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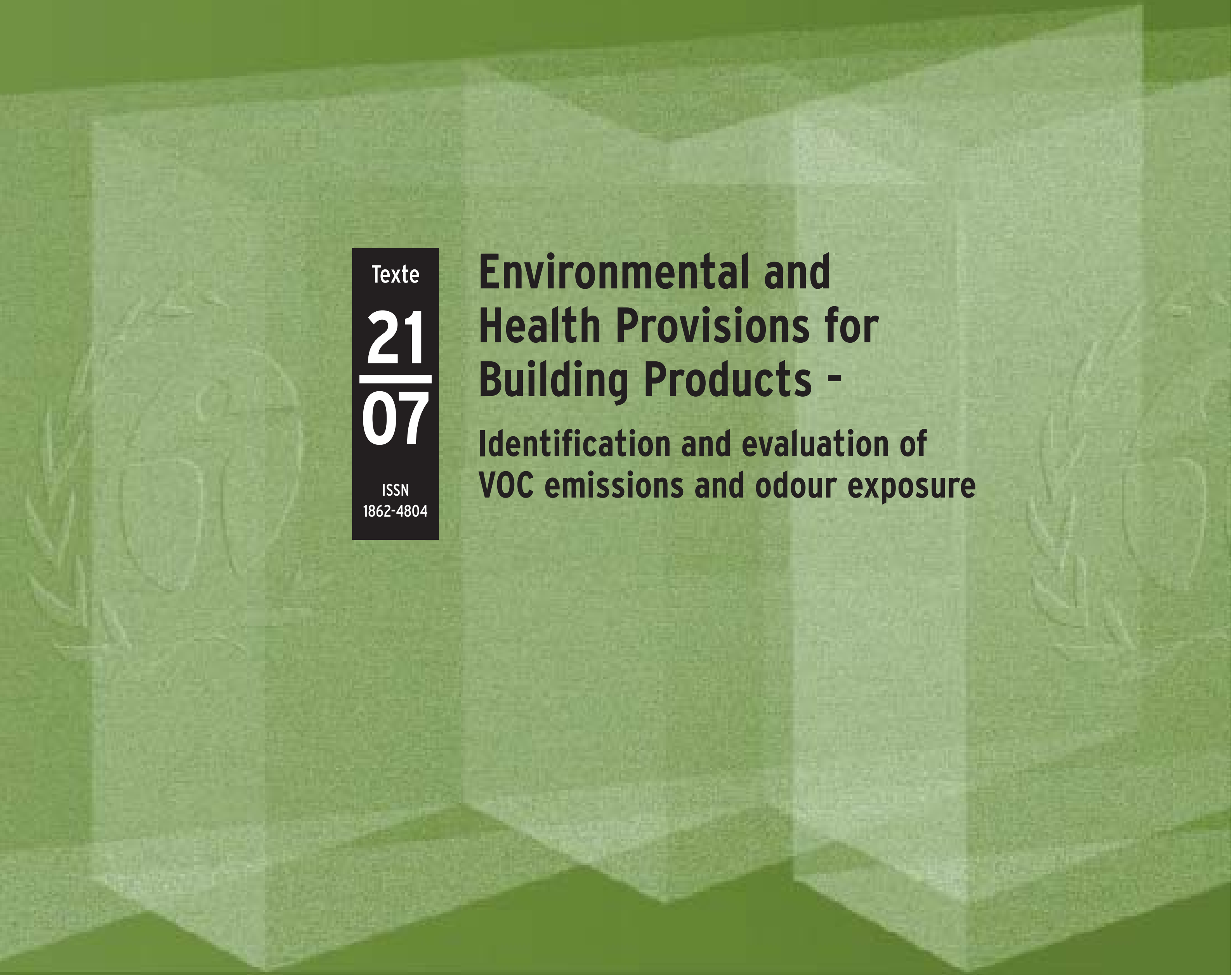

Texte

21
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ISSN
1862-4804

Environmental and Health Provisions for Building Products -

Identification and evaluation of VOC emissions and odour exposure

Umwelt
Bundes
Amt

Für Mensch und Umwelt

ENVIRONMENTAL RESEARCH OF THE
FEDERAL MINISTRY OF THE ENVIRONMENT,
NATURE CONSERVATION AND NUCLEAR SAFETY

Research Report 202 62 320
UBA-FB 001002

Texte
21
07

ISSN
1862-4804

Environmental and Health Provisions for Building Products –

Identification and evaluation of VOC emissions and odour exposure

by

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Publisher: Federal Environmental Agency (Umweltbundesamt)
P.O.B. 14 06
06813 Dessau
Tel.: +49-340-2103-0
Telefax: +49-340-2103 2285
Internet: http://www.umweltbundesamt.de

Edited by: Section III 1.4
Dr. Wolfgang Plehn
Simone Brandt

Translation: Nigel Pye

Dessau, June 2007

Report Cover Sheet

1. Report No.
UBA-FB

2.

3.

4. Report Title
Requirements to construction products on environment and health – Identification and evaluation of VOC emissions and odour exposure

5. Autor(s), Family Name(s), First Name(s)
Dr. Horn, Wolfgang; Kasche, Johannes; Bitter, Frank
Dr. Jann, Oliver; Prof. Dr. Müller, Dirk; Dr. Müller, Birgit

6. Performing Organisation (Name, Address)
Bundesanstalt für Materialforschung und –prüfung
(Federal Institute for Materials Research and Testing)
Unter den Eichen 87
12205 Berlin

7. Funding Agency (Name, Address)
Umweltbundesamt (Federal Environment Agency)
Postfach 1406, D-06813 Dessau

8. Report Date
30.04.2006

9. Publication Date

10. UFOPLAN-Ref. No.
202 62 320

11. No. of Pages
383

12. No. of Reference
66

13. No. of Tables, Diagrams
35

14. No. of Figures
85

15. Supplementary Notes

16. Abstract

In this study 50 construction products were tested in emission test chambers according to the requirements of the AgBB-scheme: 7 acrylic and 6 silicone sealants, 6 paste-like synthetic resin plasters, 13 wood based products, 4 adhesives, 5 lacquers, 6 wall paints and 3 further construction products. VOC and odour emissions were tested on the 1st, 3rd, 10th, and 28th day. In addition to the VOC-measurements, a test procedure was developed to evaluate odour emission of construction products.This test is planned to be implemented into the AgBB-Scheme. A direct evaluation by a sensory panel in the emission test chamber was not possible. So the odour samples were collected in 300- litre tedlar bags which were evaluated later. Odour intensity of the samples was compared with different acetone concentrations. Within this study an interlaboratory comparison was conducted using the newly developed odour test method. Additionally, VVOC emissions, detection of carcinogenic compounds, repeatability of emission test chamber tests, and other issues are presented. This project has shown that construction products can be evaluated in accordance with the AgBB scheme. A sensory evaluation is intended to be introduced in the AgBB scheme. A method for this evaluation is described in this study. The test procedure should be enhanced and validated for practical utilisation.

17. Keywords

construction products, AgBB scheme, emission test chamber, odour, odour evaluation, VOC, VVOC SVOC, thermal desorption, GC/MS, GC-ODP, odour standard of comparison, gas sensor, acrylic and silicone sealant, wood-based product, paints, lacquers, interlaboratory comparison

18. Price

19.

20.

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ANNEX

Preliminary note

The authors of this study express their gratitude to the members of the expert group for their intensive and constructive co-operation. They have made a substantial contribution to the success of this study. Their names are listed in the appendix.

Furthermore, we thank Ms. **Doris Brödner**, Ms. **Elevtheria Juritsch** and Ms. **Sabine Kalus**. Without their unremitting help and conscientious work the research into the building products would not have been possible.

Our thanks go to Mr. **Arne Dahms** for his creative and patient input to the development and supervision of the mobile comparative scale and AirProbe II.

The authors sincerely appreciate the scientific management and helpful assistance from staff members of the Umweltbundesamt (Federal Environment Agency). .

Some results of the study have already been published:

Horn W., Jann O. Methodik zur Erfassung von Gerüchen und Emissionen aus Bauprodukten und Holzwerkstoffen. 1. Fachtagung Holztechnologie 8. - 9. November 2006 Darmstadt

Horn W. Using the AgBB evaluation scheme for VOC and odour emissions of different construction products. CERTECH Conference: Emissions and odours from materials, October 11.-12., 2006

Horn W., Jann O., Kalus S., Brödner D. and Juritsch E. Classification of OSB Emissions Assessed with a German Evaluation Scheme. Proceedings of healthy buildings (HB 2006), Lisboa, 4-8 June, 2006

Horn W., Kasche J., Jann O., Müller D. Emissions- und Geruchsuntersuchungen an Bauprodukten - Ergebnisse eines UFO-Planprojektes. 8. Workshop “Geruch und Emissionen bei Kunststoffen“ 27.- 28. März 2006 in Kassel, Kutech.

Horn W., Müller B., Jann O., Däumling C., Kalus S., Brödner D. 2005. "Emission and odour measurement of construction products evaluated using a German construction product evaluation scheme.” Proceedings of the 10th International Conference on Indoor Air Quality and Climate - Indoor Air ’05, Beijing, China. S. 2129-2133.

Müller B., Müller D., Horn W., 2005. "The use of Gas Sampling Bags for Evaluating the Odours of building materials.” Proceedings of the 10th International Conference on Indoor Air Quality and Climate - Indoor Air ’05, Beijing, China. S 2030-2034

Jann O. und Horn W. 2005. Auswertung von Emissionsmessungen aus Holz und Holzwerkstoffen nach dem AgBB-Schema. Fachanhörung des AgBB-Schema / Holzwirtschaft, Deutsches Institut für Bautechnik (DIBt)

Kasche J, Dahms A, Müller B, Müller D, Horn W und Jann O. 2005 Olfaktorische Bewertung von Baumaterialien. 7th Workshop "Odour and Emissions of Plastic Materials", April 4-5, 2005, Kassel

List of Abbreviations

AirProbe:	sample provision device for odour samples
Direct TDS:	direct thermodesorption
DNPH:	dinitrophenylhydrazine
GC:	gas chromatograph
C substances:	carcinogenic substances
CMR:	carcinogenic, mutagenic, reproduction-toxic
L:	loading factor [$m^2\,m^{-3}$]
LDA:	linear discriminant analysis
MS:	mass spectrometry
n:	air exchange rate [h^{-1}]
n.a.:	not assessed, non-assessable
n.d.:	non-detectable
n.m.:	no measurement
LCI:	lowest concentration of interest
OSB:	oriented strand board
PCA:	principal component analysis
PI, Π:	perceived intensity
pi:	unit of perceived intensity
PF:	phenol-formaldehyde
PU foam:	polyurethane foam
q:	area-specific air flow rate [$m^3 m^{-2} h^{-1}$]
SIM:	selected ion monitoring (recording method in MS)
SVOC:	semivolatile organic compounds
VOC:	volatile organic compounds
VVOC:	very volatile organic compounds
TVOC:	sum of all VOC in retention range C_6 to C_{16}
ΣSVOC:	sum of all SVOC in the retention range C_{16} to C_{22}
TENAX:	polymer of 2,6-diphenyl-p-phenylene oxide
TDS:	thermodesorption system

1 OBJECTIVES

The objective of the project was to test and extend national and international test methods in order to appraise building products according to the assessment scheme of the Committee for Health-related Evaluation of Building Products (AgBB scheme). Thus an obligation of the "Action Programme Environment and Health" (APUG) to reduce potentially harmful emissions from building products is delivered using an efficient test and assessment process.

The AgBB scheme for the health-related evaluation of building products is an important component in the assessment of environmental and health characteristics during the utilisation phase of building products. The health-related evaluation according to the AgBB scheme requires product-specific measuring methods which provide information about the actual emission behaviour of the products. For many building products, an understanding the emission behaviour was completely missing or there were too few measurements to describe the range of the emissions sufficiently, so preventing a comprehensive assessment according to the AgBB scheme.

There are product specific measuring methods available for the determination of emissions from volatile organic compounds (VOC), semivolatile organic compounds (SVOC) and to some extent very volatile organic compounds (VVOC) for a number of products. They have been validated by the participation of various research establishments and measuring institutes and integrated into the assessment criteria for the “Blue Angel” environmental award. About to be named are products made of wood and wood-based materials (furniture, parquet, laminate floors, internal doors and linoleum, RAL-UZ 38), low-emission floor covering adhesives and other materials for installation of flooring (RAL-UZ 113), low-emission upholstered furniture (RAL-UZ 117), low-emission mattresses (RAL-UZ 119), flexible floor coverings (RAL-UZ 120) and low-emission interior sealing materials (RAL-UZ 123). Further environmental awards with reduced emission are RAL-UZ 62 for copiers, RAL-UZ 85 for printers and RAL-UZ 122 for multi-functional devices. The measurement method that the AgBB scheme is based on (emission test chamber in connection with Tenax sampling and gas chromatography/mass spectrometry) enables the determination of low VOC concentrations in the chamber air. However, VVOC’s and SVOC’s demonstrate the limits of the method. An adjustment made to the sampling methods was an attempt to improvement the analytical determination of compounds that were difficult to measure or were immeasurable.

Though an assessment of odour emissions is predicted under the term of sensor technology in the AgBB evaluation scheme, it has not been required so far for the assessment because of current measurement uncertainties. Methods used to determine odour emissions either lead to poorly reproducible results ("fruit jar method") or have so far not been developed for practical applications in connection with VOC determination in emission test chambers. Therefore urgent action was needed to develop a suitable test method to assess odour emissions from building products using a reasonable combination of existing original approaches.

At the beginning of the project building products were selected from the following product groups: joint sealing compounds, mineral building materials with organic supplements (e.g. screeds, plaster) and wall coverings based on glass-fibre. Also, various wooden materials such as OSB (oriented strand boards), glued wooden plates and cork parquet and different paints and lacquers were tested.

Commercial samples were taken from the selected product groups and screened (based on the head-space-method and/or short-time chamber/cell tests).

Up to 60 materials were to be selected and tested for their emission behaviour over a period of at least 28 days based on the chamber screening tests. The assessment of the building products was to be completed according to the AgBB scheme.

Another key objective was to contribute to the further development of the AgBB scheme and its implementation for supervision by building authorities and establish criteria for assigning the environmental award to new products.

2 INTRODUCTION

2.1 BUILDING PRODUCTS AND EMISSIONS

In order to eliminate barriers to trade for building products in the common market of the European Union and enable free traffic of goods, the Council of the European Union issued a directive for the adjustment of the legal and administrative regulations of the member states on building products on the 21 December 1988 (89/106/EWG [1]). This Construction Product Directive was to serve the harmonization of the EC domestic market. In addition to the free traffic of goods the contract also specifies that free trade must take into account all environmental health issues. A high level of protection is required based on the principles of precaution and prevention. This is to be achieved by the harmonization of the different technical regulations in the member states.

The building product directive [1] defines the term ‘building product’ as a commercial product that is manufactured with the purpose of remaining in the building over a long period of time. Those products which are in direct contact with interior air are of interest for emission tests. The bigger the surface area of the product, the greater the potential for emissions.

In the Encyclopaedia of Chemical Technology by Kirk-Othmer [2] building products are divided into two groups. Group 1 conventional materials wood, bitumen, gypsum products, cement, brick, glass and group 2 plastics. Emission of organic components is possible from both groups, however plastics or their combination with conventional materials have a greater influence on the room air.

Numerous studies were carried out in the past which deal particularly with the emissions from building products [e. g. 3, 4, 5, 6, 7, 8, - 9]. Schriever and Marutzky [3] published a literature study in 1991 which represented the knowledge at the beginning of the 1990s.

An extensive investigation was published by the EMPA in 1997 [8]. Emission from numerous building products and product classes was determined using emission chamber tests, which lasted between 20 hours to 90 days. Products of the following groups were tested in this study: adhesives, concrete, brick and stone and other heavy construction materials, mortar, mineral-based plaster and synthetic resin-based plaster, glass and surface-treated metal building materials, wood-based materials, joint sealing materials and putty, heat-insulating materials, floor coverings, PVC coverings, linoleum, textile floor coverings, coating materials, emulsion paints and other water based products (filling pre-lacquers, finishing lacquers etc.), parquet sealants, products with higher solvent content and wallpapers. The authors of this study came to the following conclusion: "It can be stated that the building materials used today can emit such a broad variety of volatile organic materials that little can be said about type and quantity of the emissions to be expected without measurements. Only a few types of building materials (e.g. wood, linoleum, polystyrene, SBR rubber) produce the same "typical" components repeatedly whose emitted quantities however can vary greatly depending upon the product." This statement still applies today; therefore an emission measurement should be performed for the health-related evaluation of products and in particular for building products. The current efforts in this field are illustrated in detail in the following Chapter 2.2 AGBB Scheme.

In the project presented here emissions were tested chiefly from the following building products according to the criteria of the AgBB scheme:

- joint sealing materials based on acrylate and silicone,
- paste like synthetic resin-based premixed plaster,
- lacquers and emulsion paints,
- wood-based materials.

Paints and lacquers are defined in the decision 96/13/EG 10 as products placed in thin layers on a surface of wood, stone, metal or other materials to protect and/or beautify the surface. After being applied, the paint and/or lacquer dries to form a solid adhesion and protective layer.

OSB are oriented strand boards, which are manufactured from long, slim strands, usually in three layers with different strand orientation [11, 12]. The individual strands are covered with a binder, usually phenol/formaldehyde (PF) or isocyanate resins and then compacted at approx. 210 °C (PF resins) or 190 °C (isocyanate resins).

Joint sealants are products which are injected into joints to seal them in such a way that the material sticks to the joint surfaces. The most important joint sealants are silicones because they exhibit high elasticity. Most silicones are products that harden through polycondensation with the loss of organic residues. Their composition is shown in Table 2-1 [2]. The silicones are classified according to the residues given off so classifying them into the following groups: acetate systems, amine/aminoxy systems, oxime systems, benzamide systems and alkoxy systems.

Acetate systems, which give off acetic acid on cross-linking and smell intensively in the first few days after application, are most well-known.

Table 2-1: Typical formulations for single-component silicone sealants

Component	**Mass fraction in percent**	
	High-strength silicone	**High-elasticity silicone**
Silicone polymer	70 - 85	40 - 60
Silicone softener	0 - 5	0 - 20
Fumed silica	6 - 12	
Calcium carbonate		40 - 60
Cross-linking agent	3 - 8	3 - 8
Adhesion enhancer	0 - 1	0 - 1
Catalyser (optional)	< 1.5	< 1.5

Another class of sealants are the acrylic sealing pastes which are dispersion sealants and do not show any chemical reaction when hardening, but attain their final strength through losing water.

The comprehensive term **synthetic resin plaster** (sample composition in Table 2-2 [13]) is used for coatings with a plaster-like appearance, which can be divided into exterior and interior plasters depending upon their binder. These plasters are aqueous dispersions which set purely by evaporating their water content and are frequently delivered in a ready-to-use paste form [14].

Table 2-2: Guide composition for an organically bound plaster, applied by roller

Component	**Mass fraction in percent**
Plastic dispersion (acrylic copolymer)	20.0
Limestone crushed sand (0.1 to 1 mm)	60.0
Talc	7.0
Water	7.0
Pigment(s)	3.0
Hydroxyethylcellulose (30,000 mPas 2%)	0.50
Cross-linking agent	0.20
Sum	97.7

Emissions from building products are usually determined in special measuring chambers. The first standards, which described these methods for VOC, were published by Nordtest in Northern Europe. The first chamber dimensions specified for testing construction units were based on a standard room. Later, further test chambers were developed and described ("Field and Laboratory Emission Cell" (FLEC), "Chamber for Laboratory Investigations of Materials, Pollution and Air Quality" (CLIMPAQ)) [15, 16, 17]. The American Society for Testing and Materials (ASTM) also developed and published standards for emission measurements in chambers [18, 19], which were supplemented by a Standard of Practice for the State of California [20]. 1999 chambers and their operating parameters have been standardised by the EN 13419 sheets 1 to 3 in Europe. These chamber measurement methods were integrated into the ISO standards ISO 16000-9, 16000-10 and 16000-11 in 2006 [21, 22, 23].

In the chamber measurement methods discussed, the use of inert chamber materials, such as glass or steel, and the operation at a standardised climate, 23 °C and 50 % relative humidity (in the ISO standard with tolerances of ± 2 °C and ± 5 % relative humidity) is prescribed. The rate of air change is usually between 0.5 and 1.25 h^{-1}, and the loading is adapted to the product to be tested. This is only a short excerpt from the chamber requirements. More details can be taken from the respective standards.

2.2 AgBB SCHEME

Humans need an environment in which they can live healthily. Those living in Central European spend a considerable part of their time within buildings, therefore indoor air quality is important for human health and comfort. In order to preserve the quality of the room contamination should be as low as possible, therefore materials and objects used should be of low-emission, i.e. they should give off as few pollutants as possible [24]. Building products here play a major role because their selection frequently does not lie at the discretion of room users, and many of them have a large surface area within the room. Protecting the health of building users is undisputed, however it was still unclear how this protection could be achieved in detail [25]. The European Collaborative Action (ECA) "Indoor Air Quality and its Impact on Man" dealt with the assessment of VOC emissions from building products. Specialist knowledge about the most diverse interior-relevant topics available in Europe was compiled and summarised by ECA experts (European Union as well as Switzerland and Norway) in reports. They contain such specific data that they can be considered "pre-normative". ECA published report No. 18 "Evaluation of VOC Emission from Building Products" - a milestone in the assessment of emissions from building products - in which an evaluation scheme for emissions from floor coverings was described as an example [26].

The Committee for Health Evaluation of Building Products (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten - AgBB) produced the AgBB scheme initially for Germany in 2003. This scheme improves on the issues of the ECA Report No. 18, and is constantly being developed aimed at a Europe-wide application. AgBB was founded in 1997 by the States‘ Working Group ‘Environment-related Health Protection‘ (Länderarbeitsgruppe "Umweltbezogener Gesundheitsschutz", LAUG) of the Association of the Senior State Health Authorities (Arbeitsgemeinschaft der Obersten Landesgesundheitsbehörden, AOLG). The AgBB scheme describes a test and an evaluation concept for emissions of volatile organic compounds from building products [25, 27]. This concept establishes adequate requirements for health compatibility of building products which will enable reliable product selection in the future. These evaluation characteristics were previously discussed fully with relevant manufacturers, specialist institutes and authorities. The German Institute for Building Technology (Deutsches Institut für Bautechnik, DIBt) has included this scheme in the approval principles for floor coverings and it will also integrate them in the approval procedures for other products [28, 29].

