



This version applies from the date it is published. The version it replaces will continue to be valid for one more year. This also applies to updated lists of LCI values. However, old and new versions must each be applied as a complete document; they may not be mingled. Important information: This interim convention does not apply for the new LCI-value for Naphthalene.

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 (Article 3, Standard Building Code (Musterbauordnung) [MBO, 2002]. 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 (Article 16 MBO).

In the European Union, the importance of building products is accounted for by the European Construction Products Directive (CPD) which came into force in 1989 [Council of the European Communities, 1989]. An important objective of this Directive, in addition to eliminating barriers to trade, is the integration of health concerns. In 1992, the European Construction Products Directive was transposed into German national legislation by the

Building Products Act (Bauproduktengesetz)¹ and by amendments to the building codes of the Federal States (Länder).

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 European Union has recognised the insufficient implementation of ER3 and issued a mandate to CEN for implementation of ER3. The mandate² provides for the development of horizontal assessment methods for dangerous substances in and their emission from, construction products. For this purpose, CEN has established the technical committee CEN TC 351. The horizontal assessment methods to be developed by this committee will form the basis for the technical specifications for building products in standardisation activities and national technical approvals.

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.

In this context, the Committee has presented a procedural scheme for health-related evaluation of VOC emissions from building products used for application indoors [AgBB, 2000]. Within this scheme, volatile organic compounds include compounds within the

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.

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)

retention range of C₆ to C₁₆, 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 C₁₆ up to C₂₂.

The scheme was extensively discussed with representatives of manufacturers and professionals after having been published first in 2000 [AgBB 2000/2001] and at the end of its introductory phase from 2002 to 2004 [Proceedings of the technical dialogues in 2001 and 2004]. As a result of these processes, the Deutsches Institut für Bautechnik (DIBt) has incorporated the evaluation scheme into its approval guidelines for the health-related evaluation of building products [DIBt, 2004, 2008], and a revised scheme was presented [AgBB, 2005]. The present version takes new experience gained into account.

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, the scheme endorses initiatives of manufacturers to produce products with lower emissions. Manufacturers can therefore declare better performance parameters for their products (with regard to VOC emissions) [ECA, 2005].

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; WHO, 2000; Doty, 2004; INDEX, 2005; Ad-hoc, 2007; Arif and Shah, 2007; Mendell, 2007]). Volatile organic compounds may have effects ranging from odour perception and irritation of the mucous membranes of the eyes, nose and throat to acute systemic effects and long-term effects. These include effects on the nervous system, 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, in the form of occupational exposure limit values (OELs). However, where hazardous substances are handled at workplaces under typical conditions, much higher substance concentrations than under indoor living conditions are generally encountered. Also, much shorter exposure times occur at workplaces in comparison to indoor situations. When extrapolating to indoor living spaces, this must be accounted for by suitable factors, as must the inclusion of particularly sensitive population groups and the absence of exposure monitoring through measurements and occupational health surveillance [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).

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

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; Ad-hoc, 2007]. However, it has to be emphasized that a TVOC guideline value – due to the varying composition of the VOC mixture occurring in indoor air – cannot be based on toxicological conditions. However, there is sufficient evidence that with increasing TVOC concentration the likelihood of complaints and adverse health effects also increases [ECA, 1997b; Ad-hoc, 2007].

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.

A research project completed in 2006 [UBA Texte, 2007] produced a method for sensory testing of building products on the basis of emission measurement in test chambers. This method, which is based on the assessment of odour intensity by a panel of trained persons with the aid of a standard of comparison, has proved its suitability and good reproducibility in a round robin test. Since the method is now generally accepted, it is currently undergoing international standardisation [ISO TC 146 / SC 6]. Once the method has been internationally harmonised and standardised and assessment limits have been defined for it, it may become a module of the AgBB evaluation scheme.

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 [DIN ISO 16000-9 to -11]). Parts 9 and 10 describe the procedure when using a test chamber and a test cell, respectively. Part 11 covers sampling and storing of samples, and preparation of test specimens.

4.2 Exposure scenarios

Health evaluation of a building product is based on the predicted indoor air exposure concentrations for a room occupant resulting from VOC (and SVOC) emissions by that product. The evaluation cannot be carried out using solely the area-specific emissions rates of the building product as determined in test chamber measurements according to the AgBB scheme (see 4.1). Rather, it is necessary to additionally consider the indoor air situation likely to be encountered under practical conditions. The exposure scenario creates the link between product emission and concentration in indoor air. Thus, the evaluation must take into account the emissions from the product, the size of the room, the air exchange rate and the emitting surface area of the building product to be installed in the room.

Under current building law in Germany, the building shell of newly constructed or extensively remodelled buildings is increasingly fitted with airtight insulation for energy reasons. This reduces the air exchange with outdoor air unless compensated by increased active airing. However, from the viewpoint of air quality, regular air exchange with ambient air is necessary to reliably transport humidity (produced e.g. by cooking or washing) as well as odours and emissions out of indoor spaces and create the prerequisites for a healthy indoor climate.

In order to take both energy and air quality aspects sufficiently into account, the AgBB scheme assumes an air exchange rate of 0.5/h for exposure analysis. Rooms equipped with modern high-insulation windows according to the energy-saving regulations normally have air exchange rates of 0.1-0.2/h. This, however, is too little from the perspective of indoor air quality. Therefore, the air exchange rate of 0.5/h assumed in the AgBB scheme presupposes increased active airing to prevent harmful consequences in terms of hygiene. Increased intensive airing by the occupants after introduction of new materials (e.g. during renovation) especially must be presupposed. Furthermore, in low energy buildings, the aim must be to consistently use low-emission building products and other materials and products for indoor use.

