Ausschuss zur gesundheitlichen Bewertung von Bauprodukten

Committee for Health-related Evaluation of Building Products

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Updated List of LCI values 2005 in Part 3

Ausschuss zur gesundheitlichen Bewertung von Bauprodukten

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A contribution to the Construction Products Directive:

Health-related Evaluation Procedure for Volatile Organic Compounds Emissions (VOC and SVOC) from Building Products

1 Introduction

The health and comfort of the occupants of indoor spaces is influenced by the indoor climate in a room (in particular temperature and relative humidity) and by potential indoor air pollutants. Such pollutants may be emitted by a variety of sources. Among these sources building products are of particular importance here since their selection is often not within the occupants' discretion and many of them cover large surface areas in a room.

In Germany the use of building products is subject to the provisions of the building codes of the Federal States (Länder). These provisions require that built structures shall be designed, built, and maintained in such a way that life, health or the natural environment are not endangered (§ 3, standard building code (Musterbauordnung MBO)). Building products used in the construction of buildings or integrated in the building have to satisfy these requirements so that chemical, physical or biological influences do not result in any hazard or unacceptable nuisance (§ 16 MBO).

The importance of building products is also accounted for in the European Union by the European Construction Products Directive (CPD) which came into force in 1989 [Council of the European Communities, 1989]. Although this Directive mainly aims at eliminating barriers to trade, it also contains – at least in a general form – provisions that take health aspects into account. The European Construction Products Directive has been transposed into German national legislation by the Building Products Act in 1992 *(*Bauproduktengesetz*)*[1] and by amendments of the building codes of the Federal States (Länder).

[1] Building Products Act (BauPG 1992): Act on marketing and free movement of building products to implement Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (Bauproduktengesetz – BauPG). Bundesgesetzblatt (Federal Law Gazette) I, No 39 of 14 August 1992, 1495-1501; amendment 1998: publication of the revision of the Building Products Act of 28 April 1988. Bundesgesetzblatt I, No 25 of 8 May 1998, 812-819.

One of the objectives of the building codes of the Federal States (Länder) and of the European Construction Products Directive is to protect the building users' health. This general objective has been formally documented in the Interpretative Document – Essential Requirement N° 3 ("Hygiene, Health and Environment"; ER 3 for short) prepared by the European Commission, which explicitly mentions that indoor pollutants, e.g. volatile organic compounds (VOC), be avoided and controlled [EC, 1994]. The "Guide for Construction Products Assessment under Health Aspects" produced by German Coordination Committee 03 of the Building and Civil Engineering Standards Committee (Normenausschuss Bauwesen) equally serves this specific purpose. Nevertheless, binding and differentiated evaluation procedures are still not available to translate the health-related requirements of the Construction Products Directive into practice.

There is no doubt that the building users' health has to be protected, but it was still not clear how this protection can be realised in detail. In a number of European countries, including Germany, manufacturers and trade associations have made an attempt to provide the user and consumer with information on the building products' quality via quality labels. However, there is no officially accepted procedure yet for the health-related evaluation of building products.

The European Union has also recognised the insufficient implementation of ER3 and has issued a mandate to CEN for implementation of ER3. The mandate[2] provides for the development of horizontal assessment methods for dangerous substances in and their emission from, construction products. These methods will then be incorporated in the technical specifications for the standardisation and authorisation of construction products.

National and international bodies, in particular the European Collaborative Action (ECA) "Indoor Air Quality and its Impact on Man", have already dealt with the evaluation of VOC emissions from building products in the 1990s. Within ECA, that is now working under the title "Urban Air, Indoor Environment and Human Exposure", experts from the EU Member States and from Switzerland and Norway are thoroughly examining the specific knowledge available in Europe over a wide range of indoor issues. The results of their work have been published in reports, which contain sufficiently detailed information to be considered as 'pre-normative' documents. One of them is Report No 18 "Evaluation of VOC Emissions from Building Products" in which a flow chart for the evaluation procedure of emissions from floor coverings is given as an example [ECA, 1997a].

The Committee for Health-related Evaluation of Building Products, *AgBB*[3] *(Ausschuss für die gesundheitliche Bewertung von Bauprodukten,)* considers as one of its main tasks to establish in Germany the fundamentals for a uniform health-related assessment of building products so that the requirements specified in the building codes of the Federal States (Länder) and the Construction Products Directive are satisfied, and an evaluation procedure will result which is as traceable and objective as possible.

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[2] Mandate M366 "Development of horizontal standardised assessment methods for harmonised approaches relating to dangerous substances under the Construction Products Directive (CPD)". European Commission, DG Enterprise, Brussels, 16 March 2005.

[3] Composed of representatives of the health authorities of the *Länder*, the Federal Environmental Agency (UBA) with the AgBB Secretariat, the German Institute for Building Technology (DIBt), the Conference of the *Länder* Ministers and Senators responsible for urban development, construction and housing (ARGEBAU), the Federal Institute for Materials Research and Testing (BAM), the Federal Institute for Risk Assessment (BfR) and Coordination Committee 03 – hygiene, health and environmental protection - of the Building and Civil Engineering Standards Committee of the German Institute for Standardisation (DIN-KOA 03)

In the following, the Committee submits a procedural scheme for health-related evaluation of VOC emissions from building products used for application indoors. Within this scheme, volatile organic compounds include compounds within the retention range of C_6 to $C_{16,}$ which are considered both as individual substances and in calculating a sum parameter following the TVOC concept (TVOC = Total Volatile Organic Compounds), and semivolatile organic compounds (SVOC) within the retention range from C_{16} up to C_{22}.

The scheme was extensively discussed with representatives of manufacturers and professionals after having been published first [AgBB 2000/2001] and at the end of its introductory phase from 2002 to 2004 [Proceedings of the technical dialogues in 2001 and 2004]. The Committee is confident that by adhering to the test values set in the scheme, the minimum requirements of the building codes for health protection with regard to VOC emissions can be met. Even though, initiatives of manufacturers to produce products with less emissions, are supported. Manufacturers can therefore declare better performance parameters for their products (with regard to VOC emissions).

2 Health-related evaluation of VOC emissions from building products

The effects of indoor air pollution have been dealt with in a large number of publications (cf. e.g. [ECA, 1991b; Maroni et al., 1995]). Volatile organic compounds may have effects ranging from odour perception and irritation of the mucous membranes of the eyes, nose and throat to effects on the nervous system and long-term effects. The latter include allergenic and allergy-promoting properties and, in particular, carcinogenic, mutagenic or reprotoxic potential.