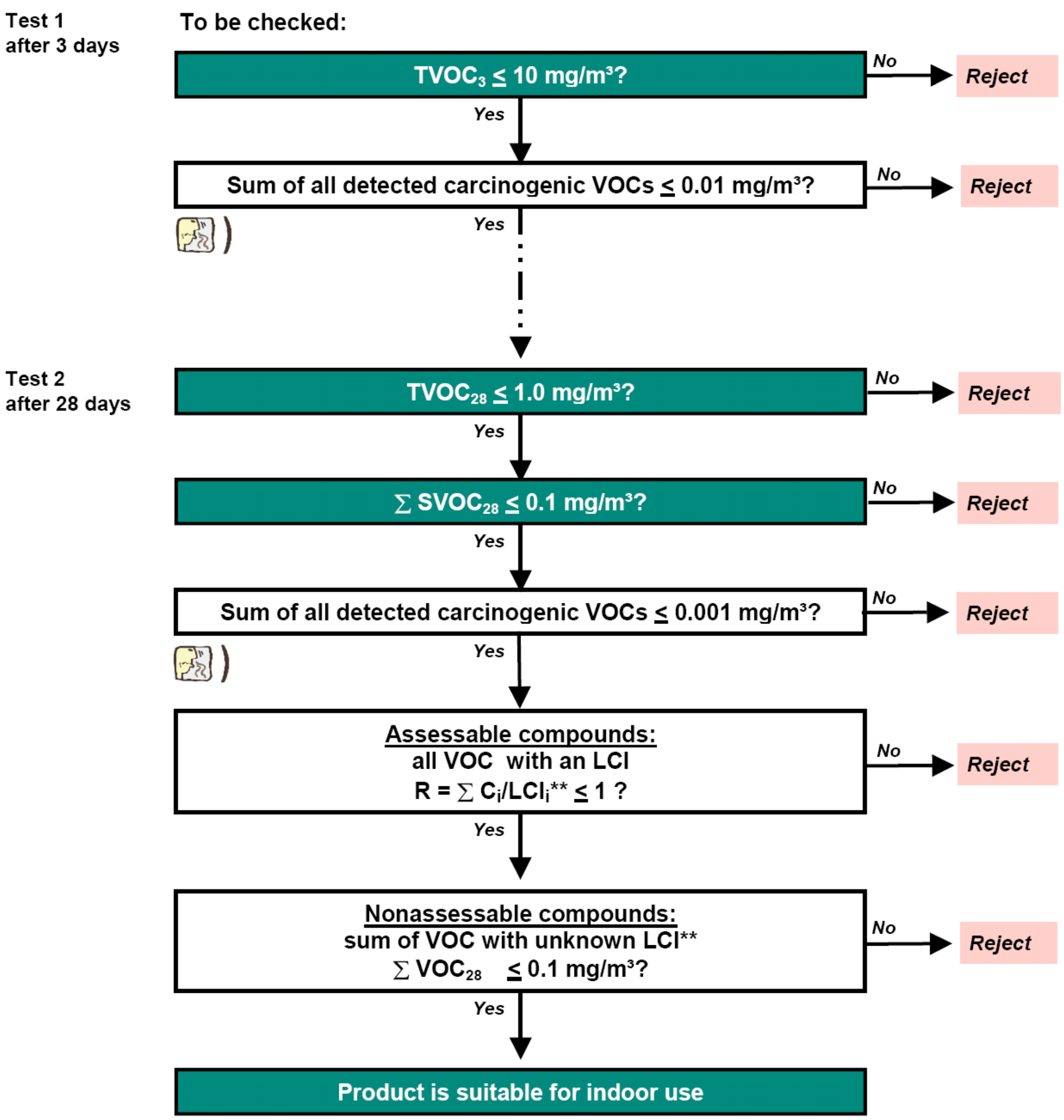

Figure 2-1 **AgBB scheme**

The assessment based on the AgBB scheme takes place using emission chamber tests on the building products. The relevant standards [21 - 23] form the basis for the measurements. The measurement cycle begins simultaneously to loading the chamber. A sample after 3 and another after 28 measuring days are used for the assessment. Figure 2-1 shows the flow chart of this assessment [25].

Table 2-3 provides information about which groups the volatile organic components can be attributed to. The basis for the retention ranges of VOCs is the elution on a nonpolar GC column analogous to ISO 16000-6 [30]. In addition to the

AgBB scheme, this standard also suggests using the ISO 16000-3 (DNPH method[1] with HPLC analysis) for proving aldehydes, in particular for the NIK[♦] (LCI) substances butenal, pentenal, pentanal and glutaraldehyde [31]. This method enables a selective verification of aldehydes and ketones which is usually fairly accurate for smaller components up to C_5. The first test takes place after 3 days when it is checked to see if the $TVOC_3$ value is smaller than or equal to 10 mg m^{-3} and the carcinogenic compounds amount to less than 0.01 mg m^{-3}. If these two provisions are met, product testing is continued.

Within the second test after 28 days many more parameters are cleanly evaluated: $TVOC_{28} \leq 1$ mg m^{-3}, $\Sigma\ SVOC_{28} \leq 0.1$ mg m^{-3} and other VOCs, which are evaluated with the help of the NIK list of the AgBB scheme. The R value is determined ($R \leq 1$) with the NIK values by summing the quotients of concentration and NIK value of the respective substances. Further, the VOCs, for which no NIK value is available, is evaluated more precisely, with a sum value of $VOC_{\text{without NIK}} \leq 0.1$ mg m^{-3}. The sum of carcinogenic VOCs must also fulfil the values of ≤ 0.001 mg m^{-3}.

Table 2-3: Definitions of VOC in the AgBB scheme based on ISO 16000-6

VOC	All substances in the retention range $C_6 – C_{16}$
TVOC	Sum of all substances ≥ 5 µg m^{-3} in the retention range $C_6 – C_{16}$
SVOC	All substances in the retention range > $C_{16} – C_{22}$
Σ SVOC	Sum of all substances ≥ 5 µg m^{-3} in the retention range > $C_{16} – C_{22}$

2.3 ODOUR MEASUREMENT

Since VOC emissions are frequently able to be smelt, and can also lead to health impairment, sensory testing was included as an important aspect in the AgBB scheme. Though many different smell measurement procedures exist - see Fischer et al. (1998) [32] and ECA (1999) [33] - so far no generally recognised method for smell evaluation of building products is available.

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[1] DNPH = dinitrophenylhydrazine

[♦] NIK = niedrigste interessierende Konzentration, comparable to the LCI value (LCI = lowest concentration of interest) according to the ECA report No. 18 [26]

Despite improving analysis possibilities and the development of artificial noses, replacing the human nose in the determination of perceived air quality has not been successful until today. Odours develop from a number of chemical substances but not all materials generate the perception of smell in humans. Many thousands of different substances can be detected in the room air, but even a quantitative determination of each single material would not enable a statement about the smell effect of a combination to be made.

Within the structure of the current investigation, the known methods of odour measurement were considered first and analyzed for their suitability for sensory assessment of building products. Since the AgBB scheme offers a recognised procedure for the assessment of emissions from building materials, a method was sought that relied on sample preparation and presentation using the laboratory equipment and procedures described in the AgBB scheme.

2.3.1 SELECTION OF A SUITABLE METHOD

Depending upon operational area and application, very different methods of sensory assessments have been established both nationally and internationally. The following table gives an overview of a part of those developed methods and their employment.

Table 2-4: Overview of established methods

Method	Field of application	Number of panellists	Question
DIN EN 13725 [34]	External area, emission assessment	4-8, trained	Odour intensity, hedonic effect, odorous substance concentration
VDA 270 [35]	Internal area, materials in the automobile industry	3-6, untrained	Odour intensity
‚Percentage Dissatisfied' [36]	Internal area, room air	>30, untrained	perceived air quality (acceptable/not acceptable)
Decipol [37]	Internal area, room air	8-10, trained	perceived air quality (decipol)

In addition to scales for odour intensity (not perceptible… clear… very strong) and hedonics (extremely unpleasant… neither nor… extremely pleasant), the well standardised method according to DIN EN 13725 uses trained panellists and the concentration of odorous substances as a characteristic physical quantity for the determination of a sample. The odour threshold of a sample is determined by dilution with smell-neutral air, which represents a yardstick (background) for the concentration of odorous substances. This method, initially developed for the determination of emissions with high concentrations of odorous substances from equipment into outside air and which are subject to rapid atmospheric dilution, has only a limited suitability for the relatively low odour emissions from building products in an undiluted form to which humans are mainly exposed.

It is only the odour intensity based on the scale of DIN EN 13725 which is estimated by untrained panellists in the VDA 270 method, developed for the automobile industry. Answers using this method show a large standard deviation when used for a rapid classification of materials. Considerable deviations were found in the classification of 20 samples in an interlaboratory comparison performed with 41 participants from the automobile industry in 2004 [38].

A simple acceptable/non-acceptable query is evaluated with the 'Percentage Dissatisfied' method, developed for the assessment of indoor air quality. Contamination by one person serves as a measure of pollution. Any pollution source is considered equivalent to one person when air pollution caused by it is perceived as being equally strong. This is supposed to provide a uniform assessment of different pollution sources. Pollution by one person is defined as 1 olf. The perceived air quality is used as a measure for the pollution concentration in indoor air with the unit pol. It is defined as the perceived air quality in a room polluted with 1 olf and a ventilation with a flow rate of 1 l/s. More common is the unit decipol with which the load of 1 olf is diluted by a volumetric air flow of 10 l/s. According to this definition the perceived air quality is linearly dependant on the pollution.

Within the method the perceived air quality is determine using different questions. For example untrained panellists can be asked whether or not they are content with the air quality. This method is based on a simple yes-no inquiry. Persons are considered as dissatisfied who, on entering the room, are not content with the air quality. The percentage of dissatisfied test participants in a collective can be determined from the ratio of the number of dissatisfied persons to all participating in the test. This represents a measure for the quality of indoor air. PD has been introduced as an international abbreviation for this percentage. This abbreviation stands for Percentage Dissatisfied.

$$PD = \frac{\text{number of dissatisfied persons}}{\text{number of all participants}} \times 100 \qquad \textbf{(Eq. 1)}$$

In addition to the two-point scale, questions have been developed which enable more differentiated statements about the air quality. A scale which divides the ranges of satisfaction and dissatisfaction into 10 stages became internationally generally accepted. This method determines the so-called acceptability of air quality.

The two methods presented for the determination of the perceived air quality employ untrained panellists. A sufficiently large group of people must be used so that the results reflect the perception of the normal population. Since the panellists receive a financial remuneration for the time, large groups can create both additional organisational work and raised costs. Besides, the result of the assessment of air quality in rooms can be affected by too many panellists, since the panellists themselves represent a pollution source for the indoor air.

Bluyssen [37] has further developed the method by introducing a comparison yardstick based on different acetone concentrations, whereby the number of test participants can be reduced to 8-10 trained panellists. The determination of a decipol value as a measure for the perceived air quality should permit a conclusion on its acceptability to be drawn up and thus on the number of dissatisfied participants. However, this relationship cannot be proved with the comparison of results from questioning the acceptability.

Previous conversion functions used to transfer assessments by untrained and trained panels are based on the assumption that the assessments are independent from external influences. Untrained panels however, show a different reaction to changes in thermal conditions of the air than trained ones. According to the investigations of Fang [39] and Böttcher [40, 41] the acceptability of air with a constant contamination load decreases with an untrained panel as the specific enthalpy rises. Whether the change in specific enthalpy is caused by a variation of temperature or humidity has no influence on this test result. A trained panel, however, showed no uniform behaviour in the assessment of air samples with different specific enthalpy. This finding explains difficulties experienced so far in converting measurement results obtained by untrained and trained panels.

2.3.2 INTRODUCTION OF THE TWO-STAGE METHOD TO DETERMINE PERCEIVED AIR QUALITY

Based on the results mentioned, a two-stage model for the determination of perceived air quality has been developed. The model takes into account the differences between untrained and trained panels.

Any material delivers various chemical substances to the ambient air. In the first assessment stage the nose as a sensor detects the odour-generating substances emitted by the material. The different sensitivity of the nose to different odour-generating substances results in perceived intensity Π of the odorants contained in air by the panel members. The relative humidity of air affects the mass transfer at the moist "sensor surface" of the nose and affects the intensity impression of an odour. Trained panels, who work with a comparative scale, try to arrange the intensity of the smell of a sample using the scale reference samples. The acceptability of the odour impression is secondary and not queried by this assessment.

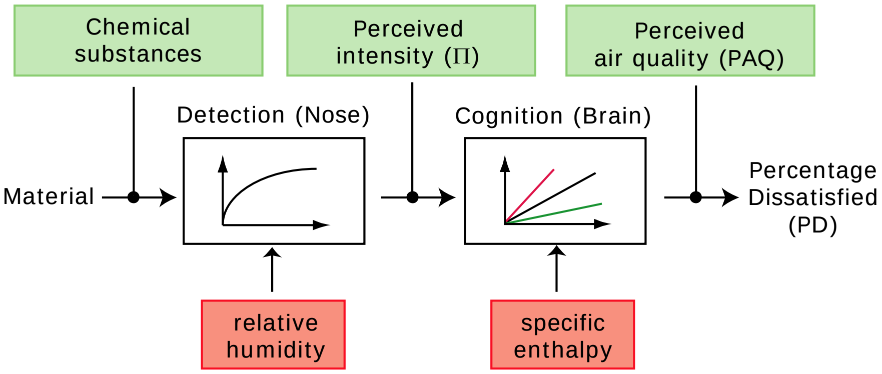


Figure 2-2: Two-stage assessment of air quality by a panel member

In the second stage of the smelling procedure, the brain assesses the signals sent by the nose. In addition to the intensity, the hedonics of the smell determines its effect on the panel member. The untrained panel is asked about the acceptability of the ambient air for daily working. No scale is available for the determination of odour intensity. The untrained panel member is not forced to concentrate on the intensity of the odour impression, thus the percentage dissatisfied is determined directly from the question on acceptability, which is then used to determine the perceived air quality. Increase in the specific enthalpy negatively affects the perceived air quality. In addition to the relative humidity, temperature also exerts an influence on the measurement result in the hedonic assessment, although the intensity of the perceived odour does not change.

2.3.3 INTRODUCTION OF PERCEIVED INTENSITY

The perceived intensity Π can only be determined with trained panels using a comparative scale. Unlike the acceptability method with untrained panels, the intensity of odorous substances in the air is determined by comparing different specified intensities of the reference material acetone. The smelling capability varies from human to human. Training and use of comparative sources ensure that the influence of subjective perception of the test result is reduced since all panel members evaluate air quality based on the same scale.

The unit of Π is pi. The comparative scale at Hermann Rietschel Institute consists of acetone-air mixtures. The gradation is linear with regard to acetone concentration. Currently, however, work is taking place on a linear intensity scale which can be used independently of the base odorant for a comparative scale. A later conversion of the results is then feasible.

The comparative scale of intensity is defined at Hermann Rietschel Institute by the following points:

- 0 pi = 20 mg acetone/m^3_{air}.
  50% of the panel can notice an odour at 20 mg acetone/m^3_{air}. It is the odour threshold for acetone. This acetone concentration corresponds approximately to 2 decipol.
- Concentrations for 1 to n pi follow a linear gradation of the acetone concentrations. The objective of further development is a linear scale with regard to perceived intensity.

2.3.4 DEVELOPMENT OF A NEW COMPARATIVE SCALE

When assessing the perceived intensity of unknown samples, trained panellists can rely on a comparative scale of acetone/air mixtures, which help to determine its intensity.

A new comparative scale was developed at the Hermann Rietschel Institute for the sensory assessment of building materials. The objective of this was to achieve a constantly adjustable acetone concentration in the sample air independent of the ambient conditions. The design scheme of the comparative scale is illustrated in Figure 2-3.

The comparative scale is in essence composed of three parts: sample air circulation, source of acetone and dosing device. The units in contact with air are almost wholly manufactured from stainless steel, glass or PTFE (polytetrafluoroethylene), which are practically smell-neutral.

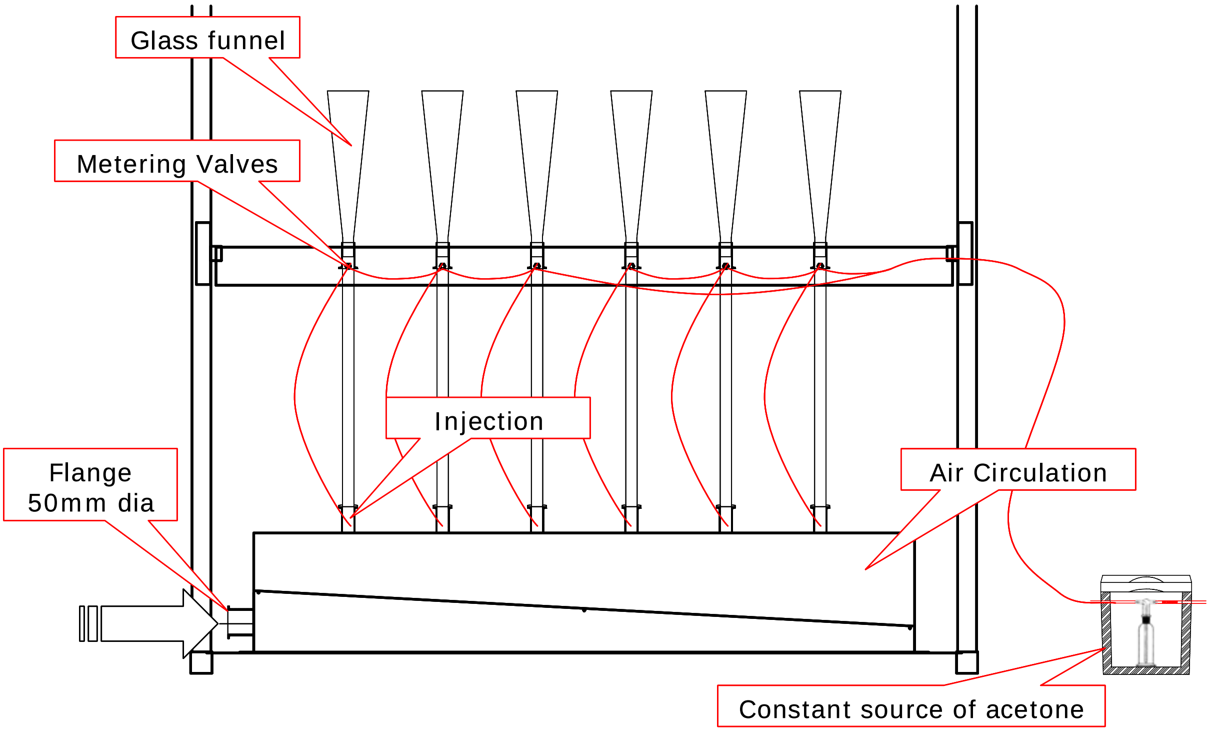


Figure 2-3: Scheme of comparative scale

Sample air circulation is connected via a flange to a suitable smell-neutral air supply. The sample air circulation provides constant flow rates between 0.9 and 1.0 l/s per marker (5.4 to 6.0 l/s for six markers) which ensures an undisturbed operation. The constant source of acetone consists of a pressure-resistant wash bottle and a cooling device. The acetone filled wash bottle is supplied with compressed air which is pumped through and then enriched. Cooling prevents an over saturation of the compressed air and a consecutive condensation in the pipes. The acetone fog is effectively separated by a cellulose filter from the enriched air.

The six funnels are supplied with the constant air/acetone mixture via a distribution hose. A metering valve per funnel regulates the amount of the acetone/air mixture added to the sample air within the range of 0 to 1150 mg m^{-3}.

The design of the air supply ensures a homogeneous mixing of the acetone in the sample air. If the air supply of the funnel with constant flow rate and constant pressure is ensured, the desired quantity of acetone can be adjusted by the metering valves. The adjusted concentrations have to be tested with a suitable measuring instrument.

Six different mixes of acetone concentrations in the range between 20 mg m^{-3} (0 pi) and 300 mg m^{-3} (15 pi) help the panellists gain their orientation in determining the perceived intensity of an unknown sample. In addition, the comparative scale enables uniform assessment criteria on different testing days and facilitates the standardisation of the method.

3 MATERIAL AND METHODS

3.1 SAMPLE SELECTION

All building products tested in this project,were commercially available. This guaranteed that such products were tested which could have been acquired by consumers. Exact manufacture data cannot usually be determined for these materials, so that no information could be given about them in the following either. The main product types were sealing compounds, timber, synthetic resin-based premixed plaster and paints and lacquers, as shown in Table 3-1. A large number of these were acquired in each case which is shown in the second column. The samples were first tested using the direct thermodesorption method (3.4.1 p. 25) in order to select the materials for the chamber tests from these results. The number of the chamber tests is indicated in the third column and the sample numbers are listed in the last column. The applied and/or quantities of the different samples used are described in Chapter 3.3 (p. 19).

Table 3-1: Overview of the tested samples

Building product	Number	Chamber tests	Numbering in project
Silicone sealing compounds	21	6	3333, 3338, 3353, 3477, 3478, 3707
Acrylic sealing compounds [#]	16	7+	3332, 3351, 3356, 3460, 3485, 3647, 3653 (laboratory comparison)
Synthetic resin premixed plaster	10	6	3342, 3345, 3357, 3487, 3614, 3623,
Timber, laminate, cork etc.	14	13	3382, 3383, 3384, 3479, 3488, 3543, 3559, 3561, 3560, 3562, 3625, 3628, 3689
Paints and lacquers	17	11	3385, 3388, 3392, 3463, 3558, 3584, 3586, 3587, 3589, 3590, 3626
Adhesives	7	4	3400, 3405, 3445, 3461
Others *	7	3	3444, 3545, 3546

[#] From among these materials, 3653, 3385 and 3403 has been measured several times in the chamber as indicated by + after the number of the chamber tests.

* Primer, gypsum wallboard, tile materials

3.2 EMISSION CHAMBERS

Investigations of emissions into the air were performed using emission test chambers which are constructed mainly from glass and have a volume of approx. 23 litres. Tests complying with the specification of the AgBB scheme usually take 28 days. Samples may not be removed from the chamber until the test is complete.

Emission test chamber parameters:

In addition to specified parameters such as temperature, relative humidity, area-specific air flow rate and air flow velocity, test chambers must meet other requirements for the determination of emissions in chambers:

- Inert emission test chamber walls [glass or high-grade steel (polished)] to minimize wall effects
- Thermally regulated shell to minimize time based and spatial temperature gradients
- Minimise sealing materials capable of causing intrinsic emissions and adsorption/desorption effects
- High-purity air supply (free of VOC and dust)
- High-purity water supply (free of VOC and particles)
- As large a source/sink ratio as possible (important for semivolatile compounds)

The emission test chambers were operated under the standard climate conditions of T = 23 °C and RH = 50 % in accordance with ISO 16000-9 [21]. No heat exchangers were used in any of the chambers for temperature regulation in order to reduce adsorbing surfaces; instead the principle of a thermally regulated blanket was applied consistently.