The AgBB requirements also must take into account as broad a range of building types and uses as possible. Since much of the building stock in Germany still consists of energy-inefficient old buildings, the requirements must consider the different air exchange rates in

these buildings. From both the perspective of indoor air quality and the broad range of buildings, an air exchange rate of 0.5/h remains the minimum air exchange rate target for all buildings, including old, new and future buildings. It is therefore deemed to be a reasonable and proper basis for the calculations in connection with evaluation of test chamber emission results.

$$C = \frac{E_a \cdot A}{n \cdot V} = \frac{E_a}{q} \quad (1)$$

Equation (1) describes the indoor air concentration C , resulting from a building product, as a function of the area-specific emissions rate E_a [$\mu\text{g}/(\text{m}^2 \text{ h})$] 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 [$\text{m}^3/(\text{h m}^2)$] called the area-specific air exchange rate.

The model room in the AgBB scheme has a base area of 3 m x 4 m and a height of 2.5 m.

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 [DIBt, 2007]). 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 $5 \mu\text{g}/\text{m}^3$ within the retention range $C_6 - C_{16}$

SVOC: all individual substances within the retention range $> C_{16} - C_{22}$

ΣSVOC : sum of the concentration of all individual substances with concentrations equal to or greater than $5 \mu\text{g}/\text{m}^3$ 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 $1 \mu\text{g}/\text{m}^3$ in order to cover the emission spectrum as fully as possible in a qualitative way.

All individual substances have to be quantified as required and need to be considered individually and in the summation if their concentration is equal to or greater than $5 \mu\text{g}/\text{m}^3$. Exceptions apply to carcinogenic substances belonging to EU categories 1 and 2 (see 4.3.1).

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

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

- TVOC₃

A product satisfies the criteria, if the TVOC value after 3 days (TVOC₃) is $\leq 10 \text{ mg}/\text{m}^3$.

- 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 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 using their individual calibration factors.

No carcinogen belonging to EU categories 1 or 2 [Directive 67/548/EEC] may exceed a concentration of $0.01 \text{ mg}/\text{m}^3$ after 3 days.

- 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

- TVOC₂₈

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 TVOC₃. When calculating the TVOC₂₈ 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 TVOC₂₈ value is $\leq 1.0 \text{ mg}/\text{m}^3$. 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 determined⁵.

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 TVOC₂₈ concentration of 1.0 mg/m³. Higher concentrations result in rejection.

- Carcinogenic substances

The emission of carcinogenic substances of EU categories 1 and 2 [Directive 67/548/EEC] is tested again, with an emphasis on the long-term behaviour from the user's point of view. No carcinogen of categories 1 or 2 [Directive 67/548/EEC] may exceed the value of 0.001 mg/m³ after 28 days. .

- 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.

- 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 whose concentrations in the test chamber exceed 5 µg/m³ are evaluated based on LCI. They are quantified using their individual calibration factors.

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

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

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 $> 5 \mu\text{g}/\text{m}^3$ 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.

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

⁵ 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} alkane, boiling point 369 °C). According to current knowledge, the analysis of 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.

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 $\geq 0.005 \text{ mg/m}^3$ does not exceed 0.1 mg/m^3 . 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.

5 References

Ad-hoc working group of members of the Federal Environment Agency's Indoor Air Hygiene Commission (IRK) and of the Working Group of the Supreme Health Authorities of the Federal States (AOLG) (2007): Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten (Evaluation of indoor air contamination by means of reference and guideline values). Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz 50:990-1005.

Arif, A.A., Shah, S.M. (2007): Association between personal exposure to volatile organic compounds and asthma among US adult population. Int Arch Occup Environ Health 80(8):711-9.

AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten) (October 2000): Vorgehensweise bei der gesundheitlichen Bewertung der Emissionen von flüchtigen organischen Verbindungen (VOC) aus Bauprodukten (Health-related evaluation procedure for VOC emissions from building products). DIBt-Mitteilungen 1/2001, 3-12.

AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten) (September 2005): Vorgehensweise bei der gesundheitlichen Bewertung der Emissionen von flüchtigen organischen Verbindungen (VOC) aus Bauprodukten (Health-related evaluation procedure for VOC emissions from building products). (<http://www.umweltbundesamt.de/bauprodukte/agbb.htm>).

Council of the European Communities (1989): Council Directive 89/106/EEC on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products. Official Journal L 40/12-26.

DIBt (Deutsches Institut für Bautechnik) (2004): Zulassungsgrundsätze zur gesundheitlichen Bewertung von Bauprodukten in Innenräumen (Approval guidelines for the health-related evaluation of indoor construction products). June 2004 version. DIBt-Mitteilungen 4/2004, 119-141.

DIBt (Deutsches Institut für Bautechnik) (2007): Zulassungsgrundsätze zur gesundheitlichen Bewertung von Bauprodukten in Innenräumen (Approval guidelines for the health-related evaluation of indoor construction products). October 2008 version. (http://www.dibt.de/de/data/Aktuelles_Ref_II_4_6.pdf).

DIN ISO 16000-3 (August 2002): Indoor air – Part 3: Determination of formaldehyde and other carbonyl compounds; Active sampling method.

DIN ISO 16000-6 (December 2004): Indoor air - 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.

DIN EN ISO 16000-9 (February 2006): Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method.

DIN EN ISO 16000-10 (February 2006): Indoor air – Part 10: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test cell method.

DIN EN ISO 16000-11 (February 2006): Indoor air – Part 11: Determination of the emission of volatile organic compounds from building products and furnishing - Sampling, storage of samples and preparation of test specimens.

