Ausschuss zur gesundheitlichen Bewertung von Bauprodukten

Committee for Health-related Evaluation of Building Products

AgBB - July 2004
LCI's in Part 3: July 2004

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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 that exists in a room (in particular temperature and relative humidity) and by potential indoor air pollutants. Such pollutants may have a variety of sources. Building products are of particular importance here since their selection is often not within the user's 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 demand 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 was 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 concerns into account. The European Construction Products Directive has been adapted to German national law by the Building Products Act in 1992 *(Bauproduktengesetz)*[1] and by the 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 adapt the Council Directive 89/106/EEC of 21 December 1988 on the approximation of acts, regulations and administrative provisions of the Member States with regard to building products (*Bauproduktengesetz – BauPG*). Federal Law Gazette (Bundesgesetzblatt) I, No 39 of 14 August 1992, 1495-1501; amendment 1998: publication of the revision of the Building Products Act of 28 April 1988. Federal Law Gazette 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 generally held objective has been formally documented in the Interpretative Document N° 3 prepared by the European Commission, which explicitly mentions the avoidance and control of indoor pollutants, e.g. of volatile organic compounds (VOC) (EC, 1994). Also, the "Guide for Construction Products Assessment under Health Aspects" produced by Coordination Committee 03 of the Building and Civil Engineering Standards Committee (Normenausschuss Bauwesen*)* serves this specific purpose. Equally, binding and differentiated assessment procedures are still not available to permit a translation of 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 is still not clear how this protection can be realised in detail. Though 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, in many cases there is no officially accepted procedure yet for the health-related assessment of building 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 assessment of VOC emissions from building products. Within ECA, experts from the EU countries 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 is given as an example for the evaluation procedure of emissions from floor coverings (ECA, 1997a).

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

After having been published (AgBB 2000), the scheme was extensively discussed with representatives of manufacturers and professionals, and certain parts of it were modified for the introductory period. 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. Equally, manufacturer initiatives to produce low-emission products are supported. Manufacturers can therefore declare better performance parameters for their products (in regard to VOC emissions).
After an introductory period of two years the Committee will assess the experiences with the scheme and report in an appropriate way.

2 Health-related evaluation of VOC emissions from building products

The effects of indoor air pollution have been dealt with by a large number of publications (cf. e.g. ECA, 1991b; Maroni et al., 1995). Volatile organic compounds may have effects ranging from unpleasant odour and irritation in the mucous membranes of the eyes, nose and throat to effects on the nervous system and long-term effects. Substances causing allergy or aggravating allergic reactions and, most specifically, those with carcinogenic, mutagenic or reprotoxic potential belong in this category.

The toxicological evaluation of substances from building products can be based on available information which, in the most favourable cases, includes knowledge on dose-effect-relationships. Such relationships permit to establish concentration levels below which no adverse effects are to be feared.

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

The aforementioned evaluation criteria are based on the analysis 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 should be stated that a TVOC guideline value – due to the varying composition of the VOC mixture occurring in indoor air –cannot be based on real toxicology. However, experience shows that with increasing TVOC concentration the likelihood of complaints and adverse health effects also increases (ECA, 1997b).

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

3 Sensory aspects

Since VOC emission is often combined with odour sensation, sensory testing is an important element of the evaluation of building products. However, it has not yet been possible to integrate this aspect of testing into the current evaluation of building products. Unlike for the case of chemical analysis, there are still differing opinions as to the optimum measurement of perceived odour. The current state of the art on odour measurement in indoor air has been compiled in comprehensive reports (Fischer et al.1998, ECA 1999).