The same surface air flow velocity of 0.1 - 0.3 $m\ s^{-1}$ was used in all chambers. The ratio of product loading factor (L) to air exchange rate (n) was specifically adjusted to the sample being tested. Many samples were tested with an area-specific air flow rate of $q = n/L = 1\ m^3m^{-2}h^{-1}$ which corresponds to a product loading factor of $1\ m^2\ m^{-3}$ at an air exchange rate of $1\ h^{-1}$. Other values used for q were $0.53\ m^3\ m^{-2}\ h^{-1}$ for plaster, 44 or 83 $m^3\ m^{-2}\ h^{-1}$ for sealing compounds and $1.25\ m^3\ m^{-2}\ h^{-1}$ for floor coverings. The value of q for the different product types is explained in the chapter Sample Preparation (3.3, p. 19). Furthermore all 23-litre chambers were equipped with the same high-purity air supply system. High-purity air was provided by an oil-free compressor in which a downstream cleaning unit removed moisture, VOC and dust from the compressed air. The cleaning unit (Ultrafilter Oilfreepac) consisted of a pre-filter (dust and aerosol separation), air drying (heatless dryer - silica gel with automatic regeneration), charcoal cartridge for VOC absorption and a fine filter and after-filter (submicrofilter < 0.01 µm, degree of separation 99.99999 %) to restrain both the fine and finest dust from the ambient air and abraised silica gel and charcoal particles.

23-litre chamber:

The 23-litre small emission test chambers are based on desiccators in accordance with DIN 55666 with additional optimisation. They are equipped with inlet and exhaust connection points and one to three sampling connection points. Air flow velocity is adjusted by a propeller which is connected through a magnetic clutch to the exterior speed-controlled motor. Specially sealed ball bearings are used on the chamber side of the propeller shaft in the magnetic clutch which, after careful cleaning of the surfaces, do not exhibit any provable emission. The air exchange rate is adjusted with the aid of a needle valve and flowmeter. The flange between the desiccator and lid is sealed using a plane ground joint fixed with variable chucks. Some connection points are provided for air sampling to which sampling tubes with 6 mm or 14 mm outer diameters can be connected. The chambers correspond to the requirements of ISO 16000-9 [21].

3.3 SAMPLE PREPARATION

Before the actual tests the building products were conditioned in air (23 °C, 50 % RH) and stored in their original packaging. The packaging was opened after acquisition; a part of the sample removed and tested directly using dynamic thermoextraction. These tests allowed a preselection of the products which could then be tested in the chamber. Depending upon type of product, different sample preparation methods were applied for investigation of their emissions, and are described in the following.

Sealing compounds:

In accordance with ISO 16000-9 and -11 the sealing compounds are tested in standard aluminium channels with internal dimensions of 10 mm (width) x 6 mm (height)[♦]. The sales units were stored at a climate of 23 °C and 50 % RH. ISO 16000-9 (formerly EN 13419-1) recommends $q = 44\ m^3m^{-2}h^{-1}$ for testing sealing compounds. Using the profile cross-section of 6 x 10 mm, the air flow rate and the size of the chambers yields a profile length of 284 mm to meet these test conditions and this results in an emission area of 0.00284 m^2 . In some tests carried out simultaneously in the CLIMPAQ in the Hermann Rietschel Institute the conditions of the Nordtest method 482 [15] were applied which suggested $q = 83\ m^3m^{-2}h^{-1}$ for testing of sealing compounds. In addition to the 23-litre chamber, one of the tests was carried out in a 1-m^3 chamber where a 2.27-m aluminium standard channel was used (4 pieces with 62 cm), which corresponds to $q = 44\ m^3m^{-2}h^{-1}$ at an air exchange rate of 1 h^{-1}.

Figure 3-1: Applying sealing compound to an aluminium standard channel

The sealing compounds are generously applied to the channels and the surplus is levelled by a trowel (Figure 3-1). After a standing period of about one hour the profiles prepared in this way are placed into the chambers.

Synthetic-resin premixed plasters:

The sales units of synthetic-resin premixed plaster to be tested were purchased from specialist shops and building markets. They were prefabricated ready-to-use pastes usually sold in buckets of 20 to 25 kg with the designations smooth plaster, coarse plaster or decorative finish coating.

[♦] The 10 x 3 mm channel required by the standard could not be acquired.

The maximum possible loading was chosen for the tests in the 23-litre chamber without any major interference to the system (air flow rate 125 l h^{-1}). This could be achieved by using a double-sided application of the product onto two glass plates of 27 x 22 cm^2 and adjusting q = 0.53 m^3 m^{-2} h^{-1}. It is best to use frosted glass plates, otherwise the relatively fresh plaster can easily slip from the smooth surface. First, the amount of plaster specified by the manufacturer was applied on one side of the plate. The plaster was then distributed as evenly as possible with the help of a trowel. After about two-hours the plates were covered on the other side. After another two hours the plates were placed into the emission test chamber.

Figure 3-2: Synthetic-resin premixed plaster placed double-sided on a glass plate

Wood-based materials:

Wood-based materials to be tested were also acquired exclusively in local specialist shops so no exact age can be specified for them either. In the case of wooden tile products, where possible the tiles were taken from the middle of the pile in order to avoid using tiles from the top of the pile in case those had been stored in the open and had aged the most. Previous investigations indicate that tiles stored the middle of the pile retained the longest initial emission levels [42]. Complete packs of products such as laminates or other floor coverings were purchased and samples taken from the middle of the pack. An area-specific air flow rate of $q = 1.25\ m^3\ m^{-2}\ h^{-1}$ was used for floor coverings and $q = 1\ m^3\ m^{-2}\ h^{-1}$ for other wood-based materials. $q = 2\ m^3 m^{-2} h^{-1}$ was only applied in a comparison test on an OSB carried out simultaneously in the CLIMPAQ, otherwise the sample material would not have fitted in the CLIMPAQ.

Figure 3-3: OSB prepared for chamber tests

The edges of the tiles in the chamber tests were covered with self adhesive aluminium foil, analogous to the edge/surface ratio in DIN V ENV 717-1 [43] for tests on wooden board materials for formaldehyde. With tile sizes of 15 x 20.8 cm^2, common in the tests (two tiles each), only one length of 9.6 cm open edge remains and thus corresponds to the edge of standard wooden board materials of 100 x 200 cm². The floor coverings (2 x cork parquet, 1 x laminate) were connected and covered back to back with a self adhesive aluminium foil along the edge. They were then placed in standing position in the 23-litre chamber.

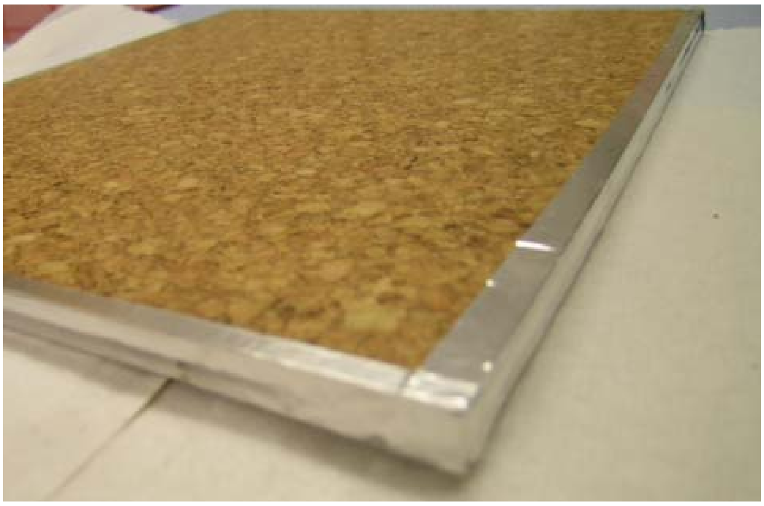


Figure 3-4: Cork parquet plates prepared for chamber tests

Paints and lacquers:

The liquid dispersion and latex wall paints were also acquired from the shops as a standard commodity and were applied evenly on the glass plates with the help of a thin film applicator with a gap of 200 µm. In order to achieve as good a coverage of the glass surface as possible, other plates of the same size were used during the application in front and behind the plate to be covered (Figure 3-5).

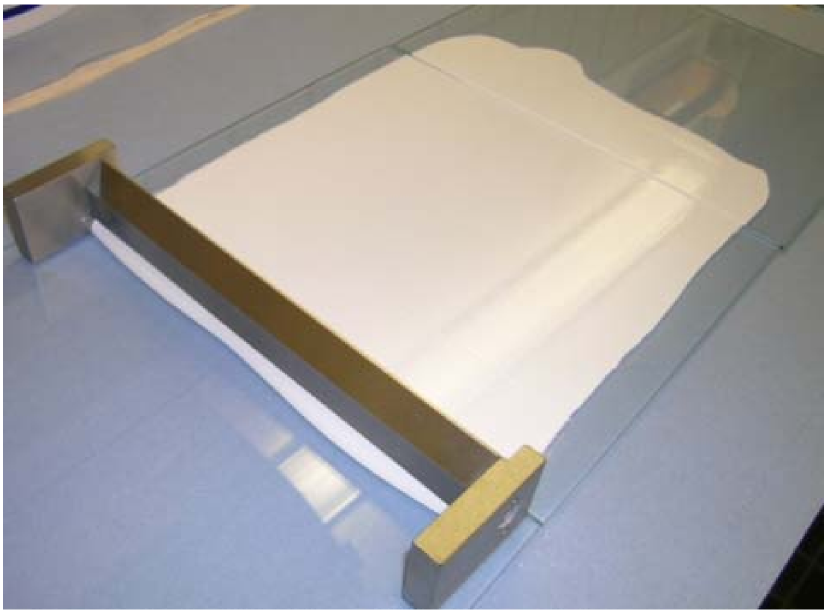


Figure 3-5: Application of wall paint on a glass plate with the help of a 200-µm thin film applicator.

The glazes or lacquers which were not wall colours were applied on carrier tiles or also on glass plates. This application was brushed on (Figure 3-6). By weighing the samples it was guaranteed that paint applications complied with the manufacturer's data. In some cases for comparison's sake the same lacquer or glaze was applied on glass or another, usually adsorbent carrier. These other carrier plates were: pine wood, beech wood, gypsum wallboard or screed.

Figure 3-6: Application by brush of a lacquer on a wood carrier material

Adhesives:

The adhesives tested were applied with a notched trowel on glass plates (22 x 27 cm^2). Like most other building products, the spread plates were placed into the chamber after about one hour.

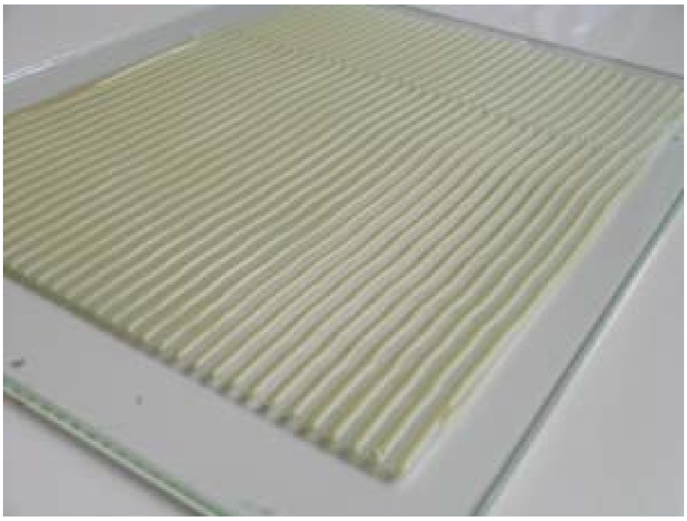


Figure 3-7: Application of an adhesive on a glass plate

Other building products tested

Other products tested in the project, such as gypsum wallboard, tile wall paper or primer, were all measured at $q = 1\ m^3\ m^{-2}\ h^{-1}$. The tile wall paper was stuck to a glass plate with the help of a special tile adhesive which had been previously tested. The primer was applied to the gypsum wallboard which had also been previously tested in the chamber.

3.4 ANALYSIS

3.4.1 VOC ANALYSIS

The VOC sampling from test chamber air took place according to ISO 16000-6 [33]. The air sample was drawn through a glass tube filled with Tenax TA (similar to Figure 3-8). 20 ng cyclodecane in 1 µl methanol as an internal standard was introduced in the Tenax tubes before sampling. The sample volume was between 0.2 and 5 litre. The sample flow rate was 100 ml min^{-1} and was maintained with a FLEC pump from the Chematec company.

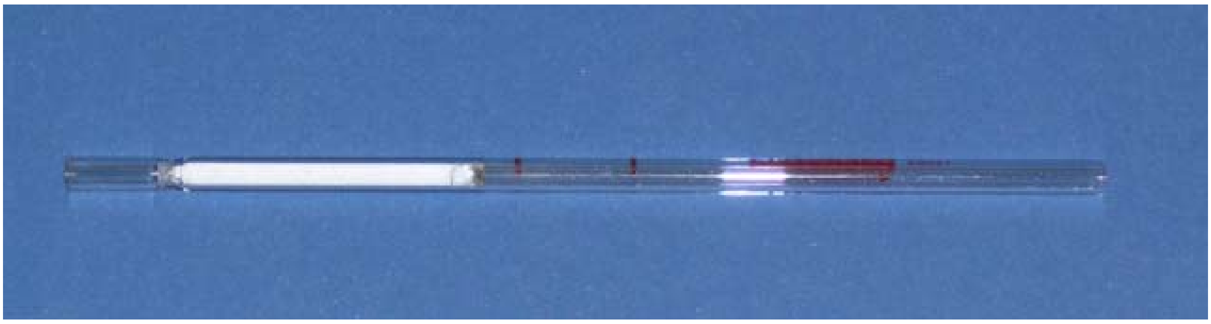


Figure 3-8: Tenax tubes as used for analysis

Chromatography conditions:

Injector (thermodesorption (TDS)):

• TDS system	Gerstel TDS – 2, splitless
• Start temperature	40°C
• Temperature programme	40 °C/min to 290°C isothermal for 5 min
• Cold injection system	Gerstel KAS – 4, electronically controlled, splitless 1 min
• Temperature programme	-100°C at 12 °C/s to 290°C isothermal for 5 min

• Liner	deactived glass tube with glass or quartz wool filling

Gas chromatograph:

• GC system	Agilent 6890
• Column type	HP 1 MS (dimethylpolysiloxane)
• Column dimensions	60 m, 0.25 mm, 0.25 µm
• Column flow	1.5 ml/min (constant flow)
• Oven programme	40 °C 3 min, 5 °C/min to 130 °C for 1.5 min at 5 °C/min to 240 °C at 25 °C/min to 290°C for 5 min

Detector:

• MS system	Agilent MSD 5973
• Temperature zones	Zone 1 (150°C/quadrupole), zone 2 (230°C/source)
• MS conditions	Solvent delay: 4.6 min; mass range 25 – 400 u
• Substance identification	Mass spectrum library NIST-02

The Tenax method enables the most VOC to be collected and detected using the method described above. In this project the determination limits for almost all components of the NIK list of the AgBB scheme were determined. Standard calibration series of the components were used for this purpose diluted to 1 ng µl^{-1} or below. This quantity corresponds to about an air concentration of 1 µg m^{-3} at a sample volume of one litre. The determination limits were estimated on the basis of the smallest calibration standards. For most of the NIK components a determination limit of 1-2 ng µl^{-1} could be established, some were slightly higher. By increasing the sample quantity for components with a higher determination limit, lower concentrations of around 1 µg m^{-3} were obtained. A few compounds, mostly those having stronger polar characteristics, exhibit higher determination limits in the column used.

3.4.2 DNPH ANALYSIS

Aldehydes and ketones, among them formaldehyde, can be proved very sensitively using 2,4-dinitrophenylhydrazine (DNPH) (ISO 16000-3 [34]). The resulting reaction products from aldehydes and ketones with DNPH can easily be measured using high performance liquid chromatography (HPLC). Naturally, for this purpose solid-phase collectors are used which are coated with the derivatization reagent (DNPH on silica gel). Commercial Supelco sampling cartridges were used for the tests in this project.

Using a FLEC pump of mostly 30 litres of air at a collection rate of 500 ml/min, the loaded cartridges were stored in a refrigerator at approx. 6 – 8 °C after sampling and extracted with 1.5 ml acetonitrile for processing. The eluate was immediately measured with an HPLC where analysis took place with following device parameters:

- HPLC: HP1100 of Agilent Company (formerly Hewlett Packard) consisting of a binary pump, gas-sampling valve, columns, thermostat, vacuum degasifier and DAD (diode-array detector)
- Column: ULTRASEP ES ALD 125 x 2.5 mm, 3 µm
- Column temperature: 35 °C
- Solvent:

Acetonitrile	Water	Time
45 %	55 %	10 min
80 %	30 %	12 min
90 %	10 %	18 min
100 %	0 %	25 min
45 %	55 %	35 min

- Flow: 0.200 ml/min
- Injection volume: 5 µl
- Wave length: 365 nm for quantification
- Assessment: HP Chem Station for LC Systems Rev.A.05.01

Figure 3-9: DNPH sampling cartridge for aldehydes and ketones

Substances calibrated using this method are:

Formaldehyde, acetaldehyde, acetone, propanal, butanal, benzaldehyde, pentanal, hexanal, heptanal, octanal, nonanal, decanal, pentenal, hexenal, heptenal, octenal, nonenal, decenal, undecenal, dodecenal, cyclohexanon and crotonaldehyde.

The procedure described here can provide determination limits from 0.5 to 2 ng µl^{-1}, where determination limits smaller than 1 ng µl^{-1} refer to the rather short-chain aldehydes and ketones such as formaldehyde, acetaldehyde and acetone. The determination limits are indicated for standard solutions, they can be somewhat higher for actual samples.

3.4.3 SVOC ANALYSIS

Figure 3-10 shows emission test chamber sampling for SVOC which is performed using polyurethane foams (PU foams) as adsorbents.

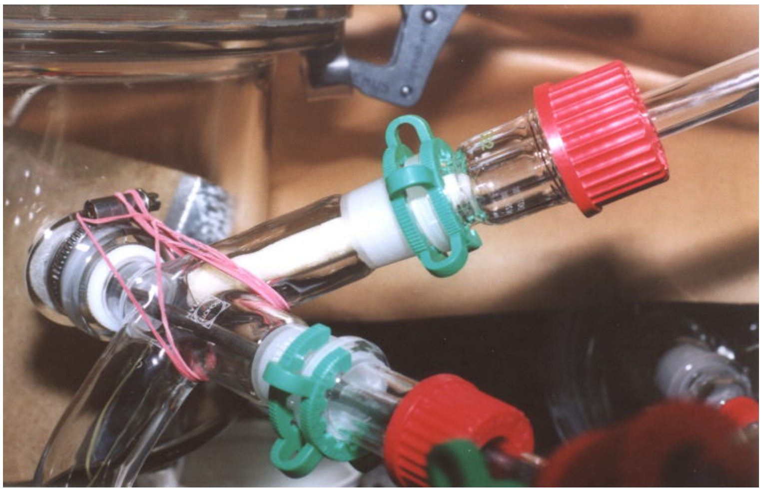


Figure 3-10: Sampling using PU foams at a 23-litre chamber with sample bodies

Glass tubes with an outside diameter of 14 mm contain two properly cleansed foam sections, one behind the other through which up to 6 m³ air is sucked in order to enrich the active substance components in the chamber air. Sampling times of up to three days are obtained for the above volumes at an average sampling speed of about 100 l/h. Following sampling the two PU foams are transferred to a 100-ml pear-shaped flask and covered with approximately 30 ml acetone and extracted in an ultrasonic bath for 45 min. Afterwards the foams are removed, squeezed and rinsed again with acetone. First 1 ml n-hexane is added to the PU foam extract, then it is concentrated in a rotary evaporator and by evaporating with nitrogen and finally made up to 1 ml and analyzed.

Chromatography conditions:

Injector (splitless):

Cold injection system	Gerstel KAS – 4, electronically controlled, splitless 1.5 min
Temperature programme	60°C at 12 °C/s to 280°C isothermal for 3 min
Injections volume:	1 µl
Syringe cleaning	3 x before and 3 x after injection with solvent

Gaschromatograph:

GC system	Agilent 6890
Column type	HP-5-MS
Column dimensions	30 m, 0.25 mm, 0.25 µm
Column flow	1.1 ml/min (constant flow)
Oven programme	40 °C 2 min, 5 °C/min to 150 °C at 10 °C/min to 300 °C for 5 min

Detector:

MS system	Agilent MSD 5973
Temperature zones	zone 1 (150°C / quadrupole), zone 2 (230°C / source)
MS conditions	Solvent delay: 6 min; mass range 25 – 400 u
Substance identification	Mass spectrum library NIST-02

3.4.4 VVOC ANALYSIS

In addition to Tenax sampling, various other adsorbents were tested in the project. Special attention was placed on phases comparable or stronger than Tenax. Essentially Carbotrap and Carbotrap C phases (each 20/40 mesh) and Carboxen 569 (20/45 mesh/all Supelco phases) were tested. Depending on their adsorption strength, two and three-phase sampling tubes were manufactured. The two-phase sampling tubes contained both Carbotrap adsorbents with the stronger adsorbent downstream in each case. The three-phase pipes also contained Carboxen. These three-phase sampling tubes had the disadvantage that no methanolic standard solution can be added to it, since the solvent remains almost entirely on the final phase. The Carbotrap adsorbents also need higher desorption temperatures than does Tenax.

Chromatography conditions:

Injector (thermodesorption (TDS)):

TDS system	Gerstel TDS – 2, splitless
Start temperature	30°C
Temperature programme	30 °C/min to 320°C isothermal for 10 min
Cold injection system	Gerstel KAS – 4, electronically controlled, splitless 1.5 min
Temperature programme	-120°C at 12 °C/s to 260°C isothermal for 5 min
Liner	Deactivated glass pipe with glass or quartz filling

Gaschromatograph:

GC system	Agilent 6890
Column type	DB-624 (methylphenylcyanopropyl polysiloxane)
Column dimensions	30 m, 0.25 mm, 1.4 µm
Column flow	1.1 ml/min (constant flow)
Oven programme	40 °C 2 min, 3 °C/min to 100 °C at 6 °C/min to 230 °C for 6 min

Detector:

MS system	Agilent MSD 5973
Temperature zones	Zone 1 (150°C/ quadrupole), zone 2 (230°C/source)
MS conditions	Solvent delay: 2.4 min; mass range 25 – 400 u
Substance identification	Mass spectrum library NIST-02

3.4.5 THERMAL EXTRACTION

Small sample quantities of a few milligrams were taken for a direct measurement in GC from all tested building products, with the exception of tile-shaped products. The pastes or liquid products were applied to an aluminium foil and after drying and ventilating over night inserted into a thermodesorption tube and directly thermodesorbed. A TDS temperature from 40 °C to 90 °C was usually used; 60 °C being indicated among the chromatography conditions as an example.