The toxicological evaluation of substances from building products can be based on available information which, in the best, includes knowledge on dose-effect-relationships. Such relationships permit to establish concentration levels below which there would be no concern about adverse effects.

The most comprehensive evaluation system is available for the workplace area for which there are maximum permitted workplace concentrations (*M*aximale *A*rbeitsplatz-*K*onzentrationen - MAK values). However, where hazardous substances are handled at workplaces under typical conditions, much higher substance concentrations than under normal indoor conditions are generally encountered. On the other hand, much shorter exposure times occur at workplaces in comparison to indoor situations. Results must therefore be adjusted by suitable factors when applying them to normal indoor living spaces [ECA, 1997a].

The procedure used to establish auxiliary parameters to evaluate building products, the so-called LCI (Lowest Concentration of Interest)[4] values, is explained in detail in the introduction of the LCI values listed in the Annex (Part 3 of this document).

The aforementioned evaluation criteria are based on the assessment of individual compounds although building occupants are exposed to a multitude of substances. This is accounted for by the total concentration of volatile organic compounds (TVOC) [Seifert, 1999; ISO 16000 /6]. However, it has to be emphasized that a TVOC guideline value – due to the

[4] In the original German text the acronym NIK is used standing for Niedrigste Interessierende Konzentration, which is the translation of LCI.

varying composition of the VOC mixture occurring in indoor air – cannot be based on toxicological conditions. However, experience shows that with increasing TVOC concentration the likelihood of complaints and adverse health effects also increases [ECA, 1997b].

3 Sensory aspects

Since VOC emission is often combined with odour perception, which may result in health impairment, sensory testing is an important element of the evaluation of building products. However, it has not yet been possible to integrate this aspect into the current evaluation of building products. Although many different odour measurement methods exist [Fischer et al., 1998; ECA, 1999], a harmonised and generally accepted procedure for odour assessment of building products is not yet available.

4 Measurement and evaluation of VOC emissions from building products

4.1 Test chamber method for VOC emissions measurement

VOC emissions from building products can be suitably measured in test chambers. Important parameters that have an influence on the result are temperature, air exchange rate, relative humidity and air velocity in the test chamber, and the amount or surface area of the material in the chamber and the method of sample preparation. The influence of these and other parameters became evident in international intercomparison tests [ECA, 1993; ECA, 1995]. Based on the results of these tests and an earlier publication on the test procedure [ECA, 1991a], a European standard for the determination of emissions from building products was published [E DIN EN 13419 1-3, to become DIN EN ISO 16000-9 to -11 in 2006]). Parts 1 and 2 describe the procedure when using a test chamber and a test cell, respectively. Part 3 covers sampling and storing of samples, and preparation of test specimens.

4.2 Exposure scenarios

To relate the results of test chamber measurements to realistic exposure situations a number of boundary conditions must be assumed. It is most important to consider a scenario that reflects exposure under practical conditions.

According to equation (1) the indoor air concentration C, for a surface-emission source depends on the area-specific emission rate E_a [µg/(m^2 h)] of the product, the air exchange rate n [h^{-1}] in the room considered and the ratio of product surface area A [m^2] to the room volume V [m^3]. Parameters n, A and V can be combined into the new parameter q [m^3/(h m^2)] called the area-specific air exchange rate.

$$C = \frac{E_a \times A}{n \times V} = E_a / q \ [\mu g/m^3] \qquad (1)$$

According to DIN 1946-6 (1994), for residential rooms, the outdoor air flow rate per square metre, i.e. the area-specific air exchange rate is between 1 and 1.5 m^3/(h m^2) depending on the actual living area. Taking the upper limit of this range, to be on the safe side, and using equation (1) an air exchange rate of approx. 0.5 h^{-1} is obtained for a room 2.7 m high and with a surface area of 3m x 4m. This value corresponds to the average encountered under practical conditions. Choosing these conditions for the chamber test of, e.g., flooring materials, the substance concentration measured in the test chamber corresponds approximately to that to be expected in such a room. However, differences due to potential sorption effects are not taken into account here.

4.3 Evaluation scheme for volatile organic compounds

For health evaluation, a product has to undergo a series of tests as shown in the flow chart in Fig. 1. The procedure starts from a product wrapped in an airtight cover. The start of the experiment (t_0) is defined as the time at which the product to be tested is unwrapped and placed into the test chamber or cell. The product remains in the test chamber or cell over the entire period of the test. For certain product groups it is necessary to define special test

conditions. These specific requirements are defined separately (see Approval guidelines for the health-related evaluation of indoor construction products, Part I and Part II [Deutsches Institut für Bautechnik, 2004]). They may also include the definition of criteria for anticipated termination of the emission measurement. In principle, anticipated termination of the test is permitted at the earliest 7 days after placing the test specimen into the chamber and under the condition that the values determined are less than half the requirements for the 28-day values and no significant increase in the concentration of individual substances is observed in comparison to the measurement on day 3. The fulfilment of these criteria has to be sufficiently demonstrated by the testing body.

In accordance with ISO 16000 /6 the following definitions apply for the emission to be determined in the test chamber:
VOC: all individual substances within the retention range C_6 - C_{16}
TVOC: sum of the concentration of all individual substances with concentrations equal to or greater than 5 µg/m^3 within the retention range C_6 - C_{16}
SVOC: all individual substances within the retention range > C_{16} - C_{22}
∑SVOC: sum of the concentration of all individual substances with concentrations equal to or greater than 5 µg/m³ within the retention range > C_{16} - C_{22}

The assignment of the individual substances to the retention ranges C_6 - C_{16} and C_{16} - C_{22} is based on the separation on a non-polar column. Individual substances comprise identified and non-identified compounds.

In the AgBB scheme, the identification of all individual substances is based on a presumed uniform detection limit of 1 µg/m^3 in order to cover the emission spectrum as fully as possible in a qualitative way.

All individual substances have to be quantified as required[5] and need to be considered individually and in the summation if their concentration is equal to or greater than 5 µg/m^3. Exceptions apply to particularly critical substances; these have to be included in the calculation of R values if their concentration in substance-specific quantification is equal to or greater than 1 µg/m^3 (see 4.3.2).