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) European standard ENV 13419, Parts 1-3 for the determination of emissions from building products was published (today E DIN EN 13419, January 2003). 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

A number of boundary conditions must be assumed if an evaluation scheme is to be derived and reasonably applied in order to relate the results of test chamber measurements to realistic exposure situations. 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 [m³]. Parameters n, A and V can be combined into the new parameter q [m³/(h m²)] called the area-specific air flow 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 flooring materials for example, the substance concentration measured in the test chamber corresponds precisely 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, DIBt 2004)

In accordance with ISO 16000 /6 the following definitions apply for the emission to be determined in the test chamber :

VOC: all individual substances with concentrations equal or greater than 0.002 mg/m³ within the retention range C_6 - C_{16}

TVOC: sum of the concentration of all individual substances within the retention range C_6 - C_{16}

SVOC: all individual substances with concentrations equal or greater than 0.002 mg/m³ within the retention range > C_{16} - C_{22}

∑SVOC: sum of the concentration of all individual substances with concentrations equal or greater than 0.002 mg/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.

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

4.3.1 Measurement and testing after 3 days

If it has been properly planned, the analysis of the chamber air can be simultaneously used to determine the VOC and TVOC values using the method published by Seifert (1999) and ISO 16000/6.

- $TVOC_3$

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 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 Annex).

The sum of all carcinogens (EU Categories 1 and 2) detected after 3 days shall not exceed 10 µg/m³ (0.01 mg/m³).

- First sensory testing

For measuring 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, reference to the necessity of a sensory test is made in the flow chart by means of a blank cell.

4.3.2 Measurement and testing after 28 days

- $TVOC_{28}$

In order to assess the long-term behaviour of the VOC emission from a building product, the TVOC value is determined again after 28 days. This measurement is performed in the same way as the measurement of the TVOC value after 3 days. When calculating the $TVOC_{28}$ value, in contrast to the instructions given in 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 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*[2] concentration in the chamber air shall also be determined.

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 mg/m³. Higher concentrations result in rejection.

- Carcinogenic substances

The emission of carcinogenic substances (EU Categories 1 and 2) is tested again, this time however 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 1 µg/m³ (or 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 by means of a blank cell. The reason for a second test is that chemical reactions may occur within the product which may lead to odour or other sensory perception.

- Evaluation of individual substances

In addition to evaluating the emission of a product via the TVOC value, the evaluation of individual VOCs is also necessary. For this purpose all compounds whose concentration in the chamber air equals or exceeds 2 µg/m³ are first identified and quantified.

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) is contained in the Annex. The details of how these LCI values have been derived are documented in the introduction to the list.
Substances with a concentration exceeding 5 µg/m³ are evaluated based on LCI. Analytically, the level of 5 µg/m³ can be easily reached. [3]

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[2] 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.
There is insufficient experience available on other sampling and test methods that may be suitable for routine analysis in combination with chamber and cell measurements. However, it can be expected that further development of analytical techniques will enable the testing of emissions of semivolatile organic compounds with an even lower volatility.

3 To calculate TVOC and TSVOC and to evaluate carcinogens, the AgBB flow chart sets a uniform detection limit of 2 µg/m³ for individual substances in order to cover the emission spectrum as completely as possible both qualitatively and quantitatively and to reject carcinogenic substances as reliably as possible. Individual substances are covered within the LCI concept starting from a concentration of 5 µg/m³. Low concentrations, in combination with very small LCI values of around 10 µg/m³, may result in unreliably high and 'false' R values and unjustified product rejection due to analytical measurement uncertainties.
The 5 µg/m³ threshold, on the other hand, is considered satisfactory to reliably reject questionable products in case of increased emissions of critical compounds.

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*. Where R_i falls below 1, it is assumed that there will be no effects. If several compounds with a concentration > 5 $\mu g/m^3$ 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

To avoid the risk of a positive evaluation of a product which emits larger quantities of nonassessable VOCs, a limit is set for those VOCs 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 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 indoor use in buildings.