Chromatography conditions:

Injector (thermodesorption (TDS)):

TDS system	Gerstel TDS – 2, splitless
Start temperature	40°C
Temperature programme	5 °C/min to 60°C isothermal for 6 min
Cold injection system	Gerstel KAS – 4, electronically controlled, splitless 1 min
Temperature programme	-100°C at 12 °C/s to 290°C isothermal for 5 min

Gaschromatograph:

GC system	Agilent 6890
Column type	HP 1 MS (dimethylpolysiloxane)
Column dimensions	60 m, 0.25 mm, 0.25 µm
Column flow	1.5 ml/min (constant flow)
Oven programme	40 °C 3 min, 5 °C/min to 130 °C for 1.5 min at 5 °C/min to 240 °C at 25 °C/min to 290°C for 5 min

Detector:

MS system	Agilent MSD 5973
Temperature zones	Zone 1 (150°C/quadrupole), zone 2 (230°C/source)
MS conditions	Solvent delay: 4.6 min; mass range 25 – 400 u
Substance identification	Mass spectrum library NIST-02

3.4.6 ODOUR DETECTOR MEASUREMENTS

Simultaneously to the pure chemical analyses several products were tested with the help of a combination of thermodesorption with gas chromatography and a olfactory detector (GC/ODP), in parallel to mass-selective detection (MSD). The following conditions were applied for these investigations:

Chromatography conditions:

Injector (thermodesorption (TDS)):

TDS system	Gerstel TDS – 3, splitless
Start temperature	40°C

Temperature programme	40 °C/min to 290°C isothermal for 3 min
Cold injection system	Gerstel KAS – 3, electronically controlled, splitless 1 min
Temperature programme	-100°C at 12 °C/s to 290°C isothermal for 5 min

Gaschromatograph:

GC system	Agilent 5890 A
Column type	HP 1 MS (dimethylpolysiloxane)
Column dimensions	30 m, 0.25 mm, 0.25 µm
Column pressure	1.2 bar (constant pressure system)
Oven programme	35 °C 6 min, 5 °C/min to 45 °C at 30 °C/min to 280 °C for 1 min

Detector:

MS system	Agilent MSD 5971
Temperature zones	Transfer line 300 °C
MS conditions	Solvent delay: 0.5 min; mass range 25 – 220 u
Substance identification	Mass spectrum library NIST-02
ODP	Transfer line 280 °C, nitrogen flushing gas (moisturised)
Split ratio	ODP : MSD = 1 : 1

3.4.7 QUALITY ASSURANCE

Many of the analyses used standardised methods for which quality assurance measures are known. Fluctuations can be expected for different substances and substance classes depending upon analytical configuration. In order to compensate somewhat for typical mass spectrometer equipment variance, the TDS tubes were provided with an internal standard – usually cyclodecane. In addition, the suitability and quality of the laboratories can be proved through participation in interlaboratory tests at such investigations.

Apart from these purely analytical factors, the result can be significantly influenced by the samples, their homogeneity and preparation for the chamber test. Some materials, such as OSB and other building products which are sold in sales units, may yield different test results. If a purely homogeneous application is provided for the latter ones, then good reproducible samples can be produced which exhibit relative standard deviations usually much smaller than 10 % and only in some cases greater than 20 %. In the tests presented here an acrylic mass was tested nine times in chamber tests. Table 3-2 shows the results of these tests.

Table 3-2: Test results of nine chamber tests of the same product

Day		1-butanol	Propylene-glycol	n-butyl-ether	Butoxyethoxy ethanol	Dodecane	TVOC
Day 1	**Mean**	**332**	**295**	**60**	**91**	**14**	**883**
	RSD %	***12***	***18***	***7***	***20***	***5***	***9***
	Median	*352*	*305*	*61*	*89*	*14*	*926*
Day 3	**Mean**	**145**	**212**	**39**	**56**	**12**	**532**
	RSD %	***18***	***7***	***7***	***15***	***11***	***7***
	Median	*130*	*206*	*38*	*63*	*12*	*537*
Day 8	**Mean**	**45**	**97**	**27**	**22**	**8**	**247**
	RSD %	***15***	***16***	***9***	***25***	***7***	***9***
	Median	*45*	*104*	*26*	*22*	*8*	*251*

RSD % = relative standard deviation

The relative standard deviations determined can be regarded as satisfactory considering the complex investigation methodology (chamber, sampling and analysis influences). It was also tested to see what deviations arise when standard solutions are prepared by different people from the same pure standard components using the otherwise same analytical technique. Three different assistants prepared the same solutions three times which were measured using the standard VOC method. A high reproducibility was found using absolute standard concentrations around 100 ng on the tube (Figure 3-11). For propylene glycol the deviation was 30 % at a very low concentration of 10 ng, the remaining components however showed less than 5 % deviation in this concentration range.

The values were corrected with the internal standards.

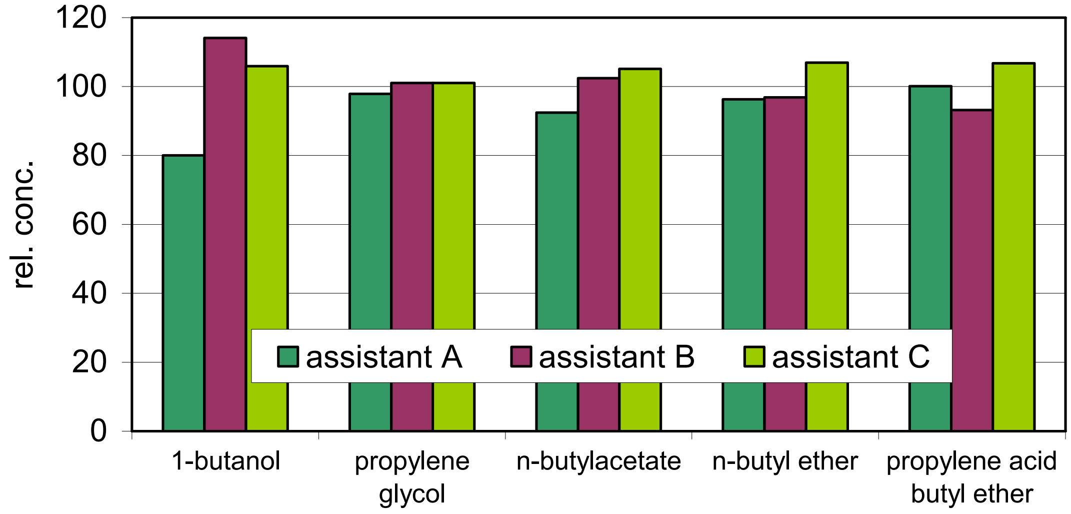


Figure 3-11: Standards with a content of approx. 100 ng ml^{-1} prepared by three different assistants (∇ 100 ng m^{-3} concentration in the air at 1 litre sample), which were tested with the same methods

3.5 ODOUR MEASUREMENTS

3.5.1 SAMPLING

The AgBB scheme does not specify the emission chamber size. With the reference to test chambers according to ISO 16000-9 temperature, humidity and air exchange rate are highly specified, however the emission chamber size can be individually specified. Emission chambers with a volume of 20 to 1000 litres for variations of specimen sizes are common in the market. By defining the loading density, very different flow rates are available for a chemical analysis and sensory assessment. For example 0.03 l s^{-1} of sample air can only be obtained for a floor covering in a sensory test using a 23-litre chamber, while 0.35 l s^{-1} of sample air when a 1 m³-chamber is used. The quantities mentioned are however insufficient to make an assessment (s. 3.5.2), so that the odour cannot be judged directly at the emission test chambers. However, in order to be able to evaluate the odour in the exhaust air stream of these chambers, the exhaust air must be collected in such a way as to not affect its odour characteristics.

Müller tested [44] numerous plastic materials for their suitability for odour sampling and Tedlar was proved suitable as a universal material. This thermoplastic material based on polyvinylfluoride is characterised by being highly inert and a minimum diffusion of VOC. 300-litres cushion-shaped containers were welded from this material which formed the core of the sampling and sample provision system called AirProbe and developed by Hermann Rietschel Institute. In order not to affect sample air, the material was annealed before and after use for several hours at a minimum of 80 °C. Production details of sampling containers and further instrumental characteristics are described in more detail in the annex.

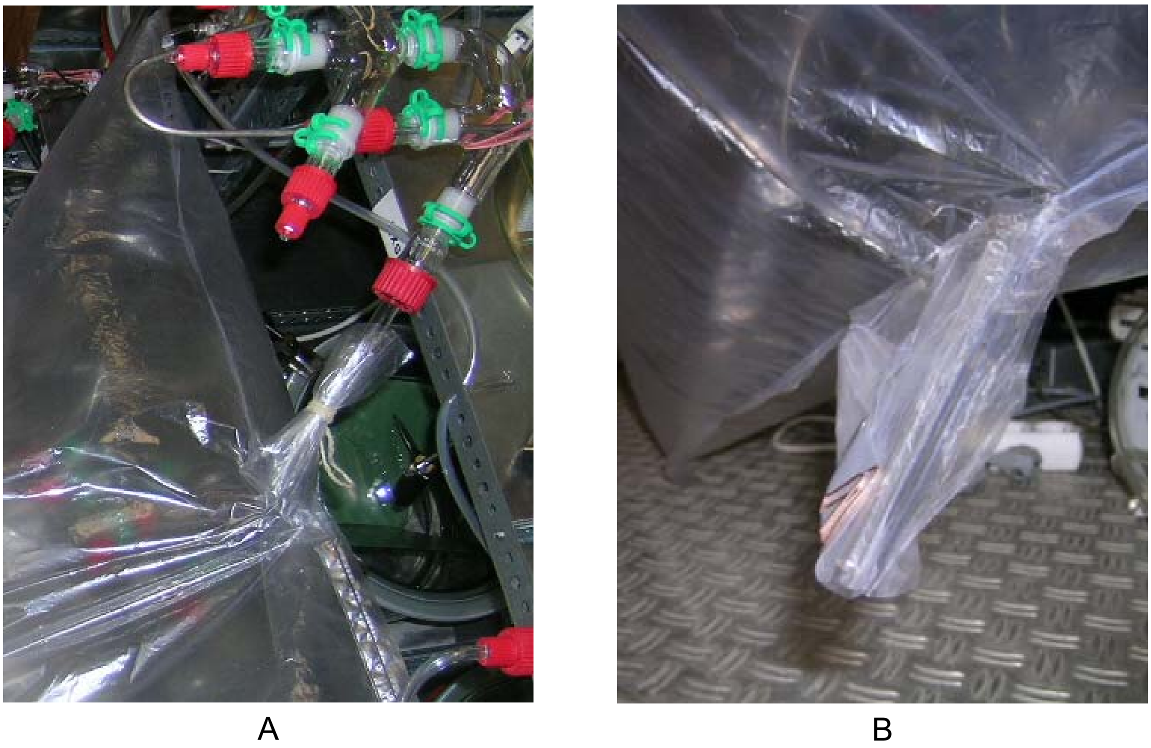


Figure 3-12: Connection of the Tedlar containers to the 23-litre chamber (A) and the provision of the container end with a small pipe (B)

It is possible to collect sample air over a long period of time using pre-treated Tedlar containers. Sample air can be stored, transported and provided under controlled boundary conditions to a panel for sensory assessment. The sampling is easy to perform using the 1-m³ chamber for which purpose all but one of the openings (diameter approx. 20 mm) of the chamber are sealed. The container is connected to this opening and is filled within about 20 min (at an air exchange rate of 1 h^{-1}). The air in the bag is exchanged two more times so that it corresponds to the air quality in the chamber. This method had to be modified for the small 23-litre chambers. The container was also firmly connected through a 14-mm tube to the exit of the test chamber which was changed to a smaller pipe (6 mm in diameter) after about 3 h. This lets surplus air flow out and the container is continuously filled up

(Figure 3-12). Thus the odour in the bag (container) filled, say overnight, can be assessed.

3.5.2 SAMPLE PROVISION

According to Silbernagel [45] resting humans breathe approximately 15 times a minute and inhale a volume of 7.5 l/min. This means that, on average, humans have a breathing volume of 0.5 l. At least this minimum volume must be provided to the panel members during the tests. Knudsen [46] investigated the evaluation of perceived air quality as a function of flow rate at the nose of the panel members and/or at the exit of the funnel. The investigation showed that measurement accuracy for the assessment of perceived air quality is only constant from a flow rate of approx. 0.5 l/s to 0.6 l/s at the funnel end. Lower flow rates fail to provide an exact assessment of perceived air quality.

Sensory investigations should be performed as far as possible in a low-odour environment. Spatial conditions in laboratories, where extensive emission tests are carried out, do not usually allow direct sensory investigations with a larger panel. The 300-litre Tedlar container described in Chapter 3.5.1 enables sensory investigations to be carried out in a neutral room. The air quality laboratory of the Hermann Rietschel Institute provides optimum site conditions for sensory assessments. The surfaces of the rest area for the panellists and the test room are built from glass. The two rooms are supplied via an air conditioning system with air where the components in contact with air are manufactured from glass or stainless steel. For routine investigations normally ventilated and non-odourous rooms are regarded as sufficient.

The AirProbe [44] is equipped with the 300-litre Tedlar containers described above which can be exchanged on site with other ones, so that repeated sampling and sample collection can take place. The device is designed for sample collection in such a way that when emptying the Tedlar container, sample air comes exclusively into contact with the odour-neutral materials stainless steels, glass and PTFE. With a volumetric air flow of 0.7 to 0.9 l/s of the sample the panel has a period of between 5 and 6 minutes for the sensory assessment of an air sample.

The following test schedule was established for a typical test day:

- The sample containers are attached and filled directly from the test chambers in BAM.

- Sample air from the test chambers and the sample container is chemically analysed to guarantee that the sample air for odour assessment agrees with the sample air for chemical analysis.
- The air samples in the containers are transported to the air quality laboratory within 3 hours.
- A trained panel evaluates each sample in the air quality laboratory.

To quality assure the results achieved, additional tests on selected building materials were carried out using CLIMPAQs in the air quality laboratory of Hermann Rietschel Institute. The CLIMPAQ was developed by Gunnarsen, Nielsen and Wolkoff at the Technical University of Denmark in Copenhagen in 1994. As in all investigations of pollution sources, low-emission materials were used to build these test chambers. The schematic structure of a chamber is depicted in Figure 3-13. The direction of air flow is indicated by arrows in Figure 3-14. The majority of the kinetic energy of the supply air is dissipated immediately after entering the chamber by an impact plate. This plate is followed by the first of two laminarisator plates. This provides for an even distribution of the air flow over the entire chamber cross-section. The actual test chamber with the material to be tested is the space between the two laminarisators.

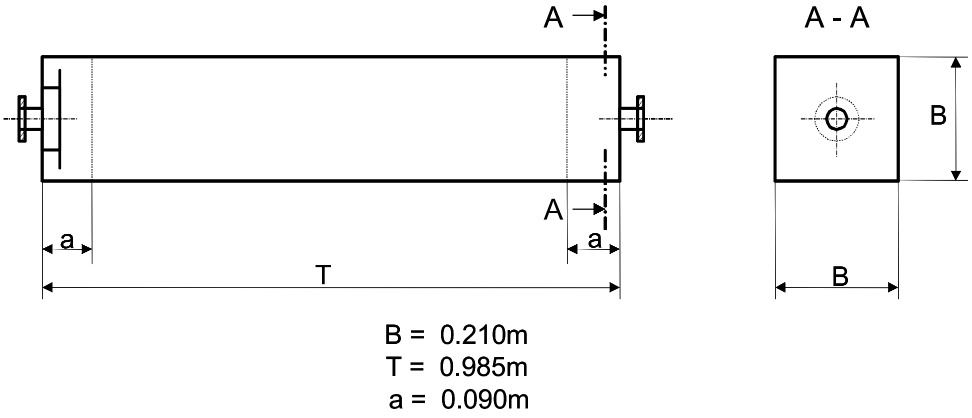


Figure 3-13: Structure of a test chamber

The air is fully contaminated by the material to be tested by the time it reaches the exit of the test chamber. The laden air is assessed by a trained sensory panel directly.

Selected building materials were simultaneously tested in the laboratory of BAM and in the air quality laboratory of Hermann Rietschel Institute. The same building material samples were placed simultaneously in a test chamber and a CLIMPAQ, and – for comparability of the measurement results – adjusted to an identical loading density. In addition to the direct comparison of the sensory assessments of the panellists at CLIMPAQ and AirProbe, the experiments could be performed with the electronic nose at the Hermann Rietschel Institute with this experimental arrangement.

The test stand for the assessment of the odour delivery of material samples in the CLIMPAQ is devised in such a way that sample air can be evaluated at different stages of dilution. Thus the influence of dilution on the odour intensity of the sample can also be examined. The experimental setup is schematically illustrated in Figure 3-14.

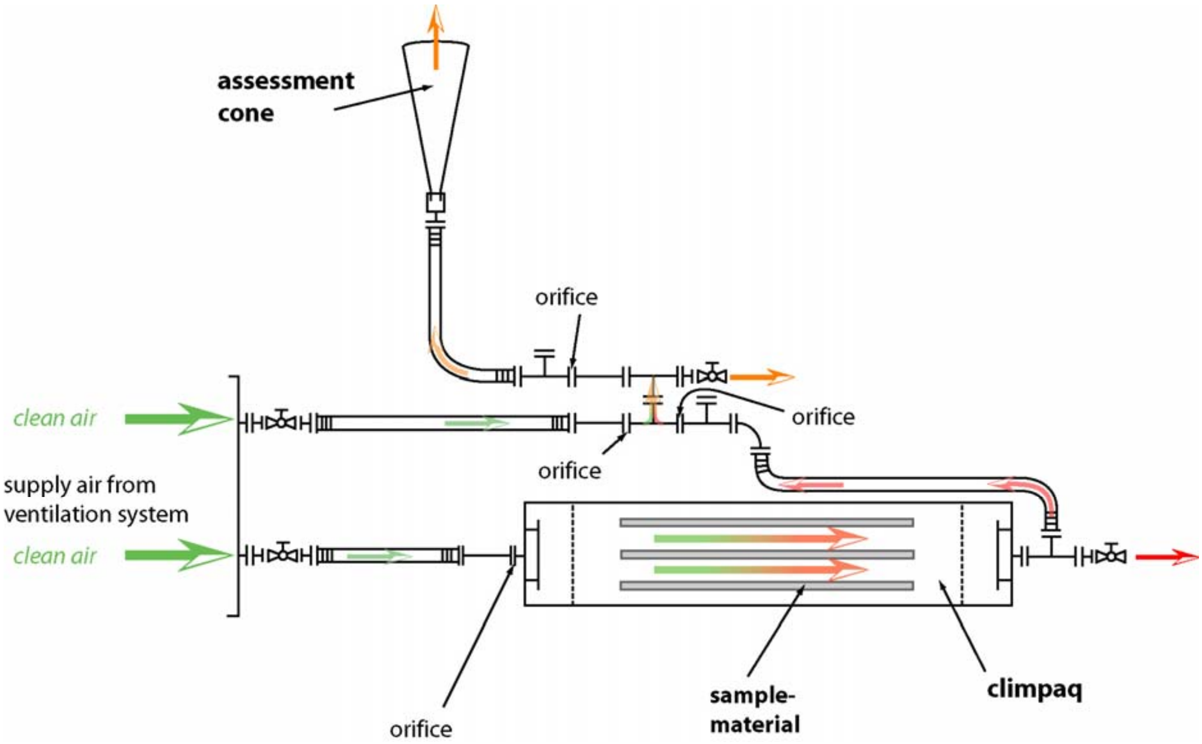


Figure 3-14: Experimental setup for the assessment of building materials in a CLIMPAQ

Clean air can be added to the sample air flow behind the CLIMPAQ. Thus the concentration of the impurities in the air flow is reduced and it is possible to adjust different dilution stages. This air is provided for assessment at a measurement funnel. The panel assesses the perceived odour intensity at the funnel while the substances in the sample air are measured using the multi-gas sensor system.

The volumetric air flow above the sample was adjusted to a constant 1 l s^{-1} in the tests, so that the same emission conditions were present in the CLIMPAQ at all dilution stages. Thus the specific flow rate was kept constant during the entire test period. A valve before the assessment funnel makes it possible to adjust a constant flow rate at the funnel to avoid a changing flow rate influencing the odour perception of the panellists.

A dilution characteristic is obtained for each tested material as a result of a test series in which the odour intensity of the sample and the sensor resistances are illustrated as a function of the concentration of the emitted substances. Böttcher's investigations [40] into the perception of odorous substances showed comparable to Weber-Fechner [41] that the perceived odour intensity can be approximated by a logarithmic relationship as a function of the concentration of the substances:

$$\Pi = a \cdot \log_{10}(\frac{c}{c_0})$$

where
a: substance or substance mix-specific constant
c: concentration of substance/substance mix [mg m^{-3}]
c_0: concentration of substance/substance mix at the odour threshold [mg m^{-3}]

Since the concentrations of the emitted substances are unknown when testing building materials, a constant emission is assumed so the equation can also be written using a flow rate-specific area load A_q as

$$\Pi = a \cdot \log_{10}(\frac{A_q}{A_{q,0}})$$

It applies to the flow rate-specific area load A_q:

$$A_q = \frac{A_{\text{sample}}}{\dot{V}}$$

where
A_{sample}: surface of the sample covered by the flow [m²]
$\dot{V}$: air flow rate [m³/h]

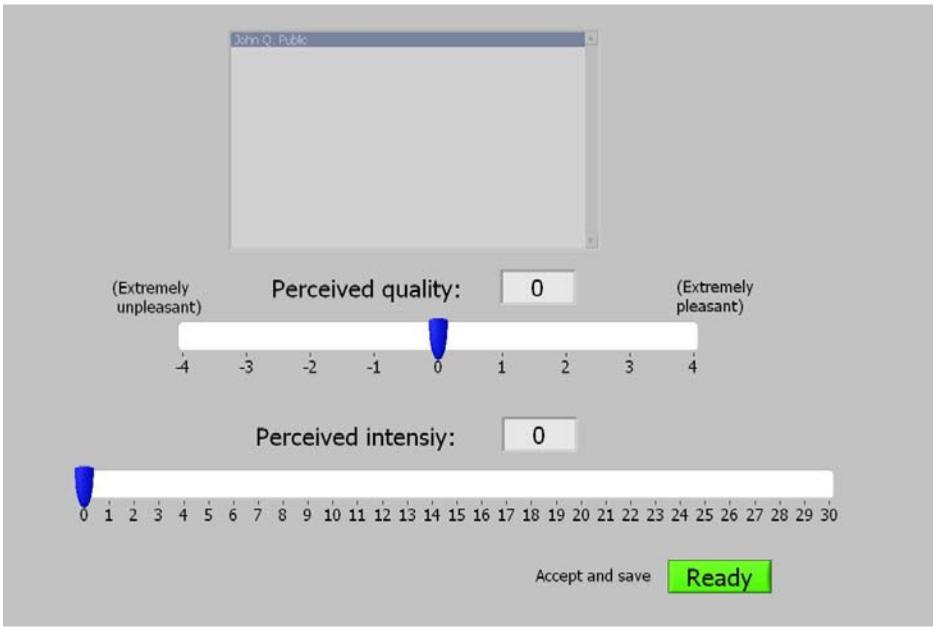
The flow rate-specific area load $A_{q,0}$ is the area load with which the odour threshold is exceeded.