VOC and SVOC shall be measured using Tenax sampling and subsequent thermodesorption and analysis by GC/MSD according to DIN ISO 16000-6. Aldehydes, in particular low-chained aldehydes listed in Group 7 of the list of LCI values, shall be determined using the DNPH method according to DIN ISO 16000-3 (see Note III in the Annex).

The following explanations are given to the flow chart in Figure 1:

4.3.1 Measurement and testing after 3 days

- $\underline{TVOC_3}$

A product satisfies the criteria, if the TVOC value after 3 days ($TVOC_3$) is ≤ 10 mg/m³.

- Carcinogenic substances

Every building product has to meet the general requirement of not emitting any carcinogenic, mutagenic or reprotoxic substances. Emission of carcinogenic substances belonging to

[5] Identified substances with LCI values as well as carcinogens have to be quantified using their individual calibration factors while identified substances without LCI values and non-identified ("unknown") substances are quantified on the basis of toluene equivalents.

categories 1 and 2 according EU Directive 67/548/EEC is first tested at this stage of the flow chart. Substances with mutagenic or reprotoxic properties and those with potential carcinogenic effects (EU category 3) are checked within the LCI concept (see Part 3) and assigned higher safety factors if necessary. Carcinogens have to be quantified in a substance-specific manner.
The sum of all EU categories 1 and 2 carcinogens [EU Directive 67/548/EEC] detected after 3 days shall not exceed 0.01 mg/m³.

- First sensory testing

For determining the equally important sensory properties it will be necessary to agree upon more precise details before an initial sensory test can be performed at this stage of the flow chart. Until an adequate test method is available, there is only a reference in the flow chart to the necessity of a sensory test.

4.3.2 Measurement and testing after 28 days

- $TVOC_{28}$

In order to assess the long-term behaviour of the VOC emissions from a building product, the TVOC value is determined again after 28 days. This is done in the same way as described for $TVOC_3$. When calculating the $TVOC_{28}$ value, in addition to the instructions given in DIN ISO 16000/6, it is important to be as complete as possible in the identification of compounds to permit the evaluation of individual substances.
A product satisfies the criteria, if the $TVOC_{28}$ value is ≤ 1.0 mg/m³. Products with a TVOC value higher than that are rejected.

- Semivolatile organic compounds (SVOC)

Products that satisfy the criteria for VOC emissions but instead exhibit increased emission of SVOC should not be given advantages. To prevent this from happening the SVOC concentration in the chamber air shall also be determined[6].

A product satisfies the criteria if the sum of the SVOC concentrations in the chamber air does not exceed 0.1 mg/m³. This corresponds to an additional content of 10 % of the maximum allowable $TVOC_{28}$ concentration of 1.0 mg/m³. Higher concentrations result in rejection.

- Carcinogenic substances

The emission of carcinogenic substances of EU categories 1 and 2 [EU Directive 67/548/EEC] is tested again, with an emphasis on the long-term behaviour from the user's point of view. The sum of all carcinogens detected shall not exceed the value of 0.001 mg/m³. Higher concentrations result in rejection.

- Second sensory testing

Until the test procedure has been agreed upon finally, the requirement for a second sensory test after 28 days is indicated. The reason for a second test is that chemical reactions may only occur within the product which may lead to odour or other sensory perception.

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6 Emission of semivolatile organic compounds with a retention time $>C_{16}$ (hexadecane) can be quantitatively determined by chamber or cell measurements over 28 days using today's modern analysis apparatus up to a volatility comparable to that of docosane (C_{22} alcane, boiling point 369 °C). According to current knowledge, the analysis semivolatile organic compounds with an even lower volatility will encounter increasing difficulty if the method of Tenax sampling and thermodesorption is used in chamber tests.

- Evaluation of individual substances

In addition to evaluating the emissions of a product via the TVOC value, the evaluation of individual VOC is also necessary. For this purpose all compounds whose concentration in the chamber air equals or exceeds 1 µg/m³ are first identified, listed with their CAS number, and quantified according to the following:

a) VOC assessable via LCI

For a large number of VOC found in indoor air a list of so-called LCI values (Lowest Concentration of Interest see footnote 4) is contained in the Annex. The details of how these LCI values have been derived are documented in the introduction to the list. Listed substances with a concentration exceeding 5 µg/m³ are evaluated based on LCI. They are quantified in a substance-specific manner.

Particularly critical substances with LCI values ≤ 10 µg/m^3 shall be included in the evaluation if their concentration equals or exceeds 1 µg/m^3.

For the evaluation of each compound *i* the ratio R_i is established as defined in equation (2).

$$R_i = C_i / LCI_i \qquad (2)$$

where C_i is the chamber concentration of compound *i*. For $R_i < 1$, it is assumed that there will be no effects. If several compounds with a concentration > 5 µg/m^3 are detected, additivity of effects is assumed and it is required that R, the sum of all R_i, shall not exceed the value 1.

$$R = \text{sum of all } R_i = \text{sum of all ratios } (C_i / LCI_i) \leq 1 \qquad (3)$$

Products which do not fulfil this condition are rejected.

b) VOC not assessable via LCI

In order to avoid the risk of a positive evaluation of a product which emits larger quantities of nonassessable VOC, a limit is set for those VOC which cannot be identified or do not have an LCI value. This limit equals 10 % of the permitted TVOC value, for the sum of such substances. A product meets the criteria when the sum of such VOC determined at concentrations ≥ 0.005 mg/m^3 does not exceed 0.1 mg/m³. Higher concentrations result in rejection.

4.4 Conclusion

A building product which fulfils the requirements set out in the flow chart (see Figure 1) is suitable for use in enclosed building spaces.

