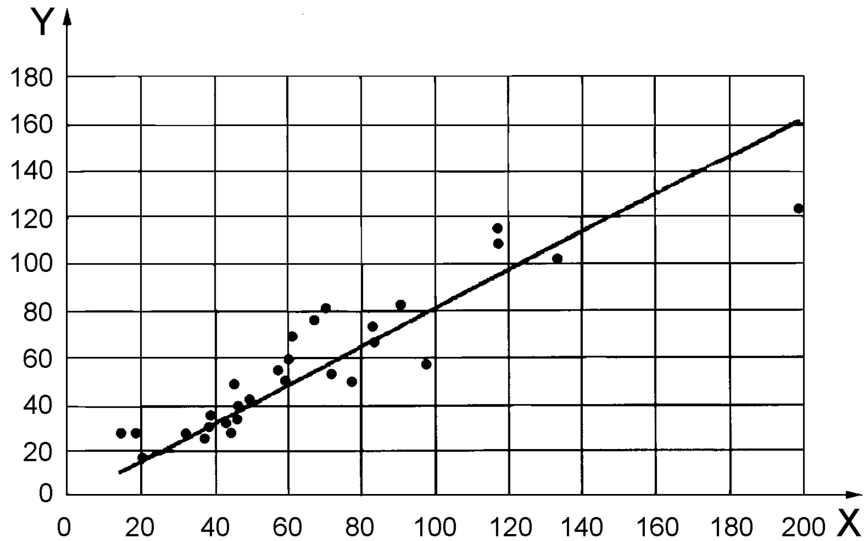
[a] Might be important with heavy traffic.

**Table B.2 — Typical formaldehyde concentrations in normal indoor and outdoor air**

| Indoor air concentrations[7] | | Outdoor air concentrations | |
|---|---|---|---|
| Mean | Range | Rural area | Urban area |
| 55 μg/m$^3$ | < 30 μg/m$^3$ to 300 μg/m$^3$ | 1 μg/m$^3$ to 5 μg/m$^3$ | 3 μg/m$^3$ to 10 μg/m$^3$ |
| **Indoor air concentrations [15]** | | **Outdoor air concentrations** | |
| Mean | Range | Mean | Range |
| 25 μg/m$^3$ | 6 μg/m$^3$ to 130 μg/m$^3$ | 2 μg/m$^3$ | 1 μg/m$^3$ to 4 μg/m$^3$ |

# Annex C
(informative)

## Correlation of formaldehyde concentrations in naturally ventilated rooms depending on ventilation




**Key**

X first measurement of formaldehyde concentration, in micrograms per cubic metre

Y second measurement of formaldehyde concentration, in micrograms per cubic metre

NOTE See text for description of sampling conditions.

**Figure C.1 — Correlation of the formaldehyde concentration in natural ventilated rooms**

The rooms were ventilated by the opening of all windows and doors for 10 min prior to the doors and windows being closed overnight. In winter, the rooms were heated to approximately 20 °C overnight.

The first sample was taken the following morning. After sampling, the room was again ventilated in the same manner for about 10 min. A second sample was taken 2 h after again closing windows and doors to determine formaldehyde.

# Annex D
(informative)

## Dependence of the confidence interval on the number of samples

**Table D.1 — Confidence interval for the determination of formaldehyde in indoor air at a concentration level of about 120 µg/m$^3$ ($t$ = student's $t$ factor; given standard deviation: 5 µg/m$^3$)**

| Number of samples | $t$ (95 %) | Confidence interval (µg/m$^3$) |
|---|---|---|
| 2 | 12,7 | 45 |
| 3 | 4,3 | 12 |
| 5 | 2,8 | 6 |
| 10 | 2,5 | 4 |

Table D.1 shows that at least 3 measurements are required when verifying compliance with the guideline value for a confidence interval of about 10 %.

# Annex E
(informative)

# Examples of screening tests

## E.1 General

Screening test methods are of the type which can quickly provide an indication of the air pollution present without using expensive analysis techniques. The result can inform a decision on the extent of further required measurements. When using screening tests, the basic demands of the measuring strategy have to be considered in any case.

## E.2 Direct-reading detector tubes

Direct-reading detector tubes measure formaldehyde in the range of 0,04 ml/$m^3$ to 0,5 ml/$m^3$. Typical commercially available devices rely on changes in colouration of adsorbing powders from the formaldehyde in air[16]. Sufficient colour change should occur at the guideline value. The system consists of two glass tubes (activation tube and detector tube) connected in series and a bellows pump. The activation tube contains a granular drying layer while the detector tube contains a chemical impregnated granular material for the detection of formaldehyde. A volume of 10 l air is drawn with the bellows pump through the detector tube system.

In the presence of formaldehyde, reaction (1) takes place:

$$HCHO + C_6H_4(CH_3)_2 + H_2SO_4 \quad \Rightarrow \quad \text{quinoid reaction product} \tag{1}$$

When formaldehyde is present, a colour change from white to pale pink will occur. The length of the colour change is a measure of the concentration which can be read from the scale on the tube. To facilitate reading of the formaldehyde content, it is useful to compare the length of the discolouration with a detector tube which is still closed.

If there is no colour change or the reading indicates less than 0,04 ml/$m^3$ on the scale, no further measurements are required. If the device shows a different colour from that described by the manufacturer, it can be an indication of the presence of other interfering pollutants. In this case, no conclusion can be drawn on the presence of formaldehyde.

## E.3 Direct-reading diffusive biosensor

Measurements with a commercially available direct-reading diffusive biosensor facilitates the assessment of the formaldehyde concentration in the range of 0,02 ml/$m^3$ to 0,7 ml/$m^3$[17]. The system involves diffusion of formaldehyde in the air onto a porous indication layer, where it is converted by enzymes and produces a colour ranging from pink to red, depending on the concentration. The enzymes and reagents required for the measuring process are arranged in a badge system which contains a sintered glass rod and an ampoule, filled with the activated solution. The ampoule is broken at the beginning of the measurement by pressing the start button whereupon the sintered glass rod is moistened which in turn activates the enzymes. In the presence of formaldehyde, reactions (2) and (3) take place:

$$HCHO + NAD^+ \xrightarrow{E_1} NADH + HCOOH \tag{2}$$

$$NADH + CPMS \xrightarrow{E_2} NAD^+ + \text{colouring molecule} \tag{3}$$

where

$E_1$ formaldehyde dehydrogenase;

$E_2$ diaphorase;

CPMS preliminary stage of colouring molecule.

After a sampling duration of 2 h, the formaldehyde concentration is established by comparing the discolouration with the attached colour-code and using a colour-code class evaluation table.

The biosensor is extremely sensitive for formaldehyde. Acetaldehyde interferes, but the response is approximately 50 times lower than that due to formaldehyde.

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