3.5.3 ASSESSMENT METHOD AND EVALUATION

The sensory testing of the building products was carried out by a trained sensory panel in the air quality laboratory of the Hermann Rietschel Institute. The four-day training and selection method are described in detail in the annex "Manual for the Measurement of Perceived Air Quality ".

Each test day starts with two evaluation series of different acetone concentrations. In this way, the panel becomes accustomed to the environment and test conditions. The test manager provides two acetone concentrations at the comparative scale, which are within the available comparative concentrations from 1 to 12 pi.

Subsequently, the panellists first evaluate the odour intensity of the building products. To facilitate the classification of the perceived intensity and improve the comparability of the test results, the comparative scale can be used for the assessment of the intensity. The panellist enters the value determined by him into data acquisition software (Figure 3-15). Additionally the hedonics is also assessed on a 9-point scale between 'extremely unpleasant' and 'extremely pleasant'. For assessment of the hedonics no comparative scale is necessary.



John Q. Public

Perceived quality: 0

Perceived intensiy: 0

Figure 3-15: Data acquisition software for the assessment of the odour sample

The assessments are saved in a text file as raw data and then evaluated automatically. For the perceived quality and perceived intensity the arithmetic mean values and the standard deviations are calculated, saved in a spread-sheet calculation and represented graphically.

3.5.4 MULTI-GAS SENSORS ("ARTIFICIAL NOSES")

In addition to odour assessment by panels the emissions of some building products were also measured using multi-gas sensor systems. Since panel tests are expensive, the viability of these sensor systems for odour assessment should be tested. Research is currently going on at Hermann Rietschel Institute to see if the sensor systems can be used to assess odour intensities.

Multi-gas sensor systems measure gaseous impurities in sample air. However, no analytical determination of the individual components and their concentrations takes place. The sensors are non-selective and only measure the cumulated signals of different substances. The systems are characterised by the combination of several different sensors, so that as many substances occurring in the air can be detected as possible. The various measurement ranges (detected substances, sensitivities) of the sensors provide a signal pattern that characterises the substance mixture. The strength of these systems lies in the capability of recognizing and evaluating changes of a certain composition. Thus the systems are particularly well suited for product monitoring e.g. in the food industry. However, individual pollutants are difficult to be quantitatively determined due to the high cross-sensitivities.

Multi-gas sensor systems apply the principle of odour perception and are therefore also called "artificial noses", although their measurement sensitivity and the ability to recognise odours are far behind the human sense of smell. The comparison with the human nose raises expectations which these systems cannot provide. The sensor systems measure the impurities and cannot directly measure odours. The sensors respond both to odorous and odourless substances. In order to determine the odour of a sample, the sensor systems must be calibrated by comparing them with assessments made by a human panel for an odour determination. Equivalent to odour assessment by the human brain, subsequent mathematical signal processing is of crucial importance. A quantitative determination of odour intensity is only feasible if combined with data analysis.

Multi-gas sensor systems can be built from different types of gas sensors, which differ in the type of detection and measurand. Commercially available systems chiefly employ metal oxides, conducting organic polymers, piezoelectric quartz and surface acoustic waves as sensors.

Hermann Rietschel Institute uses the KAMINA sensor system. KAMINA stands for **Ka**rlsruhe **mi**cro **Na**se (nose) and was developed by the Karlsruhe Research Centre. A crucial aspect of the design was to develop a product as small as possible (22 x 6.5 x 6.5 cm^{-3}) which can be produced by modern manufacturing techniques (semiconductor technology) at an advantageous price. KAMINA consists of a measurement head with a sensor chip immersed in the sample air and evaluation electronics controlling the measurement process, temperature control and ventilator control. Figure 3-16 shows KAMINA during measurement on top the assessment funnel.

Figure 3-16: Kamina sensor system during measurement on top the assessment funnel

The sensors in KAMINA are metal oxide sensors. Sensor chips with various metal oxides and different numbers of sensors are available for KAMINA. Hermann Rietschel Institute's KAMINA works with a sensor chip equipped with 38 tin oxide sensors (SnO_2). In metal oxide sensors the electrical resistance of the sensor is measured which relates to the substances adsorbed on the sensor surface. Metal oxide sensors only work in an oxygen-containing atmosphere. The oxygen adsorbs on the surface of the sensors and binds electrons of the conduction band of the metal oxides. The reduction of the free electrons leads to an increase in the electrical resistance of the sensor. A dynamic equilibrium is reached among the oxygen species adsorbed at the surface (O^-, CO^{2-}, CO^{2-}, OH^-). The presence of volatile substances causes a shift in the equilibrium balance. Oxidizeable substances react with the adsorbed oxygen and the bound electrons return to the metal oxide. The electrical resistance decreases. Reducing substances such as NO_2 and O_3 increase the electrical resistance. The change in the electrical resistance is reversible.

The different sensitivity and selectivity of the sensors are achieved by adding different catalyst materials (platinum and palladium) in different concentrations to the metal oxide. The conductivity of the sensors can also be affected by the temperature to which the sensors are heated by a hot wire. Depending upon metal oxide used in the sensor, the optimum operating temperatures are between 200 to 500 °C.

The selectivity can also be changed by coating the sensor surface with a sensitive layer which affects the material transfer to the sensor surface. The sensor chip of Kamina is provided with a sensitive layer with a thickness gradient.

In the tests the building product samples were placed into CLIMPAQs. The investigations were carried out at a constant flow rate along with the analytical measurements in the emission chambers over a period of 28 days. The area-specific air flow rate was adjusted in such a way that it corresponded to the air flow rate in the emission chambers. The design of the CLIMPAQs was planned to allow comparative measurements with both the sensor system and the panel. For the panel assessment higher air flow rates were necessary than was available at the outlet of the emission chambers. The flow rate through the CLIMPAQs was kept constant at 1 l/s and provided sufficient air for the panel assessment. The area-specific flow rate was adjusted by a suitable choice of the surface of the sample material. Sample air can also be evaluated at various dilution stages by supplying odourless air after the CLIMPAQ.

On measuring days both material samples in the CLIMPAQ and sample containers with air from the emission chambers were evaluated. Additionally air samples from the CLIMPAQ were taken using Tenax tubes and the composition of the impurities was analytically determined.

It was found that odour assessment in the CLIMPAQ was always about 1-2 pi below the assessment of the sample containers. The trend of a sample was comparable over the 28 measuring days. The chemical analysis provided comparable pollutant concentrations.

4 RESULTS AND DISCUSSION

4.1 EMISSION TESTS (VOC + ODOUR)

50 building materials were tested in 52 emission chamber tests in accordance with the provisions of the AgBB scheme. Products which failed to meet the requirements after three days, were left in the chamber for 28 days. VOC and odour emission tests were performed on seven acrylic and six silicone sealing compounds, six synthetic resin premixed plaster pastes, seven OSBs, six other wood products, 13 paints and lacquers - seven wall paints, four adhesives and three further building products on the first, third, tenth and 28th day. VOCs were tested as per ISO 16000-6 [33] and ketones and aldehydes, as special types of VOC, as per ISO 16000-3 [34]. Odour measurements were performed using the method described in Chapter 3.5. Excerpts of the results will be discussed in the following subchapters, the detailed results of all 52 chamber tests can be found in the annex. The following subchapters contain evaluations in agreement with AgBB and in Tables. The requirement values in the AgBB scheme allow alternatives to be considered in the application to the measurement results received. The values are rounded mathematically to the number of decimal places as indicated in the scheme, thus an R value of 1.49 does not constitute an excess, since the value of 1 is acceptable, while 1.51 would be too high.

4.1.1 SEALING COMPOUNDS

The sealing compounds were prepared as described in Chapter 3.3. Some tests were performed simultaneously in the 23-litre chamber and the CLIMPAQ with $q = 83\ m^3\ m^{-2}\ h^{-1}$ in the CLIMPAQ. The results for the acrylic sealing compounds are displayed in Table 4-1 and those for the silicone sealing compounds in Table 4-2. In order to be able to better compare the results, the results of the sealing compounds with different q were converted to the value of $q = 44\ m^3\ m^{-2}\ h^{-1}$ as specified in the ISO 16000-9 standard. From this, the area-specific emission rates can be obtained in units of $\mu g\ m^{-2}\ h^{-1}$. However, the AgBB scheme uses chamber concentrations in $\mu g\ m^{-3}$, which is based on a measurement at chamber conditions and loadings similar to the ISO standard mentioned. Thus the above conversion does not correspond to the provisions of the AgBB scheme for another experiment, however it is possible to compare the results with one another.

The acrylic sealing compounds belong to the product family which harden to a flexible mass by evaporation of water and solubility promoter. It is these solubility promoters (water solubility of acrylic dispersions), usually consisting of glycols, which emit the main components from the product. Since they possess rather small NIK (LCI) values and usually constitute emissions of several hundred µg m^{-3}, this can easily cause that the relevant provisions in the AgBB scheme to be exceeded (Table 4-1). Thus the 3 sealing compounds with an R value greater than unity emit large quantities of ethanediol and dipropylene glycol. Sample number 3460 was left in the emission chamber for a long time with only the VOC ethanediol being recorded. After about 6 months a concentration of 74 µg m^{-3} was still present which corresponds to a value of approx. 150 µg m^{-3} at an area-specific flow rate of $q = 44\ m^{-3}\ m^{-2}\ h^{-1}$.

Table 4-1: Overview of the assessment of acrylic sealing compounds in accordance with the AgBB provisions.

Criterion / material	$TVOC_3$	$TVOC_{28}$	$\Sigma SVOC_{28}$	R	Non assessable VOC	AgBB assessment	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		Mg m^{-3}		q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1		$m^3 m^{-2} h^{-1}$
Acrylic 3332	0.85	0.15	0.051	0.11	0.033	passed	44
Acrylic 3351	4.7	*1.15*	0	*1.26*	0.047	failed	83*
Acrylic 3356	8.3	*2.8*	0	*5.11*	0.006	failed	83*
Acrylic 3460	7.2	0.53	0	*2.02*	0.06	failed	83*
Acrylic 3485	0.47	0.05	0	0.00	0.05	passed	83*
Acrylic 3647	0.58	0.09	0	0.09	0.032	passed	83*
Acrylic 3653	0.60	0.09	0	0.09	0.032	passed	44

* The measured values in the table were converted to $q = 44\ m^3\ m^{-2}\ h^{-1}$ to enable a better comparison.

Acrylic sealing compounds keep their flexibility to a large extent after hardening by the softeners included in the system. These are phthalates in about 50 % of cases and chiefly isononyl phthalate. The sealing compounds were qualitatively tested by grinding hardened samples and extracting with toluene or dichloromethane and a subsequent injection into a GC/MS. In addition to phthalates, adipates were detected; sometimes no indication was found regarding the type of softener. The chamber test on the acrylic sealing compound 3460 ran for a period of nearly 20 months in order to try and prove emitting softeners in the air. During this period samples were taken several times on a PU foam in order to verify phthalates in the air. The determination limit for this method was about 100 ng m^{-3} (with 10 m^3 samples) for phthalates. This method was not sensitive enough for the measurement of phthalates, so none of these compounds could be proved in the air.

In addition to acryl-based sealing compounds the emissions from silicone sealing compounds were also tested. Silicone sealing compounds are used particularly on the sanitary ware, in kitchens, at windows and externally where good resistance to water and high elasticity are of prime importance. Silicone sealing compounds cannot be painted over which prohibits their use in some applications. They cross-link after application and give off an organic residue. The most familiar residue is acetic acid; other common systems are alkoxy groups, which give off alcohols and occasionally oxim releasers are used. In this project acetates and alkoxy systems were tested. The emission of acetic acid is analytically noticeable after the first few days of the test. Over this time, concentrations of several milligrams per cubic meter of acetic acid can result in the chamber air. After 28 days however none or only minor emissions of acetic acid from the products can be proved. Alkoxy based sealing compounds usually give off methanol, but this could not be proved quantitatively using the methods presented here. For some sealing compounds methanol or ethanol was found in the first hours and days, but the column used (DB-624, Section 3.4.4) did not enable an exact determination, although the concentration range lay above 1 mg m^{-3}.

Table 4-2: Overview of the assessment of silicone sealing compounds in accordance with the AgBB provisions

Criterion / material	TVOC $_3$	TVOC $_{28}$	ΣSVOC$_{28}$	R	Non assessable VOC	AgBB Assessment	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1		m^{3}m^{-2}h^{-1}
Silicone 3333	5.6	*1.4*	*1.8*	0.09	*1.4*	failed	10*
Silicone 3338	*10.3*	*1.7*	*0.18*	0.04	*1.0*	failed	44
Silicone 3353	*12.1*	*3.7*	*1.85*	*0.15*	*3.6*	failed	83*
Silicone 3477$^{\#}$	7.6	0.41	0	0.00	*0.40*	failed	44
Silicone 3478	1.1	0.21	0	0.00	*0.20*	failed	83*
Silicone 3707	7.9	0.37	0	0.00	*0.36*	failed	44

* The measured values indicated in the table were converted to q = 44 m^3 m^{-2} h^{-1} in order to be able to better compare them. # 26 µg m^{-3} of benzene was detected in the case of this silicone on the third day, while a maximum 10 µg m^{-3} of carcinogenic material may be contained according to the AgBB scheme.

Table 4-2 shows the cumulative values of the VOC assessment in accordance with the AgBB scheme. All values have been converted to q = 44 m^3 m^{-2} h^{-1} in order to be better able to compare them. It is noticeable that none of the silicone sealing compounds passed the AgBB-assessment. Even the sealing compounds, which exhibit only relatively small initial concentrations, exceeded the limit on the 28th day in the case of VOC without NIK (LCI). Emissions of cyclic siloxanes - e.g. decamethyl cyclopentasiloxane (D5) (see Figure 4-1), dodecamethyl cyclohexasiloxane (D6) or tetramethyl cycloheptasiloxane (D7) - are responsible for this for which no NIK (LCI) values are available in concentrations above 100 µg m^{-3}.

These cyclic components can be proved as emissions from all tested silicone sealing compounds. The exact cause for this is not clear; they might be impurities from the production process. Silicon oils, which are used as softeners in some sealing compounds, are open long-chained silicones. In the case of some other sealing compounds larger quantities of hydrocarbons were detected which probably have a similar function as the silicone oils. In one of the cases benzene was also found in the product, this was possibly due to contamination with one of the hydrocarbon mixtures since other cyclic aromatics were also be detected (details in the Annex (3477)).

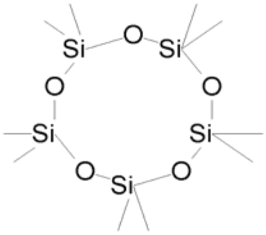


Figure 4-1: Structure of the decamethyl cyclopentasiloxane compound

The Environmental Award Jury established a new Environmental Award, the "Blue Angel" in January 2006: RAL-UZ-123, Low-Emission Sealing Materials [47]. The criteria for the tests of sealing compounds here are analogous to the AgBB scheme, although with stricter provisions on the emission values (Table 4-3). The provisions on the sum of $VOC_{without\ NIK}$ and the R value are suspended for the first validity period of 4 years. The values are only measured and indicated, but not considered when awarding of the Environmental Award.

If these conditions are assumed for the assessment of sealing compounds in Table 4-1 and Table 4-2, one silicone product and four acrylic products meet the provisions of Blue Angel. However, it must be emphasised that the products tested in this project were about twice the normal mass loading, since the profiles had a 6-mm flank height instead of 3 mm – as required by the standard – so that the results are not completely comparable with the provisions of Blue Angel.

Table 4-3: Provisions on joint sealing materials as per RAL-UZ-123

	Provision	
Substance	**3 days**	**28 days**
Sum of organic compounds within the retention range $C_6 – C_{16}$ (TVOC)	≤ 2000 µg m^{-3}	≤ 300 µg m^{-3}
Sum of organic compounds within the retention range $C_{16} – C_{22}$ (ΣSVOC)	-	≤ 30 µg m^{-3}
C substances	≤ 10 µg m^{-3} sum	≤ 1 µg m^{-3} per individual value
Sum of VOC without NIK (LCI)	-	≤ 100 µg m^{-3} [#]
R value	-	< 1 [#]
Formaldehyde		≤ 0.05 ppm
Other aldehydes		≤ 0.05 ppm

The sensory assessment is fundamentally capable of distinguishing acrylic and silicone sealing compounds from each other. After a relatively high initial value of up to 20 pi, nearly all perceived smell intensities of the acrylic products dropped considerably as shown by the example in Figure 4-2.

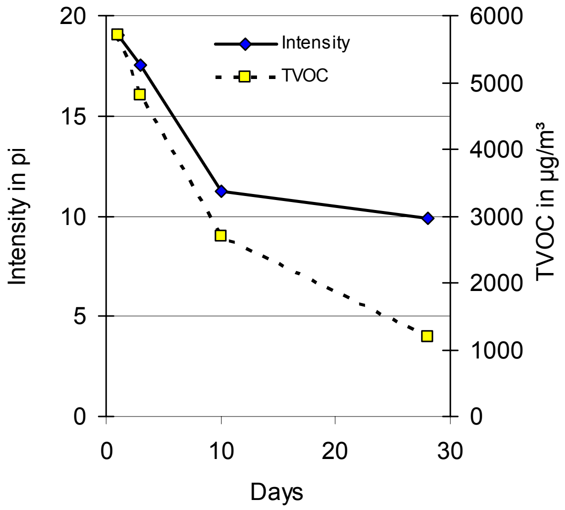


Figure 4-2: Intensity and TVOC for Acryl 3351

[#] The sum of VOC without NIK (LCI) is determined by the test institutes in the first period of the award and included in the test report, but does not lead to refusal when the limit is exceeded. The decision to include a value is taken at the hearing of the award revision by taking the results into account.

The perceived odour intensity of Acryl 3356 rose from the first to the third day of the test although the TVOC values decreased considerably in the sample air. Diethyleneglycol constitutes a material amid the individual compounds detected whose concentration increased from the first to the third day and dropped again toward the 28th day, similarly to odour and opposed to the TVOC values (Figure 4-3). Diethyleneglycol with a lower odour threshold of 0.21 mg m^{-3} was detected at a concentration unlikely to affect the odour of the sample air. It was however an indicator for a change of the composition of the emitted materials.

The two silicones tested by sensors show a completely different behaviour to acrylic sealing compounds: after decreasing on the third and tenth day, the intensity clearly increased on the 28th day again. A connection with the measured TVOC values and the measured individual compounds cannot be established.

Altogether acryls have a better sensory assessment after 28 days than silicons within the building material group of sealing compounds. Acryl 3460 and Acryl 3485 however exhibited comparatively high intensities as opposed to the other tested acrylic sealing compounds after 28 days and received a poor hedonistic assessment.

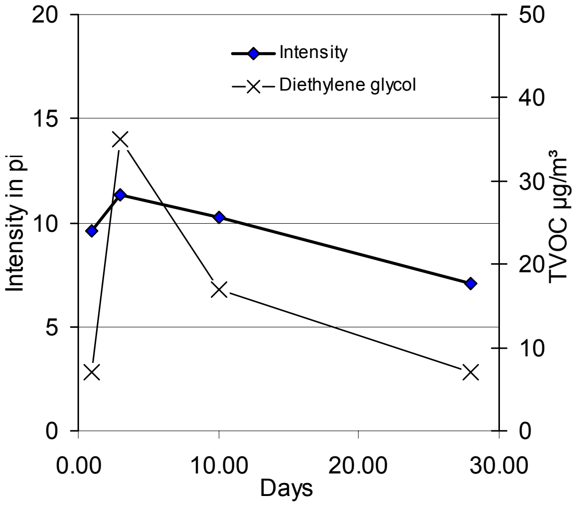


Figure 4-3: Intensity and concentration of diethyleneglycol Acryl 3356

4.1.2 SYNTHETIC RESIN PREMIXED PLASTER

The tested synthetic-resin premixed plaster pastes showed very high VOC concentrations for some products and low concentrations for others in the emission chamber tests. Since the plasters were applied on the glass plates in layers of several millimetres in thickness, they constituted a large reservoir for VOC emissions.

Consumption data for synthetic resin premixed plasters in 2005 are shown as 114.000 tonnes per year for Germany in Table 4-8 (page 59) [48]. These numbers indicate that synthetic resin premixed plasters are used in large quantities indoors and therefore their emissions should be considered.

Table 4-4: Overview of the assessment of the synthetic resin premixed plaster pastes in accordance with the AgBB provisions

Provision / material	$TVOC_3$	$TVOC_{28}$	$\Sigma SVOC_{28}$	R	Non assessable VOC	AgBB assessment	$TVVOC_{28}$ *	Area-specific air flow rate
	$mg\ m^{-3}$	$mg\ m^{-3}$	$mg\ m^{-3}$		$mg\ m^{-3}$		$mg\ m^{-3}$	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			$m^3 m^{-2} h^{-1}$
SR PP 3342	0.88	0.11	0	0.01	0.09	passed	0.006	0.53
SR PP 3345	*214*	*34.5*	*0.19*	0.34	*33.9*	Failed	0.160	0.53
SR PP 3357	0.41	0.02	0	0.00	0.003	passed	0.024	0.53
SR PP 3487#	*52.7*	*5.35*	0	0.48	*3.14*	Failed	0.008	0.53
SR PP 3614	0.98	0.27	0	0.07	*0.22*	Failed	0.014	0.53
SR PP 3623	6.31	1.28	0	*2.46*	0.10	Failed	0.026	0.53

SR PP = synthetic resin premixed plaster
* VVOCs comprise formaldehyde, acetaldehyde and acetone
# Also contains 11 µg m-3 benzene (carcinogenic) after 3 days.

