

GUIDELINE VALUES FOR INDOOR AIR POLLUTANTS

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ABSTRACT

With the major goal of defining action levels at or above which measures should be taken to avoid hazardous exposure indoors a general scheme was developed to derive guideline values for indoor air pollutants. This paper reports on the results obtained when applying the scheme to toluene, styrene, dichloromethane, pentachlorophenol, carbon monoxide and nitrogen dioxide. In addition, guideline values for the indicator "total volatile organic compounds" (TVOC) are presented which, however, have not been derived based on the scheme.

INTRODUCTION

As pointed out earlier [1], the special character of the indoor environment makes it unlikely that the regulatory approach normally selected to limit outdoor air pollutants, namely the setting of standards¹, is adequate to handle indoor air pollution. Rather than standards, guideline values² can be considered to be an appropriate tool to deal with indoor air quality as they represent a "softer" way of dealing with the problem. This "softer" way is needed given the special character of many indoor environments, especially of homes in which privacy and freedom of behaviour plays an important role. So far, guideline values for special indoor air pollutants have been proposed by committees and authors from Canada [2], Norway [3] and Denmark [4,5]. The air quality guidelines published by the World Health Organization [6], although not developed specifically for indoor air, are intended to be also applicable to indoor air.

In the mid-nineties, a group of experts in Germany started work to derive guideline values for indoor air pollutants. The major aim of this work was to define action levels at or above which measures should be taken to avoid hazardous exposure. A general scheme was developed which was applied to different types of indoor air pollutants (volatile and semi-volatile organic compounds, inorganic gases). This paper presents the general scheme and reports on its application to different indoor air pollutants.

METHODS

In their Concept for Better Indoor Air Quality published in 1992, the German Federal Government had advocated the need for guideline values for indoor air pollutants in order to

¹ In this article the word "standard" refers to a concentration level that has been set taking into account not only health aspects, but also other aspects like technical feasibility or economical considerations. In addition, for a concentration level to be considered as a standard it must be complemented by instructions on how to measure and implement it.

² In contrast to a standard a "guideline value" is a recommendation which cannot be enforced legally unless adopted in a regulatory document.

guarantee a nation-wide uniform evaluation. While it was intended to leave the final setting of guideline values to a committee with a "pluralistic" composition (the committee has not been formed since) it was felt that an ad-hoc group should prepare recommendations. This ad-hoc group was formed from members of the Indoor Air Commission of the Federal Environmental Agency, the Environmental Hygiene Committee of the Consortium of Health Ministries of the German States, and a few additional scientific experts, and started work at the end of 1993.

RESULTS

Definitions

In Germany, an important framework for the setting of indoor-related guideline values is given by the building codes (which are under the jurisdiction of the German States). The building codes demand that there be no health hazard to occupants from the building. Hence the work of the ad-hoc group focused on defining concentration levels at which such hazard would probably occur. The introduction of a safety margin would then allow the definition of a concentration where there would be no more concern for adverse health effects. The following two concentration levels were defined:

Guideline value II (GV II)

GV II is a health-related value based on current toxicological and epidemiological knowledge. If the concentration corresponding to GV II is reached or exceeded immediate action must be taken because permanent stay in a room at this concentration level is likely to represent a threat to health, especially for sensitive people. In this context, taking action means an immediate examination of the situation with regard to a need for control measures. It may include the evacuation of the room in question. If by measurement GV II has been found to be exceeded, the results should be checked by repetitive measurements carried out immediately under normal conditions of occupancy. If possible and deemed meaningful, biological monitoring of the occupants should be carried out in addition.

Guideline value I (GV I)

GV I is the concentration level at which a substance - taken individually - does not give rise to adverse health effects even at life-long exposure. An exceedance of GV I is linked with an exposure beyond normal which is undesirable from a hygienic viewpoint. Thus, there is also a need for action at concentrations between GV II and GV I. GV I is obtained by dividing GV II by a factor of 10. This factor³ is a convention. However, for odorous substances GV I must be defined based on the odour threshold ("odour detection") if the odour threshold has a lower numerical value than the concentration derived according to the general scheme. GV I can be used as the level to be reached after control measures have been applied. The level should not be "filled up"; rather, the final concentration should fall below.

The general scheme

Work was started by setting up a general scheme to derive GV II and GV I [7]. This general scheme does only apply to individual substances which are non-carcinogenic.

³ Although it is not correct to use the word "factor" for the mathematical operation in question, this word is used in order to be consistent with the general custom in the literature.

The essential steps of the scheme are (a) the identification of an effect threshold from either human or animal studies, (b) the conversion into an effect threshold for humans if animal studies are used, (c) the consideration of sensitive individuals, (d) the conversion from short-term, intermittent exposure (e.g. at the work place) to continuous exposure, (e) the consideration of physiological differences in the population, and (f) the consideration of intake pathways other than inhalation. It is important to note that the uncertainty factors indicated in the scheme are default values which can and should be changed if there is sufficient evidence for such change.