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Fig. 1: FLOW CHART FOR THE EVALUATION OF VOC* AND SVOC*EMISSIONS FROM BUILDING PRODUCTS

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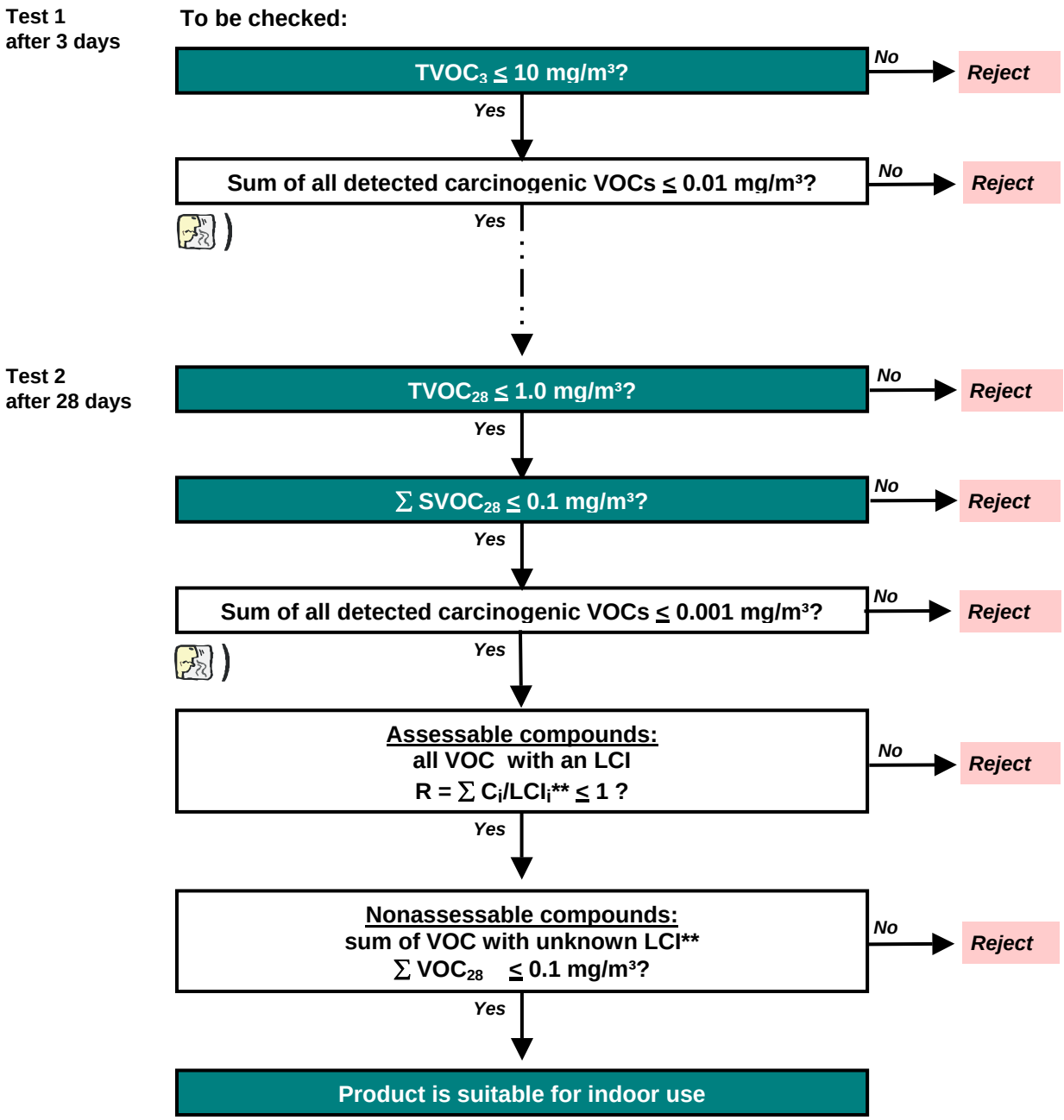
(Committee for Health-related Evaluation of Building Products)



) **Generally accepted methods for sensory tests expected to be performed at this stage have yet to be agreed upon.**

* VOC, TVOC: Retention range $C_6 - C_{16}$, SVOC: Retention range $C_{16} - C_{22}$

** LCI: Lowest Concentration of Interest (German: NIK)

European Emission Test Standard prEN ISO 16000-9 to -11

UBA II 1.2 - AgBB
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6. Annex

Establishing LCI values

1. Basic Considerations

Volatile organic compounds (VOC and SVOC) belong to the most common indoor air pollutants. Building products are important indoor sources of VOC and SVOC. In order to be fit for use under the building regulations, building products must satisfy certain health-related provisions with regard to their VOC/SVOC emissions in addition to technical criteria. This means that their emissions (technically speaking: their product- and material-specific emission factors in µg/m² h) must be reduced to such a level that – assuming long-term occupancy of a room - concentrations in indoor air resulting from such emissions do not pose any threat to the health of sensitive persons even under unfavourable but still realistic assumptions (concerning product loading factor, air exchange rate and indoor climate conditions). A procedure is presented here to derive substance-specific values for health-related evaluation of the emission from building products, the so-called LCI values (Lowest Concentration of Interest; cf. footnote 4).

The concentration of many substances present in workplace air in the form of gas, vapour or suspended particulate matter is limited by workplace regulations (Maximale Arbeitsplatz-Konzentration", MAK–value; Maximum Workplace Concentration) to ensure that the health of employees is not impaired and that they are not unduly discomforted even by repeated and extended (up to a normal 8-hour day within an average 40-hour working week) exposure, as judged by the current state of knowledge. MAK values are updated continuously and published in an official list [TRGS 900, 2004]. Compliance is checked by measurements. A working group of AgBB – complemented by manufacturers' specialists - deals with the establishment of LCI values and in doing so uses existing MAK values as a starting point, as proposed by an international expert group [ECA, 1997]. The following basic differences are valid for general indoor spaces (such as homes, kindergartens and schools) as opposed toi workplaces:

- continuous exposure in contrast to a changing and regularly interrupted workplace exposure,
- existence of risk groups which are not present in the workplace at all (children, senior citizens) or are particularly protected by occupational medicine (pregnant women, allergic persons),
- lack of exposure measurements and medical checks and, in principle, undefined overall indoor exposure.

On both objective and regulatory grounds, the LCI values for individual compounds are to be considered as calculation values used for the evaluation or certification of building products and not as indoor air limit values. Due to their origin the LCI values represent an adequate expression of the criteria required in building regulations to safeguard against health risk caused by VOC/SVOC mixtures bearing in mind that the emissions from building products into indoor air result in multi-compound mixtures.