The evaluation of the emission tests in accordance with the AgBB scheme (Table 4-4) shows that two of the six products meet the provisions. The products 3345 and 3487, which do not meet the AgBB provisions, are noticeable in that they exceed the TVOC value by a long way. The surpassing of the limit could be attributed to a glycolic component in both products and to an alkane fraction (C_8 - C_{12}) in one case. Apart from glycols and esters, alkanes and aromatics were the most frequently identified VOCs.

Synthetic-resin premixed plaster pastes are usually equipped with a preservative in order to protect the sales units from a microbial attack during the storage time. Although the preservatives were not specifically looked for in the project, they were identified in several cases. Three of the plasters contained methylisothiazolinon (MIT). This can be adsorbed well using the Tenax method (3.4.1) and desorbed using thermodesorption. Maximum concentrations of 80 and/or 200 µg m^{-3} could be proved after 28 days. In the case of synthetic-resin premixed plaster 3614, the emission exceeded the $VOC_{without\ NIK}$ after 28 days. Figure 4-4 shows the MIT concentration for the three synthetic-resin premixed plasters 3342, 3614 and 3623. It was conspicuous that with all three plasters hardly any or only minimal MIT could be determined on the first measuring day while the concentration passed through a maximum after 10 days. Also, when the screening tests were combined with thermal extraction on the synthetic-resin premixed plasters, only plaster 3342 provided any trace of MIT emission. The retarded MIT emission was possibly due to a strong interaction with other components in the plaster whose content decreased after some days.

MIT is frequently used in combination with benzisothiazolinon (BIT) for preservation purposes. However, BIT cannot be identified using the Tenax method. Neither of the PU foams (3.4.3) were able to determine BIT above the detection limit of approx. 1 µg m^{-3} based on a specific SIM method. However, the PU foam method has not been tested for BIT. The compound MIT could also be proved in several cases on the foam, however it mainly indicated lower concentrations than Tenax did. It is possible that the more volatile MIT to some extent breaks through the PU foam at a sampling volume of approx. 5 m^3.

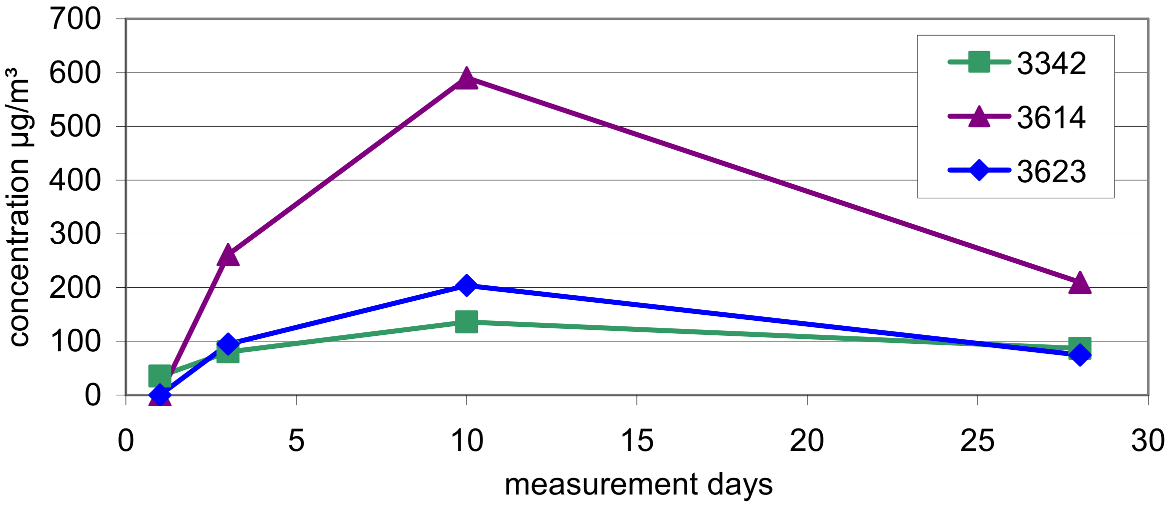


Figure 4-4: MIT concentrations for three synthetic-resin premixed plasters

Formaldehyde is another component which is used as an in-can preservative. This VVOC was detected in five of the six tested plasters, usually in concentrations (sometimes considerably) under 0.1 mg m^{-3}. Concentrations of 1.4 mg m^{-3} could only be detected on the first day in one case (plaster 3345), which then decreased in the course of 28 days to 0.12 mg m^{-3}.

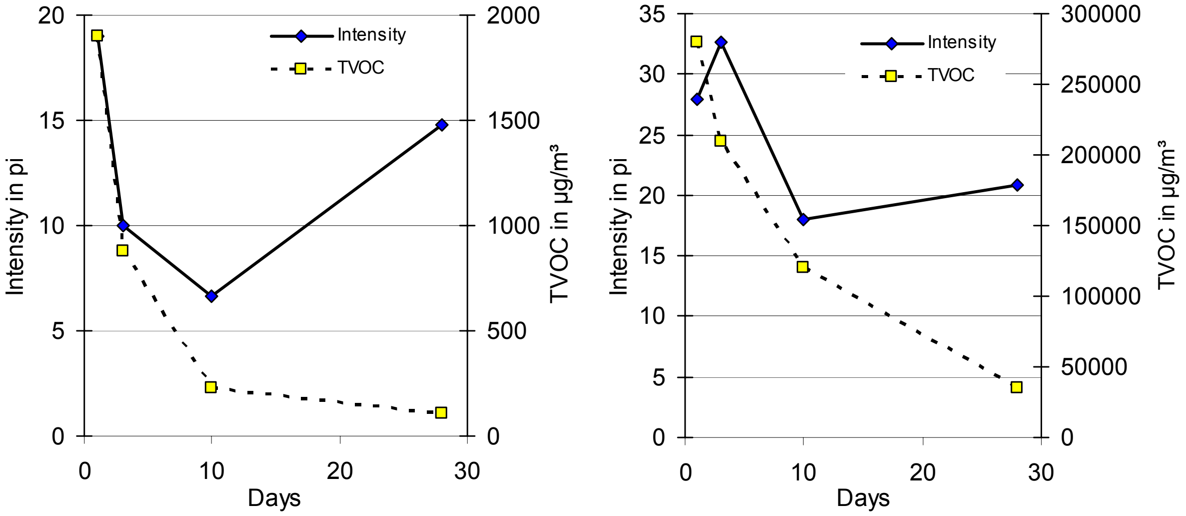


Figure 4-5: Odour intensity and TVOC of plasters 3342 (left) and 3345 (right)

The odour intensity curves of two plasters are particularly conspicuous within the group of synthetic-resin premixed plasters: plaster 3342 drops from a value of 19 pi on the first day to 6.7 pi on the tenth day and finally becomes 14.8 pi on the 28th day. The curves of the measured compounds and the TVOC values do not enable any correlation to the curve of the intensity values.

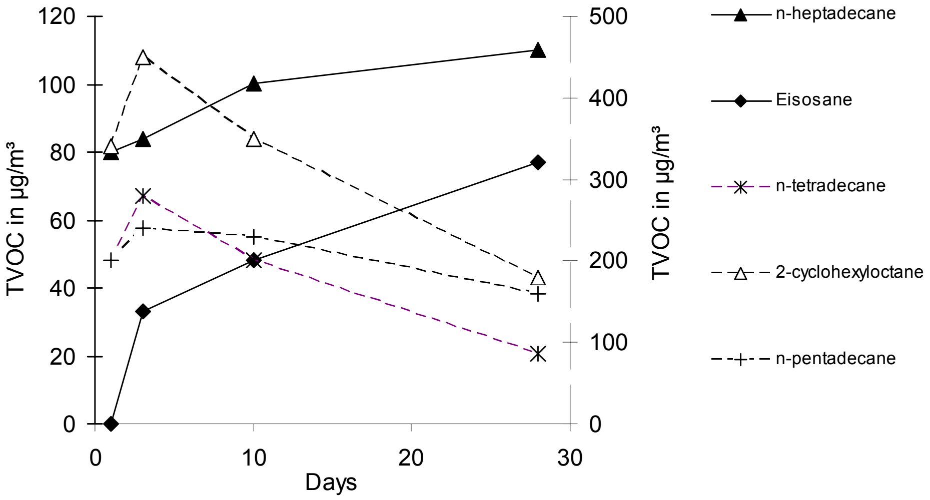


Figure 4-6: Concentration of individual compounds, plaster 3345

The intensity assessment of plaster 3345, whose extremely high TVOC values in the chemical analysis are also conspicuous, rises from 27.9 pi on the first day to 32.7 pi on the third, drops to 11.1 pi at the assessment on the tenth day and then rises again to 20.9 pi. Odour assessment does not exhibit any correlation with the TVOC curve.

Some substances can be found among the individual compounds which as escort substances may explain the curve of the odour assessment: the concentrations of tetradecane, cyclohexyloctane and pentadecane - plotted on the right ordinate in Figure 4-6 – increase from the first to the third day and then decrease again. The concentrations of heptadecane and eicosane - plotted on the left ordinate – increase from first to the 28th day. Even if the individual substances are not necessarily responsible for the odour contamination of the sample air, they are indicators of a concentration increase of a group of substances from the first to third day, which is superposed by a concentration increase of another group of substances. If odour-generating substances are present in the respective groups of substances, they might be responsible for a curve shown in Figure 4-5.

The odour intensity of the plaster 3357 was stronger on the third day than on the first day. Cyclotrisiloxane and butanol were also found here in the individual compounds, whose concentration increase to the third day and then drops again. Altogether it was found that the odour emissions from synthetic-resin premixed plasters were rather high, in addition the hedonistic assessments also gave a poor result.

4.1.3 WOOD AND WOOD-BASED MATERIALS

Numerous wood-based materials and wooden tiles were tested; most of them being of the type "Oriented band board" (OSB). In Germany, OSB is usually made out of pine wood. The fact that the materials can emit VOCs is described in the literature [e.g. 46, 49, 50]. The introduction of the AgBB scheme also initiated research activities in connection with wood-based materials. The Federal Institute for Wood Research (Bundesanstalt für Holzforschung, BFH) compiled an extensive study about the influence of the production process on the emissions of the product, looking into the splinter drying process, press temperature and time, storage conditions and time in relationship with the measured emissions [51]. Table 4-5 gives an overview of VOC emissions from OSBs. The values for TVOC after three and 28 days do not represent a problem for the OSBs, but it is noticeable that the R values of three products meet the value of 1 only by rounding off. The saturated and unsaturated aldehydes and their complementary carbonic acids here make a major contribution. The detailed results of these emission tests are listed in the annex, where it has been found that the number of the emitting components with up to 50 detected VOCs is the highest for these products.

Table 4-5: Overview of the assessment of OSBs in accordance with the AgBB provisions

Criterion / material	$TVOC_3$	$TVOC_{28}$	$\Sigma SVOC_{28}$	R	Non assessable VOC	AgBB assessment	$TVVOC_{28}$[#]	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		mg m^{-3}	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			$m^3m^{-2}h^{-1}$
OSB 3382	1.4	0.45	0	0.41	0	passed	0.071	1
OSB 3383	0.4	0.17	0	0.16	0	passed	0.092	1
OSB 3488	1.5	0.40	0	0.98	0	passed	0.120	1
OSB 3543	1.9	0.55	0	*1.04*	0	passed	0.130	1
OSB 3559	0.9	0.39	0	0.73	0	passed	0.140	1
OSB 3628	2.9	0.57	0	*1.30*	0	passed	0.270	2*
OSB 3689	1.3	0.68	0	*1.26*	0.013	passed	0.110	1

[#] VVOC comprise formaldehyde, acetaldehyde und acetone

* The measured values indicated in the table were converted to q = 1 m^3 m^{-2} h^{-1} to enable a better comparison.

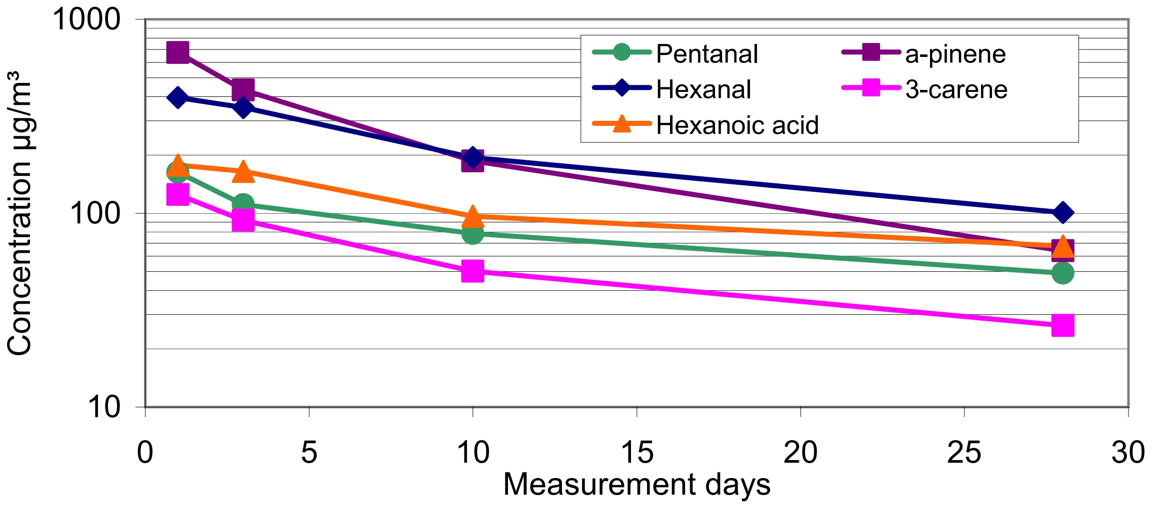


Figure 4-7: Concentration of some VOCs from OSB 3543

Further emissions - in addition to the aldehydes already mentioned - are the terpenes α-pinene and Δ_3-carene, which are both the main emissions of pure pine wood. **Figure 4-7** shows the emissions of hexanal, pentanal, hexanoic acid, α-pinene and Δ_3-carene. The concentration of these compounds decreases during the test period. The VOC concentrations tended to decrease to maximum of 10 to 20 % of the initial concentration after 28 days.

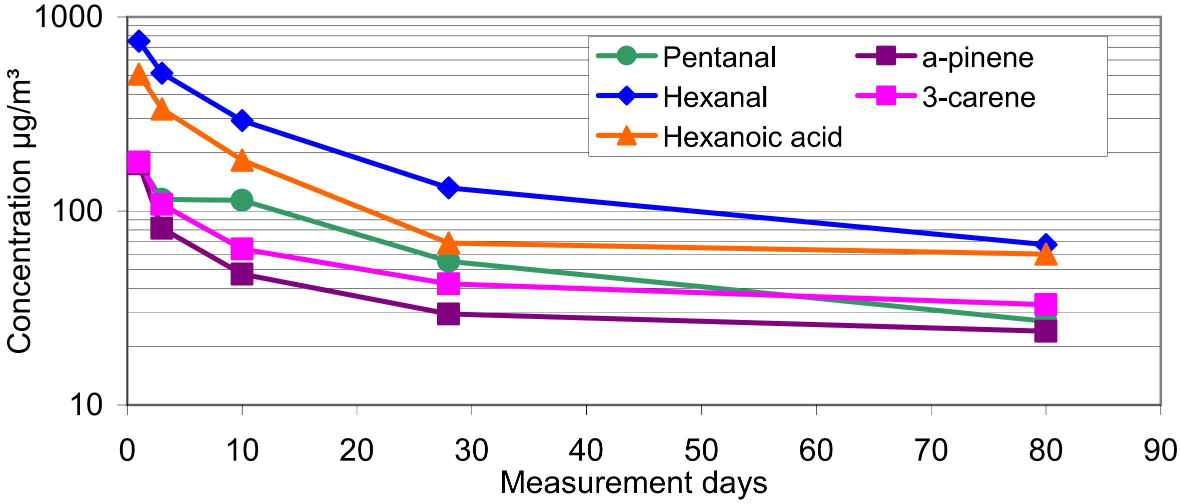


Figure 4-8: Concentration of some VOCs from OSB 3488 (tested over about 80 days)

That the concentrations of the compounds keep on decreasing beyond the 28th day, can be clearly recognised in

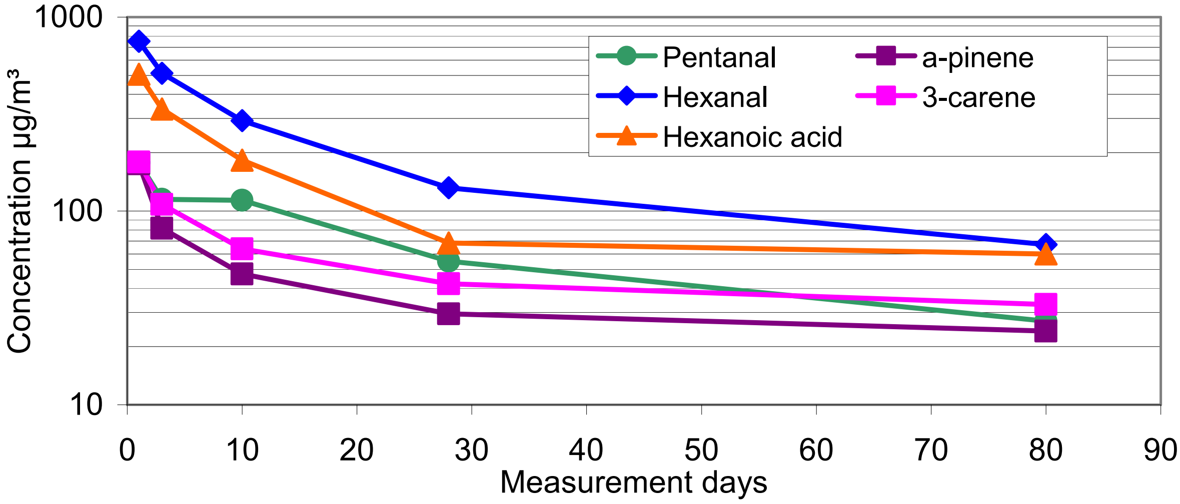


Figure 4-8. Tiles of unknown age taken exclusively from the building market were tested in the project. Makowski et. al [51] found rising emissions in production-fresh tiles particularly for aldehydes. A clear increase of the aldehyde emissions, especially in the first weeks, can occur in these tiles. Such an effect was not detected in the tests performed here, which indicates that the tiles were at least several weeks old, before they were tested.

As already described, the emissions of saturated and unsaturated aldehydes and relevant carbonic acids contribute substantially to the increase of the R value of the

OSBs. The saturated aldehydes hexanal, pentanal and heptanal and the carbonic acids pentane and hexanoic acids could be detected most often. Each of these VOCs contributes to the overall emissions with up to 100 µg m^{-3}. Components with NIK (LCI) values of 400 to 1000 µg m^{-3} have a high influence on the R value. Unsaturated aldehydes, especially octenal, which emit from some OSBs at concentrations around 10 µg m$^{-3,}$ sometimes exert an even greater influence. At a NIK (LCI) value of 18 µg m^{-3} more than half of the permissible R value of unity has already been reached.

Table 4-6: Overview of the evaluation further wood and wood-based material plates in accordance with the AgBB provisions

Criterion / material	TVOC $_3$	TVOC $_{28}$	ΣSVOC$_{28}$	R	Non assessable VOC	AgBB assessment	TVVOC$_{28}$	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		mg m^{-3}	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			m^{3}m^{-2}h^{-1}
Pine bd. 3384	0.37	0.21	0	0.13	0.022	passed	0.001	1
Cork p. 3479	0.19	0.11	0	0.00	0.10	passed	0.000	1.25
Chipbd. 3560	1.61	0.79	0	*1.52*	0.003	failed	0.024	1
Cork bd. 3561	0.28	0.07	0	0.03	0.04	passed	0.0	1.25
Laminate 3562	0.05	0.01	0.003	0.00	0.003	passed	0.011	1.25
Beech bd. 3625	0.14	0.06	0	0.11	0	passed	0.015	1

Pine bd. = pine board; cork bd. = cork parquet; chipbd. = chipboard; beech bd. = beech board

Table 4-6 shows the results of further wood-based materials tested in the project. One of the products of this group just missed the AgBB provisions. This chipboard used is as a flooring tile which exhibits acetic acid concentrations. Although chipboards are usually made of pine wood in Germany, the chipboard tested here probably contains a higher amount of hardwood which might explain the increased acetic acid emission.

Some of the products tested e.g. laminates, exhibited very low concentrations. Wooden boards from pine and beech were laminated boards, as supplied for furniture production. They were individually welded in the factory and stored in a stack. Acetic acid and traces of other components were emitted primarily from beech wood [52]. The emissions from the pine board are rather low; one would expect higher terpene concentrations from fresh pine boards. Two different solid wood tiles were coated with lacquer and tested following these rules and the details are discussed in Chapter 4.1.4 (page 59) and the Annex. The concentration of benzophenone in both cork parquet samples decreased during the test period only very modestly and became the main component after 28 days. It is highly probably that benzophenone comes from the lacquer used for coating the parquet. Since cork is an adsorbent material, parts of the lacquer and thus the lacquer component benzophenone can also be adsorbed by the cork, so that benzophenone is then no longer available as a radical starter during UV hardening where it normally reacts to completion. The consequence is that the material emits benzophenone for longer periods of time. In earlier emission tests [53] higher phenol and furfural concentrations were detected from cork products. Very small quantities of these two VOCs were only found in the samples tested (less than 10 µg m^{-3}).

Emission of formaldehyde from adhesives used in wood-based materials led to initial discussions about pollutants in the interior as early as in the nineteen seventies and eighties. At that time it was the very high values for chipboards that triggered the issue. Therefore was it interesting to test the concentration at which this very volatile and irritant gas is emitted from today's products (see Table 4-7). OSBs exhibit the highest formaldehyde emissions, which reached a value of 100 µg m^{-3} in one case after ten days. Since in this case (OSB 3488) the maximum formaldehyde emission is reached, this could indicate a relatively fresh board; which however was not confirmed by the VOC data of this board (see Annex). All tested products meet the provisions of the Prohibition of Chemicals Ordinance (Chemikalienverbots-verordnung) concerning formaldehydes. Other OSBs show a relatively constant curve with a moderate decrease in the concentrations as a function of time. Apart for two exceptions they are clearly in a two-digit range. Roffael [54] shows the development over the last 50 years, indicating that modern wood products can emit considerably less than 10 µg m^{-3} of formaldehyde.