5 References

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

Valid for **INTRODUCTORY TEST PERIOD 2002-2004**

Ausschuss zur gesundheitlichen Bewertung von Bauprodukten

(Committee for Health-related Evaluation of Building Products)

Test 1
after 3 days

To be checked:

$TVOC_3 \leq 10$ mg/m³? — *No* → ***Reject***

Yes

Sum of all detected carcinogenic VOC≤ 0.01 mg/m³? — *No* → ***Reject***

Yes

Test 2
after 28 days

$TVOC_{28} \leq 1$ mg/m³? — *No* → ***Reject***

Yes

$\sum SVOC_{28} \leq 0.1$ mg/m³? — *No* → ***Reject***

Yes

Sum of all detected carcinogenic VOC ≤ 0.001 mg/m³? — *No* → ***Reject***

Yes

Assessable compounds:
all VOC with concentration ≥ 0.005 mg/m³
$R = \sum C_i/LCI_i^{**} \leq 1$? — *No* → ***Reject***

Yes

Nonassessable compounds:
sum of VOC with unknown LCI:**

$\sum VOC_{28}^{\text{without LCI}} \leq 0.1$ mg/m³? — *No* → ***Reject***

Yes

Product is suitable for indoor use

Generally accepted methods for sensory tests expected to be performed at this stage have yet to be validated.

* 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 E DIN EN 13419 1-3

UBA II 1.2 - AgBB
July 2004

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 - emissions into the indoor air concentrations 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). 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).

Many substances that exist in the form of gas, vapour or suspended particulate matter are limited by workplace regulations (Maximale ArbeitsplatzKonzentration", MAK–value; Maximum Workplace Concentrations) 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,), and checked that they are being adhered to by measurements. A working group of AgBB – complimented by manufacturers' specialists - deals with the establishment of LCI values and in doing so they employ existing MAK values as a starting point, as proposed by an international group of experts (ECA, 1997). The following basic differences are taken into account between the conditions in general indoor spaces (such as homes, kindergartens and schools) and workplaces:

- continuous exposure opposed 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 the amount of multi-compound mixtures emitted from building products into indoor air.

2. Procedure

Since the German regulation TRGS 900 (TRGS: Technical Regulations for Hazardous Substances), does not contain values for all VOC/SVOCs 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 evidence on toxicological grounds 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.
IV. In case a substance cannot be evaluated using conditions I., II. or III., an examination takes place if an individual substance assessment can be performed 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) (ad-hoc AG, 1996). For potential carcinogenic substances (EU category 3) 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 are considered separately (see AgBB evaluation scheme). The current list of LCI values and brief notes on their origin are printed in Table 1.

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. AgBB and manufacturers perform individual assessments for currently interesting substances regularly or on demand. The LCI list is a closed list which is re-appraised and re-published approximately every other year, 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.

Literature:

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Table 1

List of LCI values

Status: July 2004

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
1. Aromatic hydrocarbons						
1-1	Toluene	108-88-3	**1.900**		190.000	
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 (Dir 96/94)	250.000	
1-8	n-Propyl benzene	103-65-1	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-9	1-Propenyl benzene (ß-methyl styrene)	637-50-3	**4.900**		490.000 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	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-15	1-Isopropyl-3-methylbenzene (m-cymene)	535-77-3	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-16	1-Isopropyl-4-methylbenzene (p-cymene)	99-87-6	**1.000**			cf. lowest LCI of saturated alkylbenzenes