2. Procedure

Since the German regulation TRGS 900 (TRGS: Technical Regulations for Hazardous Substances), does not contain values for all VOC/SVOC possibly emitted from building products, a simplified method has been developed that permits to make use, in addition to the

TRGS, of similar (workplace-related) values employed by other European countries. A stepwise procedure is used that takes into account the maximum currently available toxicological evidence for each individual substance, thus enabling the assessment of as many substances as possible. Those substances that still cannot be evaluated, are subjected to a strict limitation of their total amount, within the AgBB scheme. The selection criteria are:

I. First, each individual substance is checked, whether it has been evaluated via TRGS 900 and/or an OEL (Occupational Exposure Limit) value by the European Commission. If this is the case, the lowest value is used to establish the LCI value.
II. If condition I is not met, relevant evaluation lists of substances in the workplace air of other EU countries are examined and the lowest value used to establish a LCI value.
III. If no European legal classification is available, but a MAK value of the German Research Association (Deutsche Forschungsgemeinschaft, DFG) and/or a TLV® value of the American Conference of Governmental Industrial Hygienists (ACGIH) or a Workplace Environmental Exposure Limit (WEEL) of AIHA (American Industrial Hygiene Association) exists, then the LCI value is derived from the lowest value available.
IV. In case a substance cannot be evaluated using conditions I., II. or III., it is checked if an individual substance assessment can be performed, preferably by referring to a substance class with similar chemical structure and comparable toxicological assessment. The lowest LCI value for a substance within this assigned substance class is then used.
V. If a substance fails to meet any of the requirements in items I. to IV., it is then assigned in the scheme to the category of the substances ‘with unknown LCI value’, the so-called nonassessable compounds (see flow chart). Non-identified substances fall also into this category.

3. Calculation

Since different exposure times and different sensitivity should be considered in the general population in comparison to workplace conditions, the relevant (MAK) value is generally divided by 100 (except for irritants) applying safety factors as defined elsewhere[ad-hoc-AG, 1996]). For potential carcinogenic substances of EU category 3 (EU Directive 67/548/EEC) the value is usually divided by 1000. Reprotoxic and mutagenic substances are subjected to an individual substance assessment. Substances with carcinogenic properties according to EU categories 1 and 2 (EU Directive 67/548/EEC) are considered separately (see main text for AgBB evaluation scheme).

4. Publication

The LCI values are exclusively determined by the AgBB committee together with experts of industrial and manufacturer associations and published in the list of LCI values. The current list of LCI values and brief notes on their origin are printed in Table 1. AgBB and manufacturers perform individual assessments for currently interesting substances regularly or if there is a need. The LCI list is a closed list which is revised and re-published approximately, depending on the needs, currently every year.
For substances not yet included in the list of LCI values, manufacturers have the possibility to apply for LCI values to be established by submitting available data to the AgBB.
For transparency in establishing LCI values, the published list of LCI values contains, as a minimum, the following data:

(1) Name(s) of substance

(2) CAS No.
(3) LCI value
(4) The value used for the derivation, with source and substance-related classifications
(5) Remarks that may provide additional information on the substance or the basis for the LCI setting procedure.

Literature:

ad-hoc-AG (ad-hoc-Arbeitsgruppe aus Mitgliedern der Innenraumlufthygiene-Kommission des Umweltbundesamts und Vertretern der Arbeitsgemeinschaft der Obersten Landesgesundheitsbehörden [AOLG]) (1996): Richtwerte für die Innenraumluft: Basisschema (Guidelines for Indoor Air Quality: Basic Scheme). Bundesgesundheitsblatt 39 (11), 422-426.

ECA (1997) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Evaluation of VOC Emissions from Building Products – Solid Flooring Materials. Report No. 18, EUR 17334 EN, European Commission, Joint Research Centre, Environment Institute.

TRGS 900: (TRGS: (German) Technical Rules on Hazardous Substances) Technische Regeln für Gefahrstoffe: Grenzwerte in der Luft am Arbeitsplatz, „Luftgrenzwerte“ (Limit values relating to air in the workplace), Bundesarbeitsblatt (BArbBl) Ausgabe Oktober 2000, zuletzt geändert. Heft 5/2004 (Federal Labour Gazette). Bekanntmachung des BMWA vom 31. Dezember 2004 – IIIb3-35122 zur Anwendung der TRGS vor dem Hintergrund der neuen Gefahrstoffverordnung (Promulgation of the Federal Ministry of Economics and Labour of 31 December 2004 – IIIb3-35122 for applying the TRGS in context of the new Ordinance on Hazardous Substances).

Table 1

List of LCI values

Status: September 2005

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
1. Aromatic hydrocarbons						
1-1*	Toluene	108-88-3	**1 900**		190 000	EU: Repr. Cat. 3
1-2	Ethyl benzene	100-41-4	**4 400**		440 000	
1-3	Xylene, mix of o-, m- and p-xylene isomers	1330-20-7	**2 200**	221 000	440 000	
1-4	p-Xylene	106-42-3	**2 200**	221 000	440 000	
1-5	m-Xylene	108-38-3	**2 200**	221 000	440 000	
1-6	o-Xylene	95-47-6	**2 200**	221 000	440 000	
1-7	Cumene	98-82-8	**1 000**	100 000	250 000	
1-8	n-Propyl benzene	103-65-1	**1 000**			cf. lowest LCI of saturated alkylbenzenes, e.g. No1-10
1-9*	1-Propenyl benzene (ß-methyl styrene)	637-50-3	**2 400**			EU-OEL for α-methyl styrene
1-10	1.3.5-Trimethylbenzene	108-67-8	**1 000**	100 000	100 000	
1-11	1.2.4-Trimethylbenzene	95-63-6	**1 000**	100 000	100 000	
1-12	1.2.3-Trimethylbenzene	526-73-8	**1 000**	100 000	100 000	
1-13	2-Ethyltoluene	611-14-3	**1 000**			cf. lowest LCI of saturated alkylbenzenes
1-14*	1-Isopropyl-2-methylbenzene (o-cymene)	527-84-4	**1 100**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-15*	1-Isopropyl-3-	535-77-3	**1 100**			cf. lowest LCI of saturated