Table 4-7: Formaldehyde emissions from wood-based materials in µg m^{-3} (determined using DNPH)

Sample \ measurement day	1	3	10	28
OSB 3382	52	48	41	33
OSB 3383	30	24	20	19
OSB 3488	36	63	103	88
OSB 3543	36	36	33	34
OSB 3549	14	9	8	7
OSB 3628	72	67	64	54
OSB 3689	15	12	11	9
Chipboard 3560	11	13	12	8
Cork parquet 3561	2	2	2	N/A
Laminate 3562	10	9	9	11
Beech board 3625	2	2	N/A	2

In spite of the usually rapidly decreasing TVOC values in all wood and wood-based materials the sensory assessments in some samples were high during the entire period of 28 days (see Figure 4-9). The hedonic odour impression was assessed as rather poor.

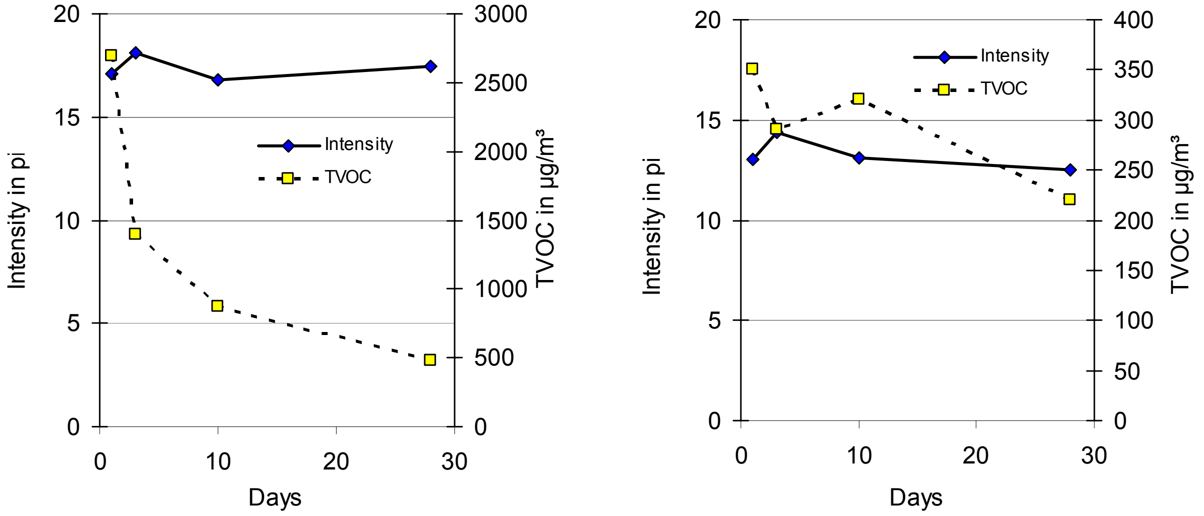


Figure 4-9: Intensity and TVOC of OSB 3382 (left) and pine board 3384 (right)

The tested OSBs all show a similar behaviour concerning odour intensity. A clear reduction was only detected in two samples: intensity drops in the OSB 3543 from 28 to 16 pi and of 18 to 13 pi in OSB 3559 (see Figure 4-10).

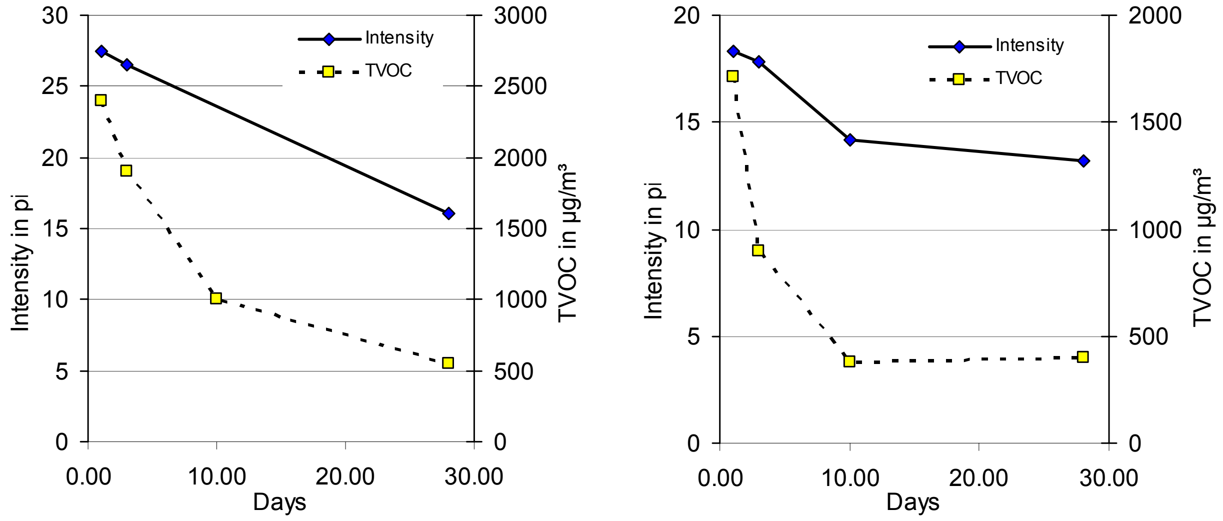


Figure 4-10: Intensity and TVOC of OSB 3543 (left), 3559 (right)

Intensity assessments found the best values in laminates, beech boards and cork parquets with about 10 pi after 28 days. Apart from one exception the OSBs and the chipboards exhibit the highest odour.

4.1.4 PAINTS AND LACQUERS

The products in the paints and lacquers group are being developed for many different fields of application so that there is a wide variety of different types available. Therefore the project was only capable of representing a narrow cross-section. The following Table 4-8 illustrates the different lacquers, as indicated by the federation of the German lacquer industry for 2005 [48]. The emissions from building paints thus represent an important source, since the interior is the most important place of use for many products.

Table 4-8: Distribution of the domestic consumption of paints and lacquers (quantities in 1000 tonnes)

Product	**Amount**	**Field of application**
Dispersion /inner wall paints	510	Building paints (1,046,000 tonne)
Façade paints	155	
Synthetic resin-based plasters	114	
Lacquers and glazes	109	
Primers/coats	60	
Trowel, other building paints	98	
Industrial lacquers	233	Industrial lacquers (474,000 tonne)
Car series lacquers	89	
Wood lacquers	65	
Corrosion protection	43	
Car repair lacquers	26	
Ship paints	18	
Others	58	
Total	1,578	

The composition of the first six products, whose binders and solvents are listed in Table 4-9, and their results evaluated in accordance with the AgBB scheme are shown in Table 4-10, are rather inhomogeneous. Lacquer 3385 proved to be a special one and it was tested twice - once on a glass plate and once on a screed sample (whose minimum blank value was determined and proved by the test). In each case the lacquer clearly exceeds at least one of the provisions according to the AgBB scheme: when applied on glass the value $VOC_{without\ NIK}$ is exceeded and when applying to screed both VOC$_{\text{without NIK}}$ and the R value are exceeded. In the TVOC values the difference between the carrier materials is easy to recognise, but it is not very pronounced.

Table 4-9: Binders and solvents in the tested products

Sample number	**Identification on the sales unit**	**Binder**	**Solvent**	**Paint**
Lacquer 3385	Floor varnish, matt	Acrylate	Water	Reed-green
Lacquer 3587	Floor varnish, high gloss	Alkyd resin	Organic	Light-grey
Lacquer 3392	Multicoloured lacquer, silk matt	Acrylate	Water	Blue
Lacquer 3388	Wood glaze matt	Acrylate	Water	Red
Lacquer 3589	Water seal	Polyurethane acrylate	Water	Colourless

Table 4-10: Overview of the assessment of paints and lacquers in accordance with the AgBB provisions.

Criterion / material	TVOC $_3$	TVOC $_{28}$	ΣSVOC$_{28}$	R	Non assessable VOC	AgBB assessment	TVVOC$_{28}$	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		mg m^{-3}	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			m^{3}m^{-2}h^{-1}
Fl lacquer 3385 G[#]	6.72	1.18	0	0.00	*1.18*	failed	0.000	1.25
Fl lacquer 3385A S[#]	4.11	0.76	0	*1.84*	*0.22*	failed	0.000	1.25
Wd glaze 3388	4.75	0.14	*0.14*	0.00	*0.14*	passed	0.000	3*
Mc lacquer 3392	0.37	0.21	0	0.13	0.022	passed	0.000	1
Fl lacquer 3587	0.48	0.16	0	0.43	0.01	passed	0.009	1.25
Pa lacquer 3589	2.11	0.29	0	0.22	*0.13*	passed	0.000	1
W paint 3463	0.11	0	0	0	0	passed	0.005	1
W paint 3463A	0.04	0	0	0	0	passed	0.000	1
W paint 3558	0.21	0	0	0	0	passed	0.000	1
W paint 3584"	0.06	0	0	0	0	passed	0.002	1
W paint 3586	0.14	0.02	0	0	0.02	passed	0.002	1
W paint 3626	0.19	0.004	0	0	0.004	passed	0.001	1
W paint 3690	0.36	0.07	0	0	0.07	passed	0.003	1

[#] G = Glass plate, S = Screed; " On plaster board with primer
Fl lacquer = floor lacquer; Wd glaze = wood glaze; Mc lacquer = multicoloured lacquer; Pa lacquer = parquet lacquer (water seal);
W paint = dispersion wall paint
* The measured values indicated in the table were converted to q = 1 m^3 m^{-2} h^{-1} to enable a better comparison.

Figure 4-11 indicates the differences between applying floor lacquer 3385 to glass and screed. It shows the concentration of the semivolatile propanoic acid ester (not identified more specifically) with a retention time of 29 minutes (corresponding to about that of tetradecane) and two very volatile components, propanediol and benzyl alcohol on different carrier plates – glass or screed. Emissions of propanoic acid ester on glass clearly differ from those of very volatile components: the emission of propanoic acid ester increases slightly at the beginning and is then fairly constant. The emission of the very volatile components however is very high for the first three days, then decreases markedly and falls below the determination limit after the tenth day. When the lacquer is applied to screed, all substances show a similar behaviour: the concentration decreases slightly and the very volatile substances can be detected until the 28th day. It has to be noted that the emission of propanediol starts at an order of magnitude lower than when it is applied to glass.

That the emission behaviour depends on the types of the carrier material can be attributed to the fact that the substances can penetrate the screed while being applied and during the test period. They then become depleted in the upper coat of paint and emitted only slowly. The components can only diffuse upward on glass, thus the very volatile components are emitted quickly and the semivolatile component is emitted at a higher concentration.

In the assessment according to AgBB (Table 4-10) the emission of propanediol leads to the fact that the provisions of the R value cannot be adhered to when applying to screed (Sample 338A). When applying it to glass (Sample 3385) the component cannot be proved after 28 days, which results in a zero R value. The emissions from the same lacquer differ greatly depending on the carrier material. Glass is the carrier material which leads to more reproducible results since different screeds can have an emission of their own or may lead to differences due to their microstructure. Glass is the best carrier for comparative tests. However, to transfer the results to current conditions, the properties of the carrier must be taken into account.

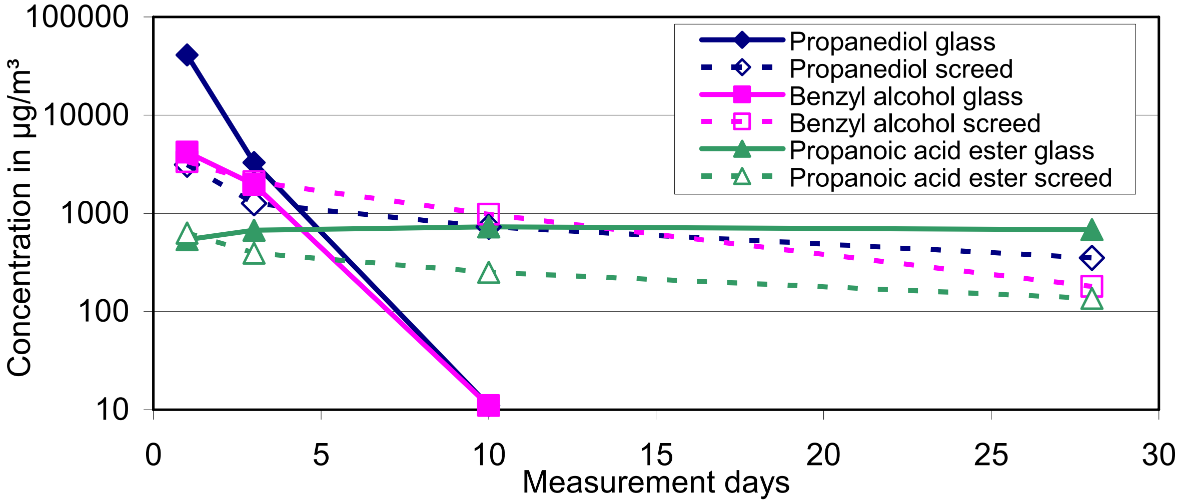


Figure 4-11: Emission curves of three compounds of the lacquer 3385 applied to glass or screed (logarithmic scaling)

The second floor lacquer 3587 tested emitted noticeably smaller quantities in comparison to lacquer 3385 and meets the provisions of AgBB. Further lacquers and glazes clearly show higher emissions compared to dispersion and latex wall paints, however are within the AgBB provisions. Lacquers and glazes are not usually used over large areas in interiors contrary to wall paints. All wall paints exhibit extremely small values, after 28 days mainly $TVOC_{28}$ close to 0 µg m^{-3}.

Table 4-11: Terpene emissions from glaze 3392 in µg m^{-3} applied to pine wood 3384

	Measurement day			
Sample	**1**	**3**	**10**	**28**
α-pinene wood only	54	68	76	51
α-pinene coat of paint	19	55	119	132
Δ_3-carene wood only	28	27	33	25
Δ_3-carene coat of paint	57	17	47	53

In addition to applying the substances to screed, wood was also used as a carrier for the paint. Section 4.1.3 described the emissions tests from pure woods, the samples used there were subsequently tested in another chamber test. The influence of parquet lacquer on the emission of acetic acid from beech wood did not show any definite change: after applying the lacquer the same value was measured as before. Other emissions were no longer detected, they were previously only a few µg m^{-3} anyway. Terpene emissions from raw pine wood and glazed wood illustrated in Table

4-11 exhibit a sealing effect on the coating in the first days which then leads to an increased emission from the uncoated board after ten and/or 28 days. Influences of the carrier material will also be discussed in the relevant sections (4.1.5 and 4.1.6).

Table 4-12: Formaldehyde emissions from paints and lacquers in µg m^{-3} (determined using DNPH)

Sample \ measurement day	1	3	10	28
Floor paint 3587	9	6	3	3
3463 disp. on 3444 NWF + 3445 adhesive	47	n.m.	5	5
3463 disp.	n.d.	1.5	n.d.	n.d.
3584 disp. on 3544 P + 3546 GC	21	3	1	2
3586 disp.	65	15	5	2
3626 disp.	n.d.	7	4	1
3690 latex disp.	30	14	8	3

disp = dispersion paint; NWF: non-woven fabric; P = primer; GC = plaster board
n.d. = non-detectable; n.m. = no measurement

In addition to low VOC emissions, dispersion paints also exhibit low formaldehyde emissions which rapidly fade away (see Table 4-12). Dispersion paints may contain formaldehyde releasers as in-can preservatives. Furthermore MIT is also a typical preservative which was found in three paints (see Table 4-13). The concentrations of this component were considerably higher than was found in dispersion paints some years ago [55]. At that time dispersion paints were predominantly conserved using chloromethyl isothiazolinon (CIT)/MIT (3:1). Because of its high allergy potential this preservative is less frequently used today and in only small concentrations (under 15 ppm content in sales units). The determination limit for MIT was at approx. 20 ng absolute using the usual Tenax method, thus the determination limit for a five-litre sample is a value of 4 µg m^{-3}. After 28 days the emission of MIT in all paints drops below the determination limit or is only a few µg m^{-3}.

Table 4-13: Methylisothiazolinon (MIT) emissions from paints

Sample \ measurement day	1	3	10	28
3558 latex disp.	n.d.	120	43	n.d.
3586 disp.	350	180	160	16
3626 disp.	120	69	n.d.	n.d.

n.d. = non-detectable
disp. = dispersion paint

Two distinctive groups can be distinguished in the building materials group of paints concerning odour intensity. Odour load in the sample air increases from the first to the third test day in the first group of five paints, while there is an initial decrease in odour intensity followed by an increase from the third to the tenth test day in the second group of five paints (Figure 4-12).

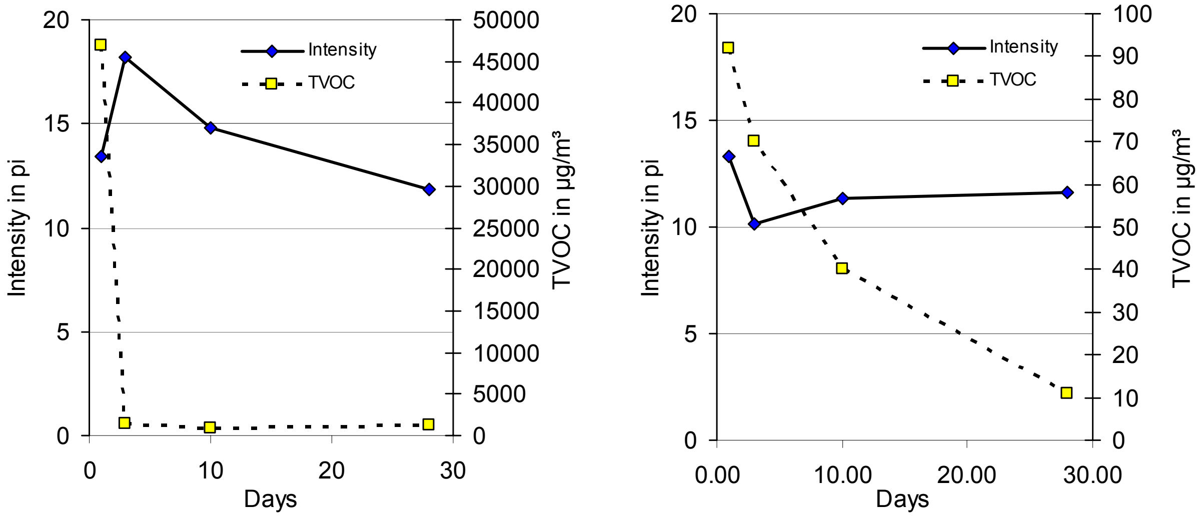


Figure 4-12: Intensity and TVOC of floor lacquer on glass plate 3385 and parquet lacquer on beech wooden plate 3589

Although the floor lacquer exhibits a much higher TVOC load as opposed to parquet lacquer, the perceived odour intensity is only estimated as slightly higher. It is assumed that the low-odour propanediol, responsible for the high TVOC values, hardly contributes to the total odour impression of the lacquer, however three single compounds were found whose concentrations also increase up to the third test day: pentanediol, ethanol and a propanoic acid ester. Even if the tests performed so far do not substantiate the statement that these materials are responsible for the increase in perceived intensity as odour-generating substances, they indicate a chemical change in the composition of the sample air in any case (Figure 4-13).

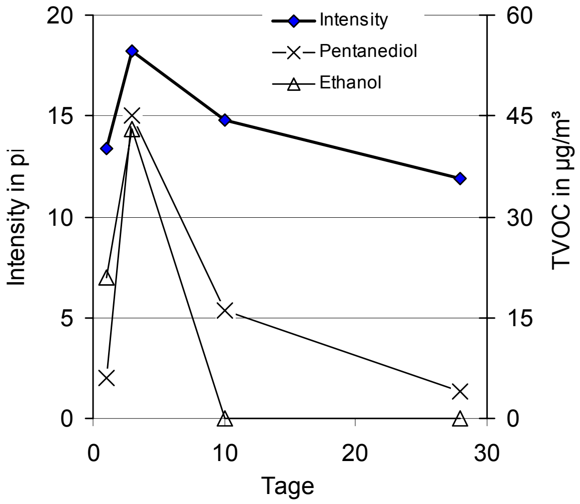


Figure 4-13: Intensity and concentration of floor lacquer 3385: pentanediol and ethanol

One or more individual substances can be found in some lacquers, which can reconstruct the fluctuations in the odour intensity. However, odour-intensive compounds can also be emitted which can escape an analytic proof.

In contrast, no relationship can be established between either the TVOC values or the measured individual compounds with the perceived intensity in dispersion paint 3584.

Altogether dispersion and latex paints exhibit the lowest perceived odour intensities after 28 days. The hedonic assessment of sample air from these paints is fairly good in comparison to lacquers and glazes.

4.1.5 ADHESIVES

In a previous project, also sponsored by the Federal Environment Agency (UBA), a test procedure was developed to determine the emissions from floor coverings [56]. Numerous floor covering adhesives were tested and the results contributed to the development of the environmental award for floor covering adhesives RAL UZ 113 [57], which has been the first environmental award using the AgBB scheme. In addition to the tests in the previous report, a current batch of the same adhesive was also tested in this project.

Adhesive 3400 corresponds to adhesive 1 in the UBA text 27/03 [56]. The detailed results of adhesive 3400 can be found in the Annex. A comparison of the results shows that the TVOC value of adhesive 1 exhibits approx. three times the concentration on the third day than adhesive 3400. However, both TVOC values are in the same order of magnitude after 28 days, but the composition of VOC is different. In the UBA text 27/03 phenoxyethanol and dodecane acid methylester (methyl laurate) were the main emissions after 28 days, in the current study, however, in addition to dodecane acid methylester, propylene glycol was the main component. SVOCs consisted of the same components with largely the same concentrations. In the current study the adhesive was tested for 67 days and it was found that hexadecane acid methylester (methyl palmitate) increased continuously from 26 to 43 µg m^{-3} during the test period.

Table 4-14: Overview of the assessment of adhesives in accordance with the AgBB provisions.

Criterion / material	TVOC_3	TVOC_{28}	ΣSVOC_{28}	R	Non assessable VOC	AgBB assessment	TVVOC_{28}	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		mg m^{-3}	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			$m^3m^{-2}h^{-1}$
Adhesive 3400	0.58	0.09	0.09	0.17	0.02	passed	0.000	3*
Adhesive 3405	0.19	0.01	0	0.00	0.01	passed	0.000	1.25
Adhesive 3445	0.10	0.05	0	0.00	0.005	passed	0.007	1.25
Adhesive 3461	0.03	0	0	0.00	0	passed	0.005	1.25

* The measured values indicated in the table were converted to q = 1.25 $m^3 m^{-2} h^{-1}$ to enable a better comparison.

The results in Table 4-14 show that all tested products adhere to the provisions of the AgBB scheme. Although these adhesives are intended for hidden use under floor coverings, they only emit very small quantities of VOC after three days. SVOCs were only detected in one adhesive (sample 3400).