Directive 67/548/EEC: Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, (Official Journal L 196, 16/08/1967, p. 1), as amended last by Regulation (EC) No 1272/2008 (Official Journal L 353, 31/12/2008, p. 1) and adapted last by Directive 2009/2/EC (31st Adaptation Directive; Official Journal L 11, 16/01/2009, p. 6).

(<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:011:0006:0082:EN:PDF>).

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:en:PDF>

Doty, R.L. et al. (2004): Assessment of upper respiratory tract and ocular irritative effects of volatile chemicals in humans. Crit. Rev.

EC (European Commission) (1994): Communication of the Commission with regard to the interpretative documents of Council Directive 89/106/EEC (construction products). Official Journal C 62 of 28/2/94).

ECA (1991a) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Guideline for the Characterisation of Volatile Organic Compounds Emitted from Indoor Materials and Products Using Small Test Chambers. Report No. 8, EUR 1593 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (1991b) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Effects of Indoor Air Pollution on Human Health. Report No. 10, EUR 14086 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (1993) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Determination of VOCs emitted from indoor materials and products - Interlaboratory comparison of small chamber measurements. Report No. 13, EUR 15054 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (1995) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Determination of VOCs emitted from indoor materials and products – Second interlaboratory comparison of small chamber measurements. Report No. 16, EUR 16284 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (1997a) (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.

ECA (1997b) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Total Volatile Organic Compounds (TVOC) in Indoor Air Quality Investigations. Report No. 19, EUR 17675 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (1999) (European Collaborative Action "Indoor Air Quality and its Impact on Man"): Sensory Evaluation of Indoor Air Quality. Report No. 20, EUR 18676 EN, European Commission, Joint Research Centre, Environment Institute.

ECA (2005) (European Collaborative Action "Urban Air, Indoor Environment and Human Exposure"): Harmonisation of indoor material emissions labelling systems in the EU – Inventory of existing schemes. Report No. 24 EUR 21891 EN, European Commission, Joint Research Centre, Institute for Health & Consumer Protection.

Fischer, J., Englert, N., Seifert, B. (1998): Luftverunreinigungen und geruchliche Wahrnehmungen unter besonderer Berücksichtigung von Innenräumen. (Air pollutants and sensory perception with special regard to the

indoor environment) WaBoLu-Hefte 1/1998. Umweltbundesamt, Institut für Wasser-, Boden- und Lufthygiene, Berlin. 110 S. ISSN 0175-4211

INDEX project (2005): Critical appraisal of the setting and implementation of indoor exposure limits in the EU. EUR 21590 EN. European Commission, Directorate-General, Joint Research Centre.

Maroni, M., Seifert, B. und Lindvall, T. (1995) Eds: Indoor Air Quality, a Comprehensive Reference Book; Air Quality Monographs – Vol 3; Elsevier Amsterdam

MBO (Musterbauordnung, 2002 version): Musterbauordnung der Bauministerkonferenz – Konferenz der für Städtebau, Bau- und Wohnungswesen zuständigen Minister und Senatoren der Länder (ARGEBAU). <http://www.bauministerkonferenz.de/>, last adapted in October 2008

Mendell, M.J. (2007): Indoor residential chemical emissions as risk factors for respiratory and allergic effects in children: a review. Indoor Air 17(4):259-77

Proceedings of technical dialogues in 2001 and 2004 and of an international conference in 2007:

1. Fachgespräch zur Vorgehensweise bei der gesundheitlichen Bewertung der Emissionen von flüchtigen organischen Verbindungen aus Bauprodukten (1st technical dialogue on the procedure for the health-related evaluation of emissions of volatile organic compounds from building products). Jointly held by AgBB, UBA, DIBt on 17 May 2001 at the DIBt. Umweltbundesamt 2001 (http://www.umweltbundesamt.de/bauprodukte/dokumente/1AgBB_Fachgesprach05_2001.pdf)

2. Fachgespräch zur Vorgehensweise bei der gesundheitlichen Bewertung der Emissionen von flüchtigen organischen Verbindungen (VOC) aus Bauprodukten (2nd technical dialogue on the procedure for the health-related evaluation of emissions of volatile organic compounds (VOCs) from building products). Jointly held by AgBB, UBA, DIBt on 25 November 2004 at the DIBt. Umweltbundesamt 2005, (<http://www.umweltbundesamt.org/fpdf-1/2898.pdf>)