(a) The identification of an effect threshold. As a rule, human data are preferred over animal data and the LOAEL (Lowest Observed Adverse Effect Level) is selected to start. As the magnitude of a LOAEL derived from an animal study will generally depend on the experimental design, it was deemed reasonable to define the "real" effect threshold as the geometric mean between the LOAEL and the NOAEL (No Observed Adverse Effect Level). Given that generally there is a tenfold difference between these two levels, the effect threshold from animal studies is obtained by dividing the LOAEL by 3 (approximate value of the square root of 10).

(b) The conversion from animals to humans. The usual default factor of 10 for interspecies effects is applied unless there is information that justifies an increase or decrease of this factor.

(c) The consideration of sensitive individuals. For ethical reasons the most sensitive individuals are generally not included in experimental studies with humans. Consequently, the commonly used default factor of 10 is applied to account for intraspecies differences. If the results of studies with sensitive population groups are used, this factor can be lower.

(d) Differences in exposure pattern. If work place studies are used to derive effects thresholds for the general population, the different exposure pattern is taken into account by using a factor of 5 (rounded; $168 \text{ h}/40 \text{ h} = 4.2$). The use of this factor requires exposure to occur at concentrations within the linear part of the dose-response curve. The factor needs to be changed if special metabolic or elimination effects justify such change. For some substances it may be appropriate to set both short-term and long-term guideline values. In such cases, the results of short-term and long-term studies, respectively, should be used.

(e) The consideration of physiological differences in the population. Children have a higher respiration rate than adults and, therefore, inhale higher amounts of pollutants in relation to body weight. This physiologically-based difference is taken into account by introducing a factor of 2 if children have not been represented adequately in the study based on which the effects threshold is derived. This "children" factor is not meant to address a special sensitivity of children and can be omitted if it is shown that special metabolic activity accelerates the elimination of the pollutant.

(f) Additional aspects. Before fixing GV II finally it should be verified that there is no additional aspect to be considered. In particular, it should be checked if inhalation is the essential pathway of intake or if other pathways need consideration in an appropriate way. The default factor of 1 given in the scheme demonstrates that it is believed that in most cases such effects are not likely to play a role.

Applications of the general scheme

Based on the general scheme the ad-hoc group is deriving guideline values for a number of substances. Although the selection of the substances handled up to now was mainly driven by demands from the practice, it was also the intention to include substances of differing nature to test the applicability and limitations of the scheme. For the time being, guideline values have been published for toluene [8], styrene [9], dichloromethane [10], pentachlorophenol [11],

carbon monoxide [12] and nitrogen dioxide [13]. For internal reasons the texts were published under the name of the member of the group that prepared the first draft and kept the responsibility for finalisation. However, all texts (including the TVOC paper, see below) were carefully discussed in the plenary of the ad-hoc group and only published after full agreement had been reached on the text. The only exception was the pentachlorophenol paper which was published under the ad-hoc group's authorship.

As far as possible each text was given the same structure. Starting with information on the substance itself and its physical and chemical properties the text gives a summary on exposure and toxicokinetics (uptake, distribution and metabolism, and elimination). This is followed by a description of the information that is available with regard to effects (with a clear focus on effects on humans), including odour perception and any known information on combined effects with other pollutants. In the final chapter the effects are evaluated, current regulation from other fields such as the workplace is presented, and - following a rationale for the selection of the endpoint considered - the general scheme is applied to derive GV II and GV I.

Toluene [8]. Based on the results of studies on neurotoxicity a LOAEL of 280 mg/m³ was defined. Applying three factors (10 for intraspecies effect, 5 for different time base, and 2 for physiological differences in children) GV II was set at 3 mg/m³. Division by 10 gives GV I with a numerical value of 0.3 mg/m³. Both guideline values are meant as averages over one- to two-week periods.

Styrene [9]. Based on the results of a number of studies on neurotoxicity and impaired colour vision, an average LOAEL of 34 mg/m³ was defined. Applying three factors (10 for intraspecies effect, 5 for different time base, and 2 for physiological differences in children) GV II was set at 0.3 mg/m³. Division by 10 gives GV I with a numerical value of 0.03 mg/m³ which is below the odour detection limit. Both guideline values are meant as averages over one week. A shorter sampling period, e.g., 30 minutes, should be selected to evaluate the justification of odour complaints.