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
1-17	1.2.4.5-Tetramethyl benzene	95-93-2	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-18	n-Butyl benzene	104-51-8	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-19	1.3-Diisopropylbenzene	99-62-7	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-20	1.4-Diisopropylbenzene	100-18-5	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-21	Phenyl octane and isomers	2189-60-8	**1 000**			cf. lowest LCI of saturated alkylbenzenes
1-22	1-Phenyldecane and isomers	104-72-3	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-23	1-Phenyl undecane and isomers	6742-54-7	**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-24	4-Phenyl cyclohexene (4-PCH)	4994-16-5	**860**			cf. styrene
1-25	Styrene	100-42-5	**860**		86.000	
1-26	Phenyl acetylene	536-74-3	**860**			cf. styrene
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, as long as indiv. isomers have not to be evaluated differently		**1.000**			cf. lowest LCI of saturated alkylbenzenes
1-30	Naphthalene	91-20-3	**50**	50.000	50.000	carc. cat. 3 (EU 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	
2-2*	n-Hexane	110-54-3	**72**	Repr.Cat.3 72.000	180.000	
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	**20.000**			cf. methylcyclo hexane
2-6	4-Isopropyl-1-methylcyclohexane	cis : 6069-98-3 trans: 1678-82-6	**20.000**			cf. methylcyclo hexane
2-7	C7-C16 hydrocarbons		**21.000**		2.100.000 for n-heptane	
3. Terpenes						
3-1	3-Carene	498-15-7	**2.000**			cf. α-pinene
3-2	α-Pinene	80-56-8	**2.000**			LOAEL 200 mg/m^3
3-3	ß-Pinene	127-91-3	**2.000**			cf. α-pinene
3-4	Limonene	138-86-3	**2.000**			cf. α-pinene
3-5	Other terpene hydrocarbons		**2.000**			cf. α-pinene
4. Aliphatic alcohols						
4-1*	Ethanol	64-17-5	**9.600**		960.000	

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
4-2	1-Propanol	71-23-8	**2.400**			OEL-Norway: 245 mg/m³ (1999)
4-3	2-Propanol	67-63-0	**5.000**		500.000	
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	**3.100**			cf. 1-butanol
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**			ACGIH: 270mg/m³ (1999)
4-12	4-Hydroxy-4-methyl-pentane-2-on (diacetone alcohol)	123-42-2	**2.400**		240.000	
4-13	C_4 - C_{10} alcohols		**3.100**			cf. 1-butanol
5. Aromatic alcohols						
5-1*	Phenol	108-95-2	**78**	7.800	19.000	TRGS 905: Mut.Cat. 3
5-2	Butylated hydroxytoluene	128-37-0	**100**		10 E	
5-3*	Benzyl alcohol	100-51-6	**440**			WEEL (AIHA) 44mg/m³
6. Glycols, Glycolethers						
6-1	Propylene glycol (1,2-Dihydroxypropane)	57-55-6	**260**			cf. ethanediol
6-2	Ethandiol	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	**260**			cf. ethanediol
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/methabolite of ethane-1,2-diol (conversion via molecular weight)
6-11	Diethylene glycol monomethyl ether acetate	124-17-4	**1.000**			glycolether group; cf. 2-(2-butoxyethoxy) ethanol
6-12	Dipropylene glycol monomethyl ether	34590-94-8	**3.100**		310.000	
6-13*	2-Methoxyethanol	109-86-4	**15**	Repr.Cat. 2		DFG-MAK 150000µg/m³
6-14*	2-Ethoxyethanol	110-80-5	**19**	Repr.Cat. 2		DFG-MAK 19000 µg/m³
6-15*	2-Propoxyethanol	2807-30-9	**860**			DFG-MAK 86000 µg/m³
6-16*	2-Methylethoxyethanol	109-59-1	**220**			DFG-MAK 22000 µg/m³