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
	methylbenzene (m-cymene)					alkylbenzenes; conversion via molecular weight
1-16*	1-Isopropyl-4-methylbenzene (p-cymene)	99-87-6	**1 100**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-17*	1.2.4.5-Tetramethylbenzene	95-93-2	**1 100**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-18*	n-Butylbenzene	104-51-8	**1 100**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-19*	1.3-Diisopropylbenzene	99-62-7	**1 400**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-20*	1.4-Diisopropylbenzene	100-18-5	**1 400**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-21*	Phenyloctane and isomers	2189-60-8	**1,600**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-22*	1-Phenyldecane and isomers	104-72-3	**1 800**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-23*	1-Phenylundecane and isomers	6742-54-7	**1 900**			cf. lowest LCI of saturated alkylbenzenes; conversion via molecular weight
1-24*	4-Phenyl cyclohexene (4-PCH)	4994-16-5	**1 300**			cf. styrene; conversion via molecular weight
1-25	Styrene	100-42-5	**860**		86 000	
1-26*	Phenyl acetylene	536-74-3	**840**			cf. styrene; conversion via molecular weight
1-27	2-Phenylpropene (α-Methylstyrene)	98-83-9	**2 400**	246 000	490 000	
1-28	Vinyl toluene (all isomers: o-,m-,p-methyl styrenes)	25013-15-4	**4 900**		490 000	
1-29	Other alkylbenzenes, unless individual isomers have to be evaluated otherwise		**1 000**			cf. lowest LCI of saturated alkylbenzenes
1-30	Naphthalene	91-20-3	**50**	50 000	50 000	EU: Carc.Cat. 3 (29.ATP)
1-31	Indene	95-13-6	**450**		45 000	
2. Saturated aliphatic hydrocarbons (n-, iso- and cyclo-)						
2-1	3-Methylpentane	96-14-0	7 200		720 000	VVOC
2-2	n-Hexane	110-54-3	**72**	72 000	180 000	EU: Repr.Cat.3
2-3	Cyclohexane	110-82-7	**7 000**		700 000	
2-4	Methyl cyclohexane	108-87-2	**20 000**		2 000 000	
2-5*	1.4-Dimethyl cyclohexane	589-90-2	**21 000**			cf. methylcyclohexane; conversion via molecular weight
2-6*	4-Isopropyl-1-methylcyclohexane	cis : 6069-98-3 trans: 1678-82-6	**29 000**			cf. methylcyclohexane; conversion via molecular weight
2-7*	C7-C16 saturated n-aliphatic hydrocarbons		**21 000**			cf. TRGS 900: 2.100.000 µg/m³ for n-heptane
3. Terpenes						
3-1*	3-Carene	498-15-7	**1 400**			cf. α-pinene
3-2*	α-Pinene	80-56-8	**1 400**			TLV DK-EPA: 140.000 µg/m³

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
3-3*	ß-Pinene	127-91-3	**1 400**			TLV DK-EPA: 140.000 µg/m³
3-4*	Limonene	138-86-3	**1 400**			TLV DK-EPA: 140.000 µg/m³
3-5*	Other terpene hydrocarbons		**1 400**			TLV DK: 140.000 µg/m³ for turpentine (This group includes all mono-terpenes, sesquiterpenes and their oxygen containing derivatives)
4. Aliphatic alcohols						
4-1	Ethanol	64-17-5	9 600		960 000	VVOC
4-2	1-Propanol	71-23-8	2 400			VVOC; OEL-Norway: 45 000 µg/m³
4-3	2-Propanol	67-63-0	5 000		500 000	VVOC
4-4	Tert-butanol, 2-methylpropanol-2	75-65-0	**620**		62 000	
4-5	2-Methyl-1-propanol	78-83-1	**3 100**		310 000	
4-6	1-Butanol	71-36-3	**3 100**		310 000	
4-7	1-Pentanol	71-41-0	**3 600**		360 000	
4-8*	1-Hexanol	111-27-3	**4 200**			cf. 1-butanol; conversion via molecular weight
4-9	Cyclohexanol	108-93-0	**2 100**		210 000	
4-10	2-Ethyl-1-hexanol	104-76-7	**2 700**		270 000	
4-11	1-Octanol	111-87-5	**2 700**			TLV (ACGIH): 270.000 µg/m³
4-12	4-Hydroxy-4-methyl-pentane-2-on (diacetone alcohol)	123-42-2	**2 400**		240 000	
4-13*	C_4 - C_{10} saturated n-aliphatic alcohols		**3 100**			cf. 1-butanol
5. Aromatic alcohols						
5-1	Phenol	108-95-2	**78**	7 800	19 000	EU: Mut. Cat. 3 (29 ATP)
5-2	Butylated hydroxytoluene	128-37-0	**100**		10 E	
5-3	Benzyl alcohol	100-51-6	**440**			WEEL (AIHA): 44 000 µg/m³
6. Glycols, Glycol ethers, Glycol esters						
6-1*	Propylene glycol (1,2-Dihydroxypropane)	57-55-6	**320**			cf. ethanediol; conversion via molecular weight
6-2	Ethanediol	107-21-1	**260**	52 000	26 000	
6-3	Ethylene glycol-monobutylether	111-76-2	**980**	98 000	98 000	
6-4	Diethylene glycol	111-46-6	**440**		44 000	
6-5	Diethylene glycol-monobutylether	112-34-5	**1 000**		100 000	
6-6	2-Phenoxyethanol	122-99-6	**1 100**		110 000	
6-7*	Ethylene carbonate	96-49-1	**370**			cf. ethanediol; conversion via molecular weight
6-8	1-Methoxy propanol-2	107-98-2	**1 900**	188 000	370 000	
6-9	2.2.4-Trimethyl-1.3-pentane diol, monoisobutyrate (Texanol®)	25265-77-4				suspended due to lack of data
6-10	Butyl glycolate	7397-62-8	**550**			cf. glycolic acid, metabolite of ethane-1,2-diol; conversion via molecular weight
6-11*	Diethylene glycol monomethyl ether acetate	124-17-4	**800**			glycolether group; cf. 2-(2-butoxyethoxy)