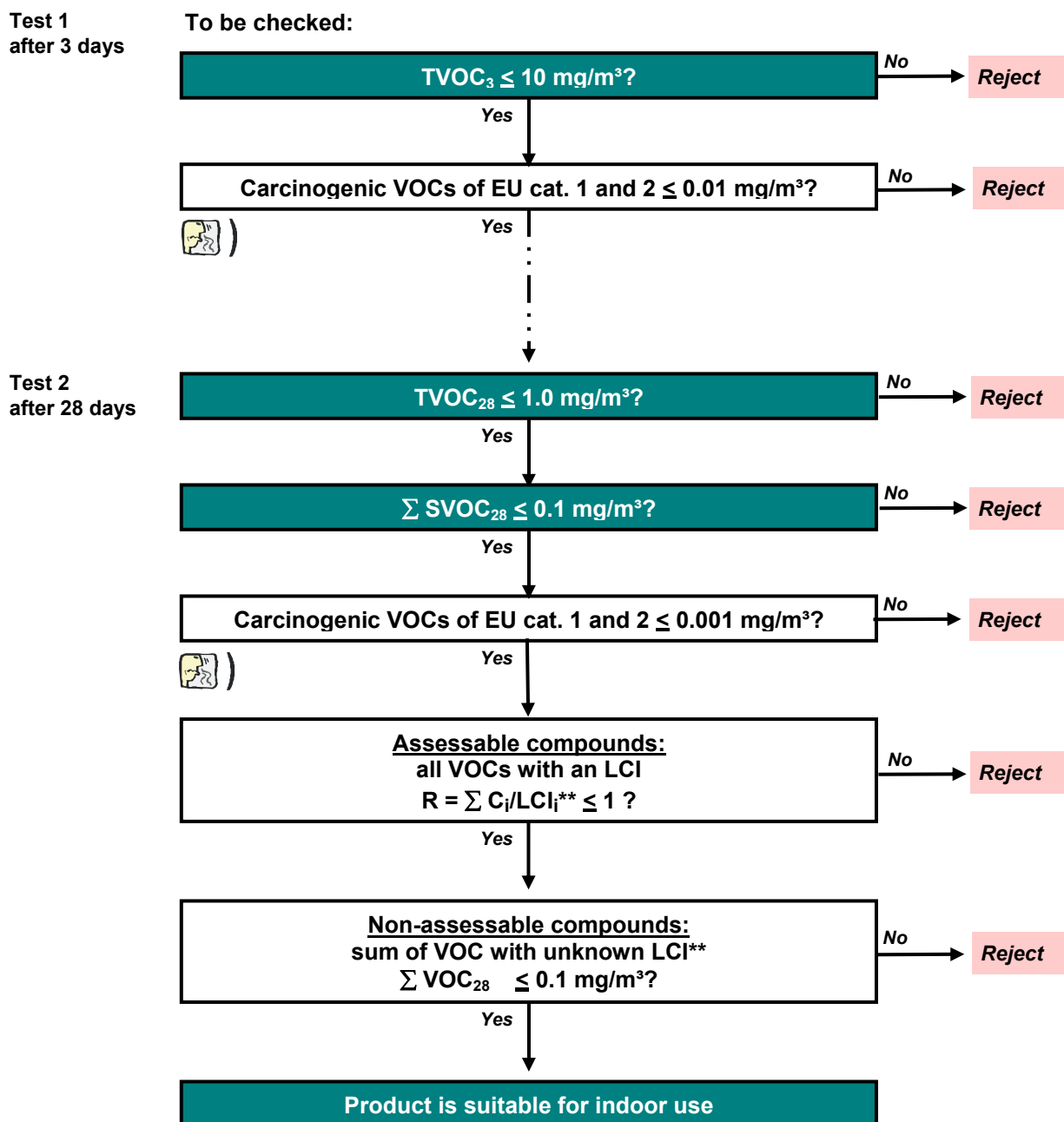
International Conference: Construction Products and Indoor Air Quality. Berlin, June 2007, Conference Report, Umweltbundesamt, 2008; http://www.umweltbundesamt.de/bauprodukte/dokumente/indoor_product_broschuere.pdf.

Seifert, B. (1999): Richtwerte für die Innenraumluft: TVOC. (Evaluation of Indoor Air Quality using the sum of volatile organic compounds (TVOC value). Bundesgesundheitsblatt 42 (3), 270-278.

UBA-Texte 16/07: Horn W., Jann, O., Kasche, J., Bitter, F., Müller, D., Müller, B. (2007): Umwelt- und Gesundheitsanforderungen an Bauprodukte – Ermittlung und Bewertung der VOC-Emissionen und geruchlichen Belastungen (Environmental and health requirements for building products – Determination and evaluation of VOC and odour emissions). Umweltbundesamt, Berlin. 383 pages. (<http://www.umweltdaten.de/publikationen/fpdf-1/3197.pdf>).

WHO (2000): Air quality guidelines. 2nd edition. Regional Office for Europe.

Fig. 1: FLOW CHART FOR THE EVALUATION OF VOC* AND SVOC* EMISSIONS FROM 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 C₆ – C₁₆, SVOC: Retention range C₁₆ – C₂₂

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

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

UBA II 1.3 –
AgBB 2010

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. German building law requires building products to 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 $\mu\text{g}/\text{m}^2 \text{ h}$) 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). However this requires regular, proper airing (see paragraph 4.2). 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).

Occupational exposure limit values (OELVs) have been defined for many substances present in workplace air in the form of gas, vapour or suspended particulate matter. These legally binding values are set at such a level that, according to current knowledge, even repeated and long-term exposure, for up to 8 hours a day within an average 40-hour working week, is generally not expected to adversely affect workers' health over their working lives. OELVs are updated continuously. They are published in *Technische Regeln für Gefahrstoffe: Arbeitsplatzgrenzwerte* [TRGS 900, 2004], and compliance with them is monitored. The German Research Foundation (DFG)'s Senate Commission for the investigation of health hazards of chemical compounds at the workplace derives and publishes maximum concentrations at the workplace (MAK-DFG values) for protection of health at work. These MAK-DFG values are usually adopted into TRGS 900. A working group of AgBB – complemented by manufacturers' specialists - deals with the establishment of LCI values and in doing so uses existing OELVs as a starting point, as proposed by an international expert group [ECA, 1997a]. The working group takes into account the following basic differences between conditions in general indoor spaces (such as homes, kindergartens and schools) and those at 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 lists from other countries for evaluation of substances in workplace air are examined and the lowest scientifically plausible value used to establish an LCI value.
- III. As a further option, 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) may be used.
- 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 non-assessable compounds (see flow chart). Non-identified substances fall also into this category.

3. Calculation

Since different exposure times and different sensitivity should be considered for the general population in comparison to workplace conditions, the relevant OEL value is generally divided by 100 applying safety factors as defined elsewhere[ad-hoc-AG, 1996]). For potential carcinogenic substances of EU category 3 (Directive 67/548/EEC) the value is usually divided by 1000. Reprotoxic and mutagenic substances are evaluated on a case-by-case basis with regard to the additional factor. 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 republished, depending on the needs.