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
6-17*	2-Hexoxyethanol	112-25-4	**1000**			cf. Ethylene glycol-monobutyl ether
6-18*	1,2-Dimethoxyethan	110-71-4	**19**	Repr.Cat. 2		cf. 2-Methoxy-ethanol (Metabolite Methoxyacetic acid) conversion via molecular weight
6-19*	1,2-Diethoxyethan	73506-93-1	**25**			cf. 2-Ethoxyethanol (Metabolite Ethoxyacetic acid) conversion via molecular weight
6-20*	2-Methoxyethyl acetate	110-49-6	**25**	Repr.Cat. 2		DFG-MAK 25000 µg/m³
6-21*	2-Ethoxyethyl acetate	111-15-9	**27**	Repr.Cat. 2		DFG-MAK 27000 µg/m³
6-22*	2-Butoxyethyl acetate	112-07-2	**1300**			DFG-MAK 130000 µg/m³
6-23*	2-(2-Hexoxyethoxy)-ethanol	112-59-4	**1000**			cf. 2-Hexoxyethanol and Diethylene glycol-monobutyl ether
6-24*	1-Methoxy-2-(2-methoxy-ethoxy)-ethan	111-96-6	**28**	Repr.Cat. 2		DFG-MAK 28000 µg/m³
6-25*	2-Methoxy-1-propanol	1589-47-5	**19**	Repr.Cat. 2		DFG-MAK 19000 µg/m³
6-26*	2-Methoxy-1-propyl acetate	70657-70-4	**28**	Repr.Cat. 2		DFG-MAK 28000 µg/m³
6-27*	Propylene glycol diacetate	623-84-7	**300**			cf. Propylene glycol
6-28*	Dipropylene glycol	110-98-5 25265-71-8	**440**		-	cf. Diethylene glycol
6-29*	Dipropylene glycol-monomethyl ether acetate	88917-22-0	**3100**			cf. Dipropylene glycol-monomethyl ether
6-30*	Dipropylene glycol-mono-n-propylether	29911-27-1	**1000**			cf. Diethylene glycol-monobutyl ether
6-31*	Dipropylene glycol-mono-n-butylether	29911-28-2 35884-42-5	**1000**			cf. Diethylene glycol-monobutyl ether
6-32*	Dipropylene glycol-mono-t-butylether	132739-31-2 (Mixture)	**1000**			cf. Diethylene glycol-monobutyl ether
6-33*	1,4-Butandiol	110-63-4	**2000**		200000	
6-34*	Tripropylene glycol-monomethyl ether	20324-33-8 25498-49-1	**1000**			Indiv. subst. consider.
6-35*	Triethylene glycol-dimethyl ether	112-49-2	**35**	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. 1,2-Dimethoxy-ethan and 2-Methoxy-1-propanol, conversion via molecular weight
7. Aldehydes						
7-1	Butanal	123-72-8	**640**		64.000	
7-2	Pentanal	110-62-3	**1.700**		175.000	
7-3	Hexanal	66-25-1	**640**			cf. butanal
7-4	Heptanal	111-71-7	**640**			cf. butanal
7-5	2-Ethyl-hexanal	123-05-7	**640**			cf. butanal
7-6	Octanal	124-13-0	**640**			cf. butanal
7-7	Nonanal	124-19-6	**640**			cf. butanal