	Substance	**CAS No.**	**LCI [µg/m³]**	**EU OEL [µg/m³]****	**TRGS 900 [µg/m³]****	**Remarks****
						ethanol; conversion via molecular weight
6-12	Dipropylene glycol monomethyl ether	34590-94-8	**3 100**		310 000	
6-13	2-Methoxyethanol	109-86-4	**15**			EU: Repr.Cat. 2; DFG-MAK: 15 000µg/m³
6-14	2-Ethoxyethanol	110-80-5	**19**			EU: Repr.Cat. 2; DFG-MAK: 19 000 µg/m³
6-15	2-Propoxyethanol	2807-30-9	**860**			DFG-MAK: 86 000 µg/m³
6-16	2-Methylethoxyethanol	109-59-1	**220**			DFG-MAK: 22 000 µg/m³
6-17*	2-Hexoxyethanol	112-25-4	**1 200**			cf. ethylene glycol-monobutyl ether; conversion via molecular weight
6-18	1,2-Dimethoxyethane	110-71-4	**19**			EU. Repr.Cat. 2; cf. 2-methoxy-ethanol (metabolite methoxyacetic acid); conversion via molecular weight
6-19	1,2-Diethoxyethane	73506-93-1	**25**			cf. 2-ethoxyethanol (metabolite ethoxyacetic acid); conversion via molecular weight
6-20	2-Methoxyethyl acetate	110-49-6	**25**			EU: Repr.Cat. 2; DFG-MAK: 25 000 µg/m³
6-21	2-Ethoxyethyl acetate	111-15-9	**27**			EU: Repr.Cat. 2; DFG-MAK: 27 000 µg/m³
6-22	2-Butoxyethyl acetate	112-07-2	**1300**			DFG-MAK: 130 000 µg/m³
6-23*	2-(2-Hexoxyethoxy)-ethanol	112-59-4	**1 100**			cf. 2-hexoxyethanol and diethylene glycol-monobutyl ether; conversion via molecular weight
6-24	1-Methoxy-2-(2-methoxy-ethoxy) ethane	111-96-6	**28**			EU: Repr.Cat. 2; DFG-MAK: 28 000 µg/m³
6-25	2-Methoxy-1-propanol	1589-47-5	**19**			EU: Repr.Cat. 2; DFG-MAK: 19 000 µg/m³
6-26	2-Methoxy-1-propyl acetate	70657-70-4	**28**			EU: Repr.Cat. 2; DFG-MAK: 28 000 µg/m³
6-27*	Propylene glycol diacetate	623-84-7	**670**			cf. propylene glycol; conversion via molecular weight
6-28*	Dipropylene glycol	110-98-5 25265-71-8	**550**		-	cf. diethylene glycol; conversion via molecular weight
6-29*	Dipropylene glycol-monomethyl ether acetate	88917-22-0	**3 900**			cf. dipropylene glycol-monomethyl ether; conversion via molecular weight
6-30*	Dipropylene glycol-mono-n-propylether	29911-27-1	**1 100**			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-31*	Dipropylene glycol-mono-n-butylether	29911-28-2 35884-42-5	**1 200**			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-32*	Dipropylene glycol-mono-t-butylether	132739-31-2 (Mixture)	**1 200**			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-33	1,4-Butandiol	110-63-4	**2000**		200000	
6-34	Tripropylene glycol-monomethyl ether	20324-33-8 25498-49-1	**1000**			Individ. substance evaluation
6-35	Triethylene glycol-dimethyl ether	112-49-2	**35**			EU: Repr. Cat. 2; cf. 2-methoxy-ethanol (metabolite methoxyacetic

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
						acid); conversion via molecular weight
6-36	1.2.-Propylene glycol-dimethyl ether	7778-85-0	**25**			cf. 1,2-dimethoxy-ethane and 2-methoxy-1-propanol; conversion via molecular weight
7. Aldehydes						
7-1	Butanal	123-72-8	640		64 000	VVOC
7-2	Pentanal	110-62-3	**1 700**		175 000	
7-3*	Hexanal	66-25-1	**890**			cf. butanal; conversion via molecular weight
7-4*	Heptanal	111-71-7	**1 000**			cf. butanal; conversion via molecular weight
7-5*	2-Ethyl-hexanal	123-05-7	**1 100**			cf. butanal; conversion via molecular weight
7-6*	Octanal	124-13-0	**1 100**			cf. butanal; conversion via molecular weight
7-7*	Nonanal	124-19-6	**1 300**			cf. butanal; conversion via molecular weight
7-8*	Decanal	112-31-2	**1 400**			cf. butanal; conversion via molecular weight
7-9	2-Butenal (crotonaldehyde, cis-trans-mix)	4170-30-3 123-73-9 15798-64-8	**1**		1 000	EU: Mut.Cat.3
7-10*	2-Pentenal	1576-87-0 764-39-6 31424-04-1	**12**			cf. 2-butenal, but no EU classification as mutagen; conversion via molecular weight
7-11*	2-Hexenal	16635-54-4 6728-26-3 505-57-7 1335-39-3	**14**			cf. 2-pentenal; conversion via molecular weight
7-12*	2-Heptenal	2463-63-0 18829-55-5 29381-66-6	**16**			cf. 2-pentenal; conversion via molecular weight
7-13*	2-Octenal	2363-89-5 25447-69-2 20664-46-4 2548-87-0	**18**			cf. 2-pentenal; conversion via molecular weight
7-14*	2-Nonenal	2463-53-8 30551-15-6 18829-56-6 60784-31-8	**20**			cf. 2-pentenal; conversion via molecular weight
7-15*	2-Decenal	3913-71-1 2497-25-8 3913-81-3	**22**			cf. 2-pentenal; conversion via molecular weight
7-16*	2-Undecenal	2463-77-6 53448-07-0	**24**			cf. 2-pentenal; conversion via molecular weight
7-17	Furfural	98-01-1	**20**		20 000	EU: Carc.Cat.3
7-18	Glutardialdehyde	111-30-8	**4**		420	
7-19	Benzaldehyde	100-52-7	**90**			WEEL (AIHA): 8 800 µg/m^3
8. Ketones						
8-1	Ethylmethylketone	78-93-3	**3 000**	300 000	600 000	
8-2	3-Methylbutanone-2	563-80-4	**7 000**		705 000	
8-3	Methylisobutylketone	108-10-1	**830**		83 000	
8-4	Cyclopentanone	120-92-3	**6 900**		690 000	
8-5	Cyclohexanone	108-94-1	**400**	40 800	80 000	
8-6*	2-Methylcyclopentanone	1120-72-5	**8 000**			cf. cyclopentanone; conversion via molecular weight