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.

References:

Ad-hoc working group of members of the Federal Environment Agency's Indoor Air Hygiene Commission (IRK) and of the Working Group of the Supreme Health Authorities of the Federal States (AOLG) (1996): Richtwerte für die Innenraumluft: Basisschema (Guideline values for indoor air quality: Basic scheme). Bundesgesundheitsblatt 39 (11), 422-426.

ECA (1997a) (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: Technische Regeln für Gefahrstoffe: Grenzwerte in der Luft am Arbeitsplatz, „Arbeitsplatzgrenzwerte“ (Technical regulations on hazardous substances: Limit values relating to air in the workplace), January 2006 version, amended and supplemented last in February 2010 (GMBI. No 5-6, p. 111) (<http://www.baua.de/cae/servlet/contentblob/666762/publicationFile/55576/TRGS-900.pdf>).

Directive 67/548/EEC: Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, (Official Journal L 196, 16/08/1967, p. 1), as amended last by Regulation (EC) No 1272/2008 (Official Journal L 353, 31/12/2008, p. 1) and adapted last by Directive 2009/2/EC (31st Adaptation Directive; Official Journal L 11, 16/01/2009, p. 6). (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:011:0006:0082:EN:PDF>). (Annex I: http://www.baua.de/nn_12288/de/Themen-von-A-Z/Gefahrstoffe/Rechtstexte/pdf/RL-67-548_EWG-Anhang-I.pdf).

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (Official Journal L 353, 31/12/2008, p. 1), as amended last by Regulation (EC) No 790/2009 (Official Journal L 325, 05/09/2009, p. 1) (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:EN:PDF>)

Commission Regulation (EC) No 790/2009 of 10 August 2009 amending, for the purposes of its adaptation to technical and scientific progress, Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures (Official Journal L 325, 05/09/2009, p. 1) (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:235:0001:0439:EN:PDF>)

Directive 91/322/EEC: Commission Directive 91/322/EEC of 29 May 1991 establishing indicative limit values by implementing Council Directive 80/1107/EEC on the protection of workers from the risks related to exposure to chemical, physical and biological agents at work (OJ L 177, 05/07/1991, p. 22) as amended last by Commission Directive 2006/15/EC (OJ L 38, 09/02/2006, p. 36) (<http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1991/L/01991L0322-20060301-en.pdf>).

Directive 2000/39/EC: Commission Directive 2000/39/EC of 8 June 2000 establishing a first list of indicative occupational exposure limit values in implementation of Council Directive 98/24/EC on protection of the health and safety of workers from the risks related to chemical agents at work (OJ L 142, 16/08/2000, p. 47) as amended last by Commission Directive 2006/15/EC (OJ L 38, 09/02/2006, p. 36) (<http://eur-lex.europa.eu/LexUriServ/site/en/consleg/2000/L/02000L0039-20060301-en.pdf>).

Directive 2006/15/EC: Commission Directive 2006/15/EC of 7 February 2006 establishing a second list of indicative occupational exposure limit values in implementation of Council Directive 98/24/EC and amending Directives 91/322/EEC and 2000/39/EC (OJ L 38, 09/02/2006, p. 36) (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_038/l_03820060209en00360039.pdf).

Directive 2009/161/EU: Commission Directive 2009/161/EU of 17 December 2009 establishing a third list of indicative occupational exposure limit values in implementation of Council Directive 98/24/EC and amending Commission Directive 2000/39/EC (OJ L 338, 19/12/2009, p. 87) (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:338:0087:0089:EN:PDF>)

SCOEL Recommendations of the European Commission (SCOEL = Scientific Committee on Occupational Exposure Limits):
<http://ec.europa.eu/social/keyDocuments.jsp?pager.offset=0&langId=de&mode=advancedSubmit&policyArea=0&subCategory=0&year=0&country=0&type=0&advSearchKey=scoel>

Denmark AT (Arbejdstilsynet): Grænseværdier for stoffer og materialer AT – vejledning C.0.1, August 2007, Erstatte April 2005 (<http://www.arbejdstilsynet.dk/~media/3FA26655715740ED84EA28EC1191FB62.ashx>).

Finland STM (2009) (Sosiaali- ja terveystieteiden ministeriö): HTP Values 2009, Concentrations Known to be Harmful. Helsinki, 2009, (Publications of Social Affairs and Health, Finland; ISSN 1236-2115; 2009:12) (http://www.stm.fi/c/document_library/get_file?folderId=39503&name=DLFE-9912.pdf).

France INRS (2006) (Institut national de recherche et de sécurité): Valeurs limites d'exposition professionnelle aux agents chimiques en France INRS 2006 ([http://www.inrs.fr/INRS-PUB/inrs01.nsf/inrs01_catalog_view_view/5462CE3DF935FAFBC12571B20023D726/\\$FILE/ed984.pdf](http://www.inrs.fr/INRS-PUB/inrs01.nsf/inrs01_catalog_view_view/5462CE3DF935FAFBC12571B20023D726/$FILE/ed984.pdf)).

The Netherlands SER (2006) (Sociaal-Economische Raad): Wettelijke grenswaarden Staatscourant 28 december 2006 nr. 252/ pg. 23, last amended 22.04.2008 No 78 (http://www.ser.nl/nl/taken/adviserende/grenswaarden/nieuwsrubriek/invoering_grenswaarden.aspx).

Sweden AFS (Arbetsmiljöverkets författningssamling): Hygieniska gränsvärden och åtgärder mot luftföroreningar (Occupational Exposure Limit Values and Measures Against Air Contaminants) (AFS 2005:17) (http://www.av.se/dokument/afs/AFS2005_17.pdf), Hygieniska gränsvärden och åtgärder mot luftföroreningar är en ändring av föreskriften AFS 2005:17 med samma namn (AFS 2007:2) (http://www.av.se/dokument/afs/AFS2007_02.pdf).