Dichloromethane [10]. Based on the results of studies on neurotoxicity a LOAEL of 690 mg/m³ was defined. Effects were observed after a 1.5-h exposure at this level. This would correspond to a CO-Hb level of 1.9 %. Linear conversion of the LOAEL to a 24-h period results in a value of 43 mg/m³. Applying the two factors: 10 for intraspecies effect, and 2 for physiological differences in children GV II was set at 2 mg/m³, valid for a time period of 24 h. Division by 10 gives GV I with a numerical value of 0.2 mg/m³.

Pentachlorophenol [11]. Following intensive discussion it was felt that the general scheme could not be applied in the case of pentachlorophenol (PCP). In view of the deficits of human studies on the effects of PCP the results of animal studies (which, however, are not satisfactory either) needed to be included in the evaluation. It was felt that exposure to PCP should primarily be evaluated using the results of human biomonitoring (HBM). The recommendations of the HBM Commission of the Federal Environmental Agency [14] should be followed which define a value of 70 µg PCP/l serum (or 40 µg PCP/l urine) as the level at which measures to reduce exposure should be taken almost immediately. For public buildings where HBM is not feasible the exceedance of an indoor air concentration of 1 µg/m³ requires mitigation measures. The level to be attained following such mitigation is 0.1 µg/m³.

Carbon monoxide [12]. Based on the well-known cardiovascular effects of carbon monoxide (CO) the LOAEL was defined in terms of an carboxyhemoglobin (CO-Hb) level and amounts to 2.5-3 % CO-Hb. At equilibrium, which is reached after 8 hours in case of slight physical activity, this corresponds to 15 mg CO/m³. Since the CO-Hb level was derived from human studies including sensitive subjects, there is no need for further factors. Thus, GV II (8 h) was

set at 15 mg/m³. An additional GV II (30 min) was set at 60 mg/m³. The resulting GV I concentrations are 1.5 and 6 mg CO/m³, respectively.

Nitrogen dioxide [13]. A short-term (30 min) LOAEL of 350 µg/m³ can be derived from studies with asthmatics. As physical activity does not lead to higher sensitivity, no "children" factor was introduced and GV II (30 min) was set at 350 µg/m³. For the long-term situation a LOAEL of 60 µg/m³ results from studies with children including sensitive individuals. Thus, GV II (1 week) was set at 60 µg/m³. The result of the division of GV II by 10 to obtain GV I shows the limits of the general scheme in this case. Indoor NO₂ concentrations of 35 µg/m³ (30 min) and 6 µg/m³ (1 week) are not likely to be achievable given that ventilation alone may introduce outdoor air containing such concentration levels in many places. Consequently, no numerical values were not set for GV I.

The evaluation of indoor air quality using TVOC as an indicator

In the past there has been much controversy concerning the use of the construct "Total Volatile Organic Compounds" (TVOC) to evaluate indoor air quality. It was felt that a report published by a working group of the European Collaborative Action "Indoor Air Quality and its Impact on Man" [15] provided most useful information on how to use or not to use this construct. The ad-hoc group decided to give recommendations for practical use based on this report [16] emphasising that there is no dose-effect relationship between TVOC concentrations and health effects but rather an increasing probability of such effects at increasing TVOC levels. Consequently, the general scheme used for the substances discussed above was not applied and - rather than defining GV II and GV I - three ranges were defined for the TVOC level.

A room with 10-25 mg TVOC/m³ should at best be used temporarily. In rooms for permanent occupancy a long-term level of 1-3 mg TVOC/m³ should not be exceeded. Under precautionary aspects the long-term goal remains to achieve levels between 0.2 and 0.3 mg TVOC/m³ or even lower (however, outdoor air pollution must be taken into account). The setting of ranges rather than of individual numbers is intended to reflect not only the limited knowledge of the health effects of mixtures of VOC but also the uncertainties caused by sampling and analytical procedures. Information about individual VOC and VOC profiles remains important for source identification and control.

DISCUSSION

Setting guideline values for indoor air has some tradition in Germany where the first value ever set for formaldehyde was derived in 1977 (0.1 ppm). In contrast to this and to additional indoor air guideline values published meanwhile in other countries for a few specific substances [2-4,5], the new approach selected in Germany was to define two concentration levels. GV II is the level of concern for human health at which measures have to be taken while GV I is the level at which there is no such concern even at life-long exposure. To derive these guideline values in a traceable way a general scheme was developed in which, starting from an effect threshold, a number of uncertainty "factors" are applied. It is essential to note that all "factors" in the scheme are default values which can and should be changed if there is good reason to do so. The example of pentachlorophenol has shown that the scheme is not applicable for all indoor pollutants. Work to derive guideline values for more indoor air pollutants is ongoing.

Being aware of the ongoing discussion about the meaning of a TVOC value concentration ranges were derived at three different TVOC levels (not using the scheme, however). Each of these ranges is linked with an indication of the possibility for a room to be occupied without causing adverse health effects or complaints. The caveats to be considered are expressed in the accompanying text [16].

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