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
8-7	2-Methylcyclohexanone	583-60-8	**2 300**		230 000	
8-8	Acetophenone	98-86-2	**490**			TLV (ACGIH): 49 000 µg/m³
8-9*	1-Hydroxyacetone (2 Propanone, 1-hydroxy-)	116-09-6	**300**			oxidation product of propylene glycol, cf. ethanediol; conversion via molecular weight
8-10*	see 9-10					
9. Acids						
9-1	Acetic acid	64-19-7	**500**		25 000	Individual substance evaluation (plausibility)
9-2	Propionic acid	79-09-4	**310**	31 000	31 000	
9-3*	Isobutyric acid	79-31-2	**370**			cf. propionic acid; conversion via molecular weight
9-4*	Butyric acid	107-92-6	**370**			cf. propionic acid; conversion via molecular weight
9-5*	Pivalic acid	75-98-9	**420**			cf. propionic acid; conversion via molecular weight
9-6*	n-Valeric acid	109-52-4	**420**			cf. propionic acid; conversion via molecular weight
9-7*	n-Caproic acid	142-62-1	**490**			cf. propionic acid; conversion via molecular weight
9-8*	n-Heptanoic acid	111-14-8	**550**			cf. propionic acid; conversion via molecular weight
9-9*	n-Octanoic acid	124-07-2	**600**			cf. propionic acid; conversion via molecular weight
9-10*	2-Ethylhexane acid	149-57-5	**50**			EU: Repr.Cat. 3; TLV (ACGIH): 5 000 µg/m³
10. Ester and Lactones						
10-1	Methyl acetate	79-20-9	6 100		610 000	VVOC
10-2	Ethyl acetate	141-78-6	15 000	734 000	1 500 000	VVOC
10-3	Vinyl acetate	108-05-4	36		36 000	VVOC; EU: Carc.Cat.3
10-4	Isopropyl acetate	108-21-4	**4 200**		420 000	
10-5	Propyl acetate	109-60-4	**4 200**		420 000	
10-6	2-Methoxy-1-methylethyl acetate	108-65-6	**2 700**	275 000	270 000	
10-7*	n-Butyl formiate	592-84-7	**2 000**			TRGS 900: 120 000 µg/m³ for methylformiate; conversion via molecular weight
10-8	Methyl methacrylate	80-62-6	**2 100**		210 000	
10-9	Other methacrylates		**2 100**			cf. methylmethacrylate
10-10	Isobutyl acetate	110-19-0	**4 800**		480 000	
10-11	1-Butyl acetate	123-86-4	**4 800**		480 000	
10-12*	2-Ethylhexyl acetate	103-09-3	**3 500**			cf. 2-ethyl-1-hexanol; ; conversion via molecular weight
10-13	Methyl acrylate	96-33-3	**180**		18 000	
10-14	Ethyl acrylate	140-88-5	**210**		21 000	
10-15	n-Butyl acrylate	141-32-2	**110**	11 000	11 000	
10-16	2-Ethylhexyl acrylate	103-11-7	**820**		82 000	
10-17	Other acrylates (acrylic acid ester)		**110**			cf. n-butyl acrylate
10-18	Dimethyl adipate	627-93-0	**7 300**			cf. methanol (metabolite), conversion via molecular

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]**	TRGS 900 [µg/m³]**	Remarks**
						weight
10-19	Dibutyl fumarate	105-75-9	**4 800**			cf. butanol (metabolite), conversion via molecular weight
10-20	Dimethyl succinate	106-65-0	**6 200**			cf. methanol (metabolite), conversion via molecular weight
10-21	Dimethyl glutarate	1119-40-0	**6 800**			cf. methanol (metabolite), conversion via molecular weight
10-22	Hexamethylene diacrylate	13048-33-4	**10**			WEEL (AIHA): 1 000 µg/m³
10-23*	Maleic acid dibutylester	105-76-0	**190**			Individ. substance evaluation
10-24	Butyrolactone	96-48-0	**2 700**			Individ. substance evaluation
11. Chlorinated hydrocarbons						
11-1	Tetrachloroethene	127-18-4	**340**		345 000	EU: Carc.Cat.3
12. Others						
12-1	1.4-Dioxan	123-91-1	**73**		73 000	EU: Carc.Cat.3
12-2	Caprolactam	105-60-2	**50**	10 000	5 000	
12-3	N-methyl-2-pyrrolidon	872-50-4	**800**		80 000	
12-4	Octamethylcyclotetra-siloxane	556-67-2	**1 200**			EU: Repr.Cat.3 Individ. substance evaluation
12-5	Hexamethylenetetramine	100-97-00	**30**			OELs Norway/Sweden: TWA 3 000 µg/m³,
12-6	-2-Butanonoxime	96-29-7	**20**			EU: Carc.Cat.3 Individ. substance evaluation
12-7	Tributyl phosphate	126-73-8	**25**		2 500	
12-8	Triethyl phosphate	78-40-0	**25**			cf. tributyl phosphate
12-9*	5-Chloro-2-methyl-2H-isothiazol-3-one (CIT)	26172-554	**1**			TRGS 900: 50 µg/m³ for a 3:1 mixture with 2-methyl-4-isothiazolin-3-one

*: new or altered in 2005
** for better comparison, concentration values are given in micrograms per cubic meter
VVOC in the list are marked by grey shading. They are not currently considered in the AgBB evaluation scheme.

Additional remarks:

I) **Links to lists of carcinogenic substances** of categories 1 and 2 according to Directive 67/548/EEC:

- **BGIA**, Berufsgenossenschaftliches Institut für Arbeitsschutz (BG-Institute for Occupational Safety) http://www.hvbg.de/d/bia/fac/kmr
- **BAuA**, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (Federal Institute for Occupational Safety and Health) http://www.baua.de/

II. Data treatment

A software tool has been developed for the collection and storage of emissions data and the calculation of the test result. This software is available to all testing laboratories. The DIBt requires its use for transmission of emissions data in the context of applications for product authorisation.

III. Analysis of aldehydes

Determination of the emission of saturated and unsaturated aldehydes of Group 7 of the LCI list by gas chromatography poses problems in the concentration range of

interest. For example, in the case of butanal and glutaric dialdehyde, the ratio of the limit of quantification and the LCI value is very small if the GC/MS method with Tenax thermodesorption (DIN ISO 16000-6) is applied. In addition, sampling on Tenax is only suitable to a limited extent for quantitative determination of butanal, butenal and pentanal. Since butenal in particular, but also unsaturated aldehydes and glutaric dialdehyde have a very low LCI value, an analytical method with a particularly low limit of quantification (LOQ) has to be chosen for these substances. The DNPH method with HPLC analysis (DIN ISO 16000-3) is well suited for this purpose due to a LOQ in the range of < 1µg/m^3 for the aldehydes contained in the LCI list.

Therefore, for quantitative determination of aldehydes, in particular butenal, pentenal, pentanal and glutaric aldehyde, the DNHP method should be used for sampling.

Use of the DNHP method enables the quantitative determination not only of aldehydes belonging to the class of VOC, but also of some VVOC such as butanal, acetone, formaldehyde and acetaldehyde. Although the determination of these compounds is not required in the AgBB evaluation scheme, it will generate additional information for product evaluation.