UK HSE (Health and Safety Executive): List of approved workplace exposure limits Guidance Note EH40 2005 from EH 40/2005 CIS 05-401 (as consolidated with amendments October 2007) (<http://www.hse.gov.uk/coshh/table1.pdf>).

DFG (2009) (Deutsche Forschungsgemeinschaft): MAK- und BAT-Werte-Liste 2009, Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe, Mitteilung 45, Wiley-VCH.

ACGIH (2009) (American Conference of Governmental Industrial Hygienists): TLVs[®] and BEIs[®] Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.

AIHA (2009) (American Industrial Hygiene Association): Workplace environmental exposure level guides. (<http://www.aiha.org/1documents/Committees/WEEL-WEELsLevels2007.pdf>).

Table 1

List of LCI values 2010

Closing date: April 2010

	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	192 000	190 000	EU: Repr. Cat. 3
1-2	Ethyl benzene	100-41-4	4 400	442 000	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	Isopropylbenzene (Cumene)	98-82-8	1 000	100 000	100 000	
1-8	n-Propyl benzene	103-65-1	1 000			cf. lowest LCI of saturated alkylbenzenes, e.g. No 1-10
1-9	1-Propenyl benzene (β-methyl styrene)	637-50-3	2 400			EU-OEL for α-methyl styrene: 246 000 µg/m³
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-methylbenzene (m-cymene)	535-77-3	1 100			cf. lowest LCI of saturated 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	2 500	246 000	250 000	
1-28	Vinyl toluene (all isomers: o-, m-, p-methyl styrenes)	25013-15-4	4 900		490 000	

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
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	10	50 000		EU: Carc.Cat. 3 (1991) Individ. substance evaluation (SCOEL 2008)
1-31	Indene	95-13-6	450			OELs Denmark, France: 45 000 µg/m³
2. Aliphatic hydrocarbons (n-, iso- and cyclo-)						
2-1	3-Methylpentane	96-14-0				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	700 000	
2-4	Methyl cyclohexane	108-87-2	8 100		810 000	
2-5	--					2)
2-6	-					2)
2-7	--					2)
2-8	n-Heptane	142-82-5	21 000	2 085 000		
2-9	Other saturated aliphatic hydrocarbons, up to C8		15 000		1 500 000	
2-10	Other saturated hydrocarbons, C9 or higher		6 000		600 000	
3. Terpenes						
3-1	3-Carene	498-15-7	1 500			cf. 3-2 to 3-5
3-2	α-Pinene	80-56-8	1 500			OEL Sweden: 150 000 µg/m³
3-3	β-Pinene	127-91-3	1 500			OEL Sweden: 150 000 µg/m³
3-4	Limonene	138-86-3	1 500			OEL Sweden: 150 000 µg/m³
3-5	Other terpene hydrocarbons		1 500			OEL Sweden: 150 000 µg/m³ (This group includes all mono-terpenes, sesquiterpenes and their oxygen containing derivatives)
4. Aliphatic alcohols (n-, iso- and cyclo-)						
4-1	Ethanol	64-17-5				VVOC
4-2	1-Propanol	71-23-8				VVOC
4-3	2-Propanol	67-63-0				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	Pentanol (all isomers)	71-41-0 30899-19-5 94624-12-1 6032-29-7 548-02-1 137-32-6 123-51-3 598-75-4 75-85-4 75-84-3	730			MAK-DFG: 73 000 µg/m³
4-8	1-Hexanol	111-27-3	2 100		210 000	
4-9*	Cyclohexanol	108-93-0	2 100			TLV (ACGIH): 206 000 µg/m³
4-10	2-Ethyl-1-hexanol	104-76-7	1 100		110 000	
4-11	1-Octanol	111-87-5	1 100		106 000	
4-12	4-Hydroxy-4-methyl-pentane-2-one (diacetone alcohol)	123-42-2	960		96 000	
4-13*	Other saturated n- and iso-alcohols, C4-C10		1 100			cf. 1-octanol and 2-ethyl-1-hexanol; saturated cyclic alcohols are excluded

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
4-14*	Other saturated n- and iso-alcohols, C11-C13		1 100			cf. 1-octanol and 2-ethyl-1-hexanol; saturated cyclic alcohols are excluded
5. Aromatic alcohols						
5-1*	Phenol	108-95-2	10	8 000	7 800	EU: Mut. Cat. 3 Individ. substance evaluation
5-2	BHT (2,6-di-tert-butyl-4-methylphenol)	128-37-0	100			OELs Denmark, Finland, France, Great Britain: 10 000 µg/m³
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	2 500			Individ. substance evaluation
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	670	67 500		MAK-DFG: 67 000 µg/m³
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-2-propanol	107-98-2	3 700	375 000	370 000	
6-9	2,2,4-Trimethyl-1,3-pentane diol monoisobutyrate (Texanol®)	25265-77-4	600			Individ. substance evaluation
6-10	Butyl glycolate	7397-62-8	550			cf. glycolic acid, metabolite of ethanediol; conversion via molecular weight
6-11	Diethylene glycol monomethyl ether acetate	124-17-4	850			MAK-DFG: 85 000 µg/m³
6-12	Dipropylene glycol monomethyl ether	34590-94-8	3 100	308 000	310 000	
6-13*	2-Methoxyethanol	109-86-4	3[#]	3 110	16 000	EU: Repr. Cat. 2
6-14*	2-Ethoxyethanol	110-80-5	8	8 000	19 000	EU: Repr. Cat. 2
6-15	2-Propoxyethanol	2807-30-9	860			
6-16	2-Methylethoxyethanol	109-59-1	220		22 000	
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	4[#]			EU: Repr. Cat. 2; cf. 2-methoxy-ethanol (metabolite methoxyacetic acid); conversion via molecular weight
6-19*	1,2-Diethoxyethane	73506-93-1	10			cf. 2-ethoxyethanol (metabolite ethoxyacetic acid); conversion via molecular weight
6-20*	2-Methoxyethyl acetate	110-49-6	5	4 900	25 000	EU: Repr. Cat. 2
6-21*	2-Ethoxyethyl acetate	111-15-9	11	11 000	27 000	EU: Repr. Cat. 2
6-22	2-Butoxyethyl acetate	112-07-2	1300	133 000	130 000	
6-23	2-(2-Hexoxyethoxy)-ethanol	112-59-4	740			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-24	1-Methoxy-2-(2-methoxy-ethoxy) ethane	111-96-6	28		28 000	EU: Repr. Cat. 2
6-25	2-Methoxy-1-propanol	1589-47-5	19		19 000	EU: Repr. Cat. 2
6-26	2-Methoxy-1-propyl acetate	70657-70-4	28		28 000	EU: Repr. Cat. 2
6-27*	Propylene glycol diacetate	623-84-7	5 300			cf. propylene glycol; conversion via molecular weight