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
7-8	Decanal	112-31-2	**640**			cf. butanal
7-9*	2-Butenal (crotonaldehyde, cis-trans-mix)	4170-30-3	**1**	Mut.Cat.3	1.000	
7-10	2-Pentenal (trans)	1576-87-0	**10**			cf. 2-butenal
7-11	Hexenal, trans-2-	6728-26-3	**10**			cf. 2-butenal
7-12	2-Heptenal cis: trans:	2463-63-0 18829-55-5	**10**			cf. 2-butenal
7-13	2-Octenal	2363-89-5	**10**			cf. 2-butenal
7-14	2-Nonenal (trans)	2463-53-8	**10**			cf. 2-butenal
7-15	2-Decenal	3913-71-1	**10**			cf. 2-butenal
7-16	2-Undecenal	2463-77-6	**10**			cf. 2-butenal
7-17	Furfural	98-01-1	**20**	Carc.Cat.3	20.000	
7-18	Glutaraldehyde	111-30-8	**4**		420	
7-19*	Benzaldehyde	100-52-7	**90**			WEEL (AIHA) 8,8 mg/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	**6.900**			cf. cyclopentanone
8-7	2-Methylcyclohexanone	583-60-8	**2.300**		230.000	
8-8	Acetophenone	98-86-2	**490**			ACGIH: 49 mg/m³
8-9	1-Hydroxyacetone (2 Propanone, 1-hydrocx-)	116-09-6	**260**			oxidation product of propylene glycol, cf. ethane-1,2-diol
8-10*	2-Ethylhexane acid	149-57-5	**50**	Repr.Cat. 3		Deduction from TLV 5mg/m^3
9. Acids						
9-1	Acetic acid	64-19-7	**500**		25.000	Indiv. subst. consider. (plausibility)
9-2	Propionic acid	79-09-4	**310**	31.000	31.000	
9-3	Isobutyric acid	79-31-2	**310**			cf. propionic acid
9-4	Butyric acid	107-92-6	**310**			cf. propionic acid
9-5	Pivalic acid	75-98-9	**310**			cf. propionic acid
9-6	n-Valeric acid	109-52-4	**310**			cf. propionic acid
9-7	n-Caproic acid	142-62-1	**310**			cf. propionic acid
9-8	n-Heptanoic acid	111-14-8	**310**			cf. propionic acid
9-9	n-Octanoic acid	124-07-2	**310**			cf. propionic acid
10. Ester and Lactones						
10-1	Methyl acetate	79-20-9	**6.100**		610.000	
10-2	Ethyl acetate	141-78-6	**15.000**	734.000	1.500.000	
10-3	Vinyl acetate	108-05-4	**36**	Carc.Cat.3	36.000	
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	**1.200**		120.000 for metylformiate	

	Substance	CAS No.	LCI [µg/m³]	EU classifi-cation	TRGS 900 or others [µg/m³]	Remarks
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	**270**			OEL-DK: 270 mg/m^3
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 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**			TSCA: 1mg/m³, TWA-8hr: 1mg/m³ (AIHA 1999)
10-23*	Maleic acid dibutylester	105-76-0	**50**			OECD-SIDS: 5 mg/m^3
10-24*	Butyrolactone	96-48-0	**2.700**			Individual substance consideration
11. Chlorinated hydrocarbons						
11-1	Tetrachloroethene	127-18-4	**340**	Carc.Cat.3	345.000	
12. Others						
12-1	1.4-Dioxan	123-91-1	**73**	Carc.Cat.3	73.000	
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**	Repr.Cat.3		expert judgement
12-5	Hexamethylenetetramine	100-97-00	**30**			OEL:Norway/Sweden: TWA 3 mg/m³, Jan. 1999
12-6	-2-Butanonoxime	96-29-7	**20**	Carc.Cat.3		expert judgment
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) 2-Methyl-2H-isothiazol-3-one (MIT) mixture, ratio 3:1	26172-554 2682-20-4 55965-84-9	**1**		50	evaluation for a ratio of 3:1

*: new or altered in 2004

In addition:

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

- **BIA**, Berufsgenossenschaftliches Institut für Arbeitsschutz #### http://www.hvbg.de/d/bia/fac/kmr/kmr.htm
- **BAuA**, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin http://www.baua.de/prax/ags/

II) **Recommendation:**

It is recommended by the NIK-WG to additionally do an parallel sampling using the DNPH-method (DIN ISO 16000-3) to capture also the more volatile aldehydes like butanal, butenal and pentanal quantitatively. It is assumed for those substances that sampling onto Tenax is not quantitative and will give minor results. Because of the small NIK for butenal it is necessary to get a quantification as correct as possible. The DNPH-method followed by HPLC-analysis seems to be better suitable for that.
The simultaneous use of DNPH cartridges and Tenax tubes would allow a comparison between the two methods regarding other aldehydes starting from hexanal.
Using the DNPH-method would also facilitate the quantitative capture of some VVOC like acetone, formaldehyde and acetaldehyde. Their determination is not required within the AgBB-evaluation but might be very informative for product evaluations.