[#] An evaluation within the framework of the LCI-concept will take place only from a measured concentration of 5 µg/m³.

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
6-28*	Dipropylene glycol	110-98-5 25265-71-8	670		67 000 (CAS No. 25265-71-8)	
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	740			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-31	Dipropylene glycol mono-n-butylether	29911-28-2 35884-42-5	810			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-32	Dipropylene glycol mono-t-butylether	132739-31-2 (Mixture)	810			cf. diethylene glycol-monobutyl ether; conversion via molecular weight
6-33	1,4-Butanediol	110-63-4	2 000		200 000	
6-34	Tripropylene glycol monomethyl ether	20324-33-8 25498-49-1	1 000			Individ. substance evaluation
6-35*	Triethylene glycol dimethyl ether	112-49-2	7			EU: Repr. Cat. 2; cf. 2-methoxy-ethanol (metabolite methoxyacetic acid); conversion via molecular weight
6-36*	1,2-Propylene glycol dimethyl ether	7778-85-0	25			cf. 2-methoxy-1-propanol (metabolit methoxypropionic acid); conversion via molecular weight
6-37	TXIB	6846-50-0	450			Individ. substance evaluation
6-38	Ethyldiglycol	111-90-0	350		35 000	
6-39	Dipropylene glycol dimethyl ether	63019-84-1 89399-28-0 111109-77-4	1 300			
6-40*	Propylene carbonate	108-32-7	250			Individ. substance evaluation
6-41*	Hexylene glycol (2-Methyl-2,4-pentanediol)	107-41-5	490			MAK-DFG: 49 000 µg/m³
7. Aldehydes						
7-1	Butanal	123-72-8				VVOC TRGS 900: 64 000 µg/m³
7-2	Pentanal	110-62-3	1 700			OEL Denmark, France, TLV (ACGIH): 175 000 µg/m³
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 [#]			EU: Mut.Cat.3 ¹⁾
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	20			cf. 2-pentenal;

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
		30551-15-6 18829-56-6 60784-31-8				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			EU: Carc. Cat. 3 Individ. substance evaluation
7-18*	Glutardialdehyde	111-30-8	2 [#]		200	
7-19	Benzaldehyde	100-52-7	90			WEEL (AIHA): 8 800 µg/m³
7-20	Acetaldehyde	75-07-0				VVOC
7-21	Propanal	123-38-6				VVOC
8. Ketones						
8-1	Ethylmethylketone	78-93-3	6 000	600 000	600 000	
8-2	3-Methylbutanone-2	563-80-4	7 000			OELs Denmark, France: 705 000 µg/m³
8-3	Methylisobutylketone	108-10-1	830	83 000	83 000	
8-4	Cyclopentanone	120-92-3	900			OEL Denmark: 90 000 µg/m³
8-5	Cyclohexanone	108-94-1	410	40 800	80 000	
8-6	2-Methylcyclopentanone	1120-72-5	1 000			cf. cyclopentanone; conversion via molecular weight
8-7	2-Methylcyclohexanone	583-60-8	2 300			OELs Denmark, France, Finland: 230 000 µg/m³
8-8	Acetophenone	98-86-2	490			TLV (ACGIH): 49 000 µg/m³
8-9*	1-Hydroxyacetone (1-Hydroxy-2-propanone)	116-09-6	2 400			oxidation product of propylene glycol; conversion via molecular weight
8-10	Acetone	67-64-1				VVOC
9. Acids						
9-1	Acetic acid	64-19-7	500	25 000	25 000	Individ. substance evaluation
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-Ethylhexanoic acid	149-57-5	50			EU: Repr. Cat. 3; TLV (ACGIH): 5 000 µg/m³
10. Esters and Lactones						
10-1	Methyl acetate	79-20-9				VVOC
10-2	Ethyl acetate	141-78-6				VVOC
10-3	Vinyl acetate	108-05-4				VVOC; EU: Carc. Cat. 3
10-4	Isopropyl acetate	108-21-4	4 200			OEL Finland, MAK-DFG: 420 000 µg/m³
10-5	Propyl acetate	109-60-4	4 200			OEL Finland, MAK-DFG: 420 000 µg/m³
10-6	2-Methoxy-1-methylethyl acetate	108-65-6	2 700	275 000	270 000	
10-7	n-Butyl formate	592-84-7	2 000			TRGS 900: 120 000 µg/m³ for methylformate; conversion via molecular weight

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
10-8*	Methyl methacrylate	80-62-6	2 100	205 000	210 000	
10-9	Other methacrylates		2 100			cf. methylmethacrylate
10-10	Isobutyl acetate	110-19-0	4 800			MAK-DFG: 480 000 µg/m³
10-11	1-Butyl acetate	123-86-4	4 800			MAK-DFG: 480 000 µg/m³
10-12	2-Ethylhexyl acetate	103-09-3	1 400			cf. 2-ethyl-1-hexanol; conversion via molecular weight
10-13*	Methyl acrylate	96-33-3	180	18 000	18 000	
10-14*	Ethyl acrylate	140-88-5	210	21 000	21 000	
10-15	n-Butyl acrylate	141-32-2	110	11 000	11 000	
10-16*	2-Ethylhexyl acrylate	103-11-7	380		38 000	
10-17	Other acrylates (acrylic acid ester)		110			cf. n-butyl acrylate
10-18*	Dimethyl adipate	627-93-0	50			Dicarboxylic acid (C4-C6)- dimethylester, mixture MAK-DFG: 5 000 µg/m³ Individ. substance evaluation
10-19*	Dibutyl fumarate	105-75-9	50			Individ. substance evaluation
10-20*	Dimethyl succinate	106-65-0	50			Dicarboxylic acid (C4-C6)- dimethylester, mixture MAK-DFG: 5 000 µg/m³ Individ. substance evaluation
10-21*	Dimethyl glutarate	1119-40-0	50			Dicarboxylic acid (C4-C6)- dimethylester, mixture MAK-DFG: 5 000 µg/m³ Individ. substance evaluation
10-22	Hexamethylene diacrylate	13048-33-4	10			WEEL (AIHA): 1 000 µg/m³
10-23*	Maleic acid dibutylester	105-76-0	50			Individ. substance evaluation
10-24	Butyrolactone	96-48-0	2 700			Individ. substance evaluation
10-25*	Diisobutyl glutarate	71195-64-7	100			Individ. substance evaluation
10-26*	Diisobutyl succinate	925-06-4	100			Individ. substance evaluation
11. Chlorinated hydrocarbons						
11-1	Tetrachloroethene	127-18-4	70			EU: Carc. Cat. 3 OELs Denmark, Finland, Sweden : 70 000 µg/m³
12. Others						
12-1	1,4-Dioxane	123-91-1	73	73 000	73 000	EU: Carc. Cat. 3
12-2	Caprolactam	105-60-2	240	10 000	5 000	Individ. substance evaluation
12-3*	N-methyl-2-pyrrolidone	872-50-4	400	40 000	82 000	EU: Repr. Cat. 2 Individ. substance evaluation
12-4	Octamethylcyclotetrasiloxane (D4)	556-67-2	1 200			EU: Repr. Cat. 3 Individ. substance evaluation
12-5	Hexamethylenetetramine	100-97-00	30			OELs Norway, Sweden: 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				SVOC, EU: Carc. Cat. 3
12-8*	Triethyl phosphate	78-40-0	17			cf. tributyl phosphate - OELs Denmark, France: 2 500 µg/m³; TLV (ACGIH): 2 200 µg/m³; conversion via molecular weight
12-9	5-Chloro-2-methyl-2H- isothiazol-3-one (CIT)	26172-554	1[#]			Individ. substance evaluation
12-10	2-Methyl-4-isothiazoline-3-on (MIT)	2682-20-4	100			Individ. substance evaluation
12-11*	Triethylamine	121-44-8	42	8 400	4 200	
12-12*	Decamethylcyclopentasiloxane (D5)	541-02-6	1 500			cf. Octamethylcyclotetra- siloxane; conversion via molecular weight
12-13*	Dodecamethylcyclohexa- siloxane (D6)	540-97-6	1 200			cf. Octamethylcyclotetra- siloxane;

	Substance	CAS No.	LCI [µg/m³]	EU OEL [µg/m³]	TRGS 900 [µg/m³]	Remarks
						Individ. substance evaluation

*: new or altered in 2010

#: An evaluation within the framework of the LCI-concept will take place only from a measured concentration of 5 µg/m³.

VVOC very volatile organic compounds (in the list are marked by grey shading). They are not currently considered in the AgBB evaluation scheme.

SVOC semivolatile organic compounds

1) The occupational exposure limit value for this substance, on which LCI derivation was based, has been annulled. The current LCI value will continue to apply until suitable data are available or a new OELV has been defined.

2) In order to maintain compatibility with the ADAM template, assigned numbers in the LCI list cannot be reassigned when a substance or a group of substances has been deleted or moved to another place.

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 (ADAM, AgBB-DIBt-Auswertemaske) has been developed for the collection and storage of emissions data and the calculation of the test result. This software can be obtained from the DIBt against payment of a nominal fee (contact DIBt, Ms. Gerloff, Kolonnenstr. 30L, 10829 Berlin, phone +49(0)30 78730-353, fax +49(0)30 78730-11353).

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/m³ 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.

IV Analysis of saturated aliphatic hydrocarbons (LCI 2-9 and LCI 2-10)

Subdividing this group of compounds is necessary because of their different LCIs. It is based on the appearance of an "alkane hump" in the gas chromatogram at the retention time of n-nonane, i.e. an LCI of 15 000 applies to aliphatic hydrocarbons with a retention time shorter than that of n-nonane and an LCI of 6 000 to aliphatic hydrocarbons with a retention time equal to or exceeding that of n-nonane.

The allocation of individual peaks of saturated aliphatic hydrocarbons which cannot be identified exactly shall also be based on the retention time of n-nonane.