Furthermore, all tested adhesives meet the provisions of Blue Angel RAL-UZ-113 (see Table 4-15). It must be conditionally noted that one of the four tested adhesives was intended to be used as a non-woven fabric adhesive (3445) and another one as a cork wall adhesive (3461), so that only two floor covering adhesives were tested.

Table 4-15: Provisions to floor covering adhesives in accordance with RAL-UZ-113

	Provision	
Substance	**3 days**	**28 days**
Sum of organic compounds within retention range C_6 – C_{16} (TVOC)	≤ 1000 µg m^{-3}	≤ 100 µg m^{-3}
Sum of organic compounds within retention range C_{16} – C_{22} (ΣSVOC)	-	≤ 50 µg m^{-3}
C substances	≤ 10 µg m^{-3} sum	≤ 1 µg m^{-3} each value
Sum of VOC without NIK (LCI)		≤ 40 µg m^{-3}
R value		< 1
Sum of formaldehyde + acetaldehyde		≤ 0.05 ppm

Among the four adhesives, cork and non-woven fabric adhesives emitted formaldehyde, the concentrations determined are shown in Table 4-16. A formaldehyde releaser is also assumed to be the formaldehyde source here, which protects the adhesive against micro-biological infestation during storage. Formaldehyde is emitted over the entire test period of 28 days from the adhesive in easily detected quantities showing a decreasing concentration. The non-woven fabric adhesive was tested separately (3445 non-woven fabric adhesive) and in two compound systems. For this purpose the fresh adhesive was covered with non-woven fabric immediately after applying it to the glass plate and tested in the test chamber (3444 non-woven fabrics on 3445 adhesive). In another test a coat of paint was applied to the adhesive covered with a non-woven fabric after a wait of three days (3463 disp. on 3444 non-woven fabrics on 3445 adhesive). Interestingly enough the application of the non-woven fabric triggers a higher initial formaldehyde emission. A homogeneous distribution and an enlargement of the emitting surface can explain this. Applying the paint has hardly any influence, the detected emissions originate from the adhesive. For completeness' sake the emission from the paint was also included in the Table (3463).

VOC emissions of the first four samples in Table 4-16 show a performance similar to formaldehyde: placing the non-woven fabric increases the overall emission on the first day to be followed by a strong decrease in the next few days. Ethanediol was emitted as a special component from the non-woven fabric. This reached a maximum of 120 µg m^{-3} on the third day and dropped to values of between 10 and 20 µg m^{-3} during the course of the tests. Emissions of dimethyl phthalate were detected from the adhesive, but this component (like ethanediol) was no longer detected after applying the paint, which indicates a sealing action of the paint – analogous to formaldehyde emission.

Table 4-16: Formaldehyde emissions from adhesives, system built structures and other building products in µg m^{-3} (determined using DNPH)

Sample \ measurement day	1	3	10	28
3445 Non-woven fabric adhesive	25	24	11	7
3444 Non-woven fabric on 3445 adhesive	220	8	2	2
3463 Disp. on 3444 non-woven fabric on 3445 adhesive	47	n.m.	5	5
3463 Disp. on glass	n.d.	1.5	n.d.	n.d.
3461 Cork adhesive	9	13	16	5
3546 Plaster board (GC)	20	15	3	3
3544 Primer on 3546 GC	6	6	3	4

Disp. = dispersion wall paint

n.d. = non-detectable

n.m. = no measurement

With regard to the performance of perceived odour intensity no similarities were found within the building materials group of adhesives. Despite the different performances, altogether high intensity values of 14-15 pi were found for all adhesives on the 28th day, although some of the TVOC values were very low.

The high intensity value of floor adhesive 3400 increased from the first to the third day and then decreased up to the 28th test day. TVOC and individual compounds do not enable the establishment of any direct relationship to the intensity value for this building material.

Noticeable is the intensity curve of the non-woven fabric adhesive 3445 whose value was 2.7 pi on the first day and which increased until the last day (Figure 4-14). The hedonic assessments correlate with the intensity assessments. The values of the building material combination of non-woven fabric and adhesive 3444 – described in the following chapter in greater detail – however suggests a rather technical problem during filling of the sample container on the first day.

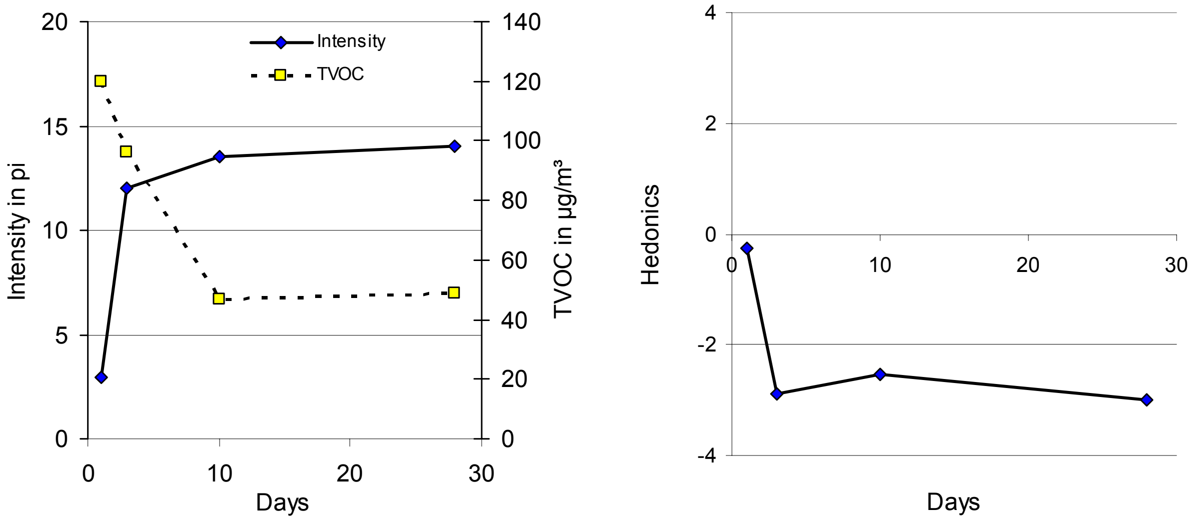


Figure 4-14: Intensity and hedonic curves, non-woven fabric adhesive 3445

4.1.6 OTHER BUILDING PRODUCTS

In this section all products are summarised of which only one piece was tested in the project in each case. They are products that were used as an application surface for other products – mainly paints. Table 4-17 shows the assessment of emission measurements in accordance with the AgBB scheme. There were no problems in this group either to adhere to the provisions. Plaster board was selected as a carrier for the primer, which in turn was used to test a coat of paint. A sealing effect of the coat of paint was established – exactly in the same way as in the composite system with an adhesive. The formaldehyde emissions from the plaster board may stem from the paper which serves as a skin and protection for the gypsum layer.

Table 4-17: Overview of the assessment of other building products in accordance with the AgBB provisions

Criterion / material	TVOC $_3$	TVOC $_{28}$	ΣSVOC$_{28}$	R	Non assessable VOC	AgBB assessment	TVVOC$_{28}$	Area-specific air flow rate
	mg m^{-3}	mg m^{-3}	mg m^{-3}		mg m^{-3}		mg m^{-3}	q
Provision	≤ 10	≤ 1	≤ 0.1	≤ 1	≤ 0.1			m^{3}m^{-2}h^{-1}
NWF + A. 3444	0.20	0.03	0	0.07	0.01	passed	0	1.25
P. 3544	0.05	0	0	0.00	0	passed	0.004	1
GC. 3546	0.06	0.01	0	0.02	0	passed	0.007	1

NWF + A. = non-woven fabric + adhesive; P. = primer; GC. = plaster board

The perceived odour intensity of the building material combination of non-woven fabric 3444 and adhesive 3445 is lower after 28 days than that of non-woven fabric adhesive 3445. Both TVOC value and all concentrations of the individual compounds are lower for the building material combination on the 28th day (Figure 4-15).

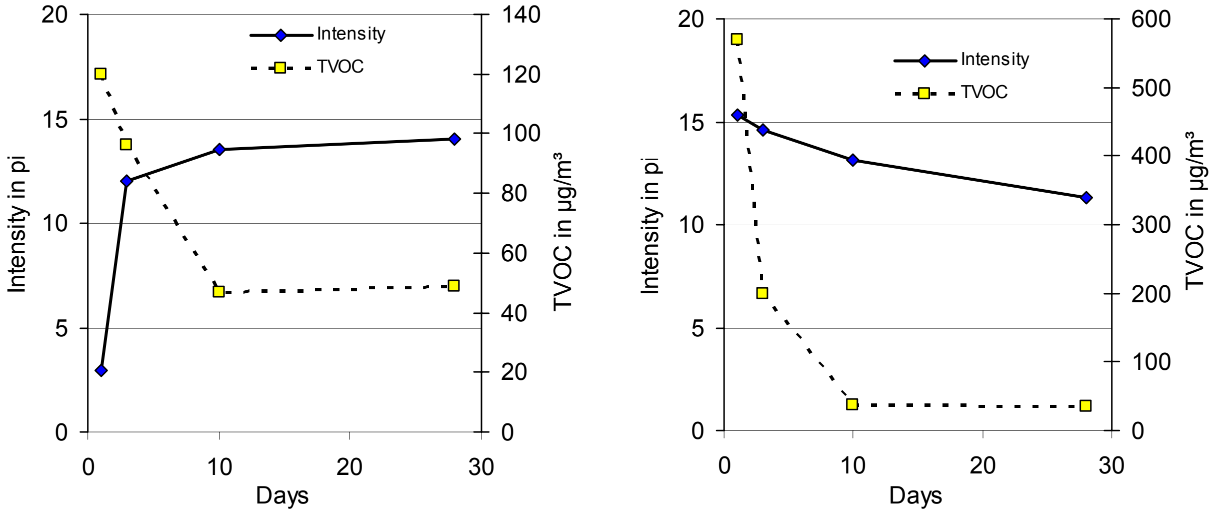


Figure 4-15: Intensity and TVOC curves of adhesive 3445 (left) and non-woven fabric with adhesive 3444 (right)

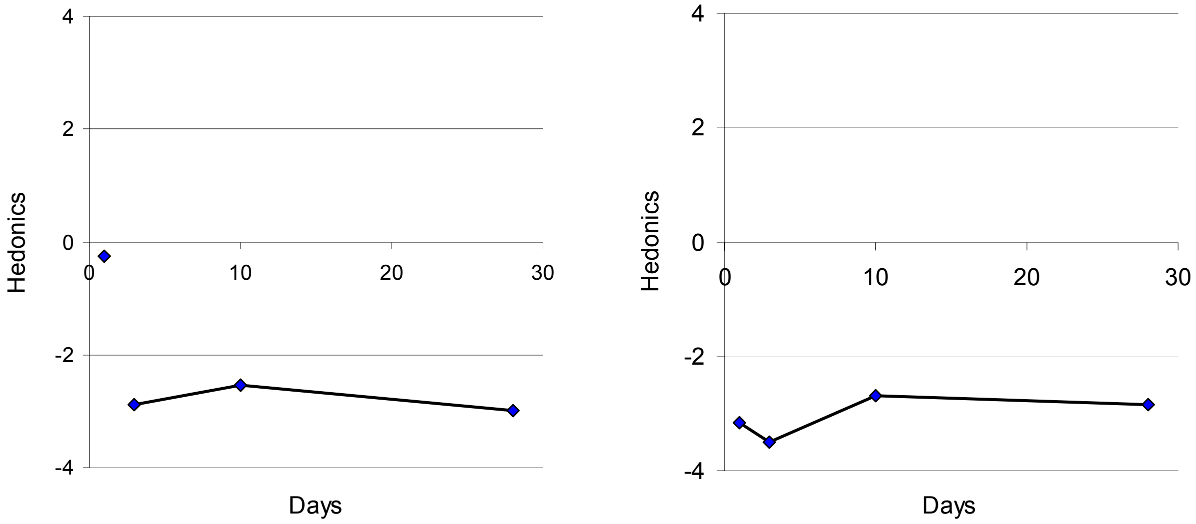


Figure 4-16: Curves of hedonic assessment of adhesive 3445 (left) and non-woven fabric with adhesive 3444 (right)

Better intensity values have practically no influence on the curves of hedonic assessment (Figure 4-16).

The building material combination of primer on plaster board 3544 performed better with an intensity of 6.3 pi after 28 days than the untreated plaster board which was assessed with 11.1 pi after 28 days.

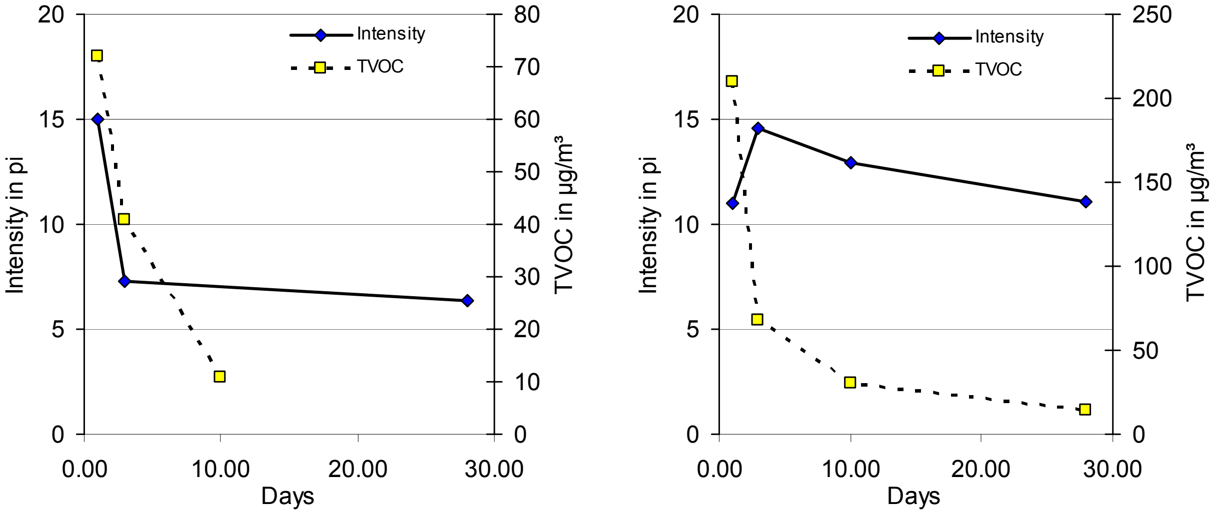


Figure 4-17: Intensity and hedonic curves for primer on plaster board 3544 (left) and plaster board 3546 (right)

The great differences in the intensity assessment are also reflected in the hedonic assessment. Both TVOC values and the concentrations of all analysed individual compounds are clearly lower for the building material combination. No correlation can be recognised within the individual compounds with the increase in intensity of the plaster board 3544 on the third day. However, the first test day was only performed with two test persons thus it cannot be evaluated statistically.

4.2 ODOUR MEASUREMENTS USING A MULTI-GAS SENSOR SYSTEM

In addition to odour assessments with panellists, measurements using a multi-gas sensor system were performed for seven selected building products. The investigation was aimed at proving the suitability of such systems to determine the odour intensity of building products using technical measurement instruments. The tested building products are listed in Table 4-18.

Simultaneously to the measurements in emission chambers, the same building products were placed into CLIMPAQs and exposed to a constant flow rate of odourless air over 28 days. The area-specific air flow rate q was adjusted based on Nordtest NT BUILD 482 [15] and was identical to q in the emission chambers. Since the flow rates of assessment air needed for odour measurements are much higher than the flow rate in the emission chambers, the material surface in the CLIMPAQ measurements was increased accordingly.

Table 4-18: Building materials tested in CLIMPAQs

Sample	**Building product**	**Material surface**	**Area-specific air flow rate**	**Measurement day**			
		m^2	**$m^3\ m^{-2}\ h^{-1}$**	**1**	**3**	**10**	**28**
3460	Acrylic sealing compound	0.041	83	M/P	M/P	M/P	M/P
3478	Silicone sealing compound	0.041	83	M/P	M/P	M/P	-
3400	Floor adhesive	1.20	3	M/P	M/P	M/P	P
3388	Wood glaze	1.20	3	M/P	M/P	M/P	M/P
3628	OSB	1.20	3	P	P	M/P	P
3626	Dispersion paint	1.84	2	P	P	M/P	P
3647	Acrylic sealing compound	0.043	83	M/P	M/P	M/P	M/P

M: Measurements using the multi-gas sensor system
P: Assessment of the odour intensity by panellists

Table 4-18 indicates that measurement results from the multi-gas sensor system on the first, third, tenth and 28th day are not available for all building products. Due to the low odour intensity of the silicone sealing compound as early as on the tenth day, no assessable measurements were possible on the 28th day. The measurements of floor adhesive on the 28th day and the measurements of OSB and dispersion paint on the first and third day (the two material samples were measured simultaneously in two different CLIMPAQs), could not be evaluated due to instrumentation difficulties. This was because the electronic files of measured values in the sensor system could not be opened for data processing. Panellist assessments were only carried out for OSB and dispersion paint on the 28th day.

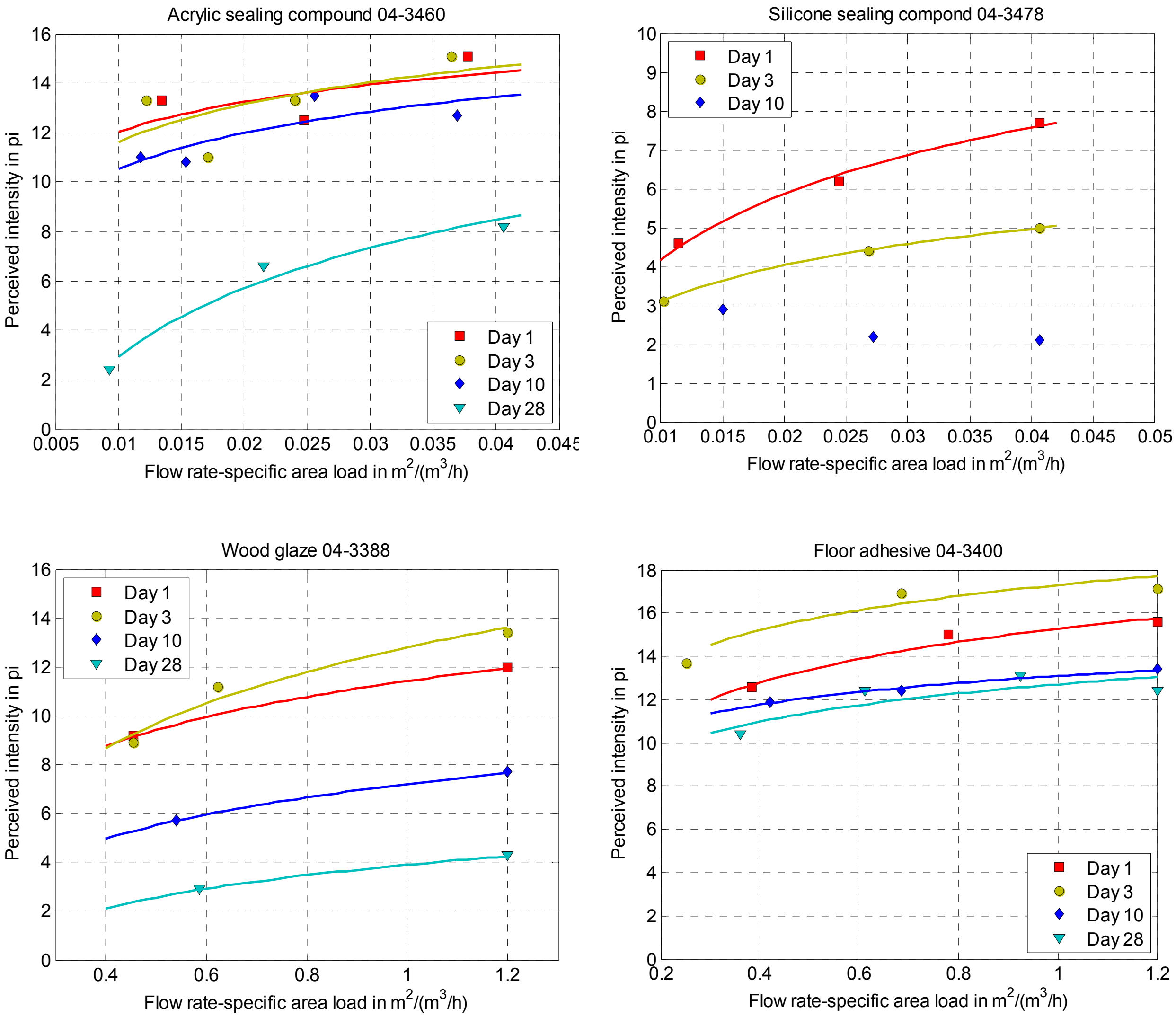


Figure 4-18: Odour intensity characteristics of building products on four different measuring days

It is not appropriate to use the multi-gas sensor systems to determine odours without a suitable calibration. For this reason it is necessary to carry out comparative assessments with panellists simultaneously to the measurements to establish calibration functions. The sensors of the sensor system used provide resistance values, which change as a function of the gaseous substances in sample air. The measurement results yield a pattern from different sensor resistance values, which changes depending upon the substances in sample air. This sensor pattern must be converted into odour intensity using suitable data processing methods for which a calibration database is needed.

Figure 4-18 andFigure 4-19 illustrate the odour assessment by panellists from seven building products. Several assessments were performed at different dilution stages on the measurement days, so making it possible to determine odour characteristics. The characteristics explain the dilution behaviour of the odour emissions delivered by the sample on the one hand, and inaccuracies of the assessment by panellist on the other provided that a sufficient number of measurement points are available. This is not the case in the measurements of dispersion paint and OSB. Since the assessments of the two building products were simultaneously performed, two different dilution stages could only be assessed on a measurement day in each case due to time limitations. The data for these measurements are insufficient for the determination of an odour characteristic and the emission curves drawn can only represent a tendency. The slope of the characteristics indicates how increasing the air flow can reduce odour intensity. If the characteristic is flat, even a large dilution can only enable a modest improvement in the intensity.

The investigations indicate that the logarithmic odour characteristics can properly fit the measurements at different dilution stages.

The assessments of building products by panellists of undiluted sample air are summarised in Figure 4-20. The diagram shows the changes in the odour intensities of the samples from the first to the 28th measurement day. The odour intensity decreases for all building products over the period of 28 days. The floor adhesive sample exhibited only a moderate reduction between the tenth and 28th day and the odour level remained rather high even after 28 days. The other building products showed a reduction of 3-4 pi in odour intensity during this period. A special behaviour was experienced on the third day: the intensity increased in some building products until the third day and then decreased in the latter part of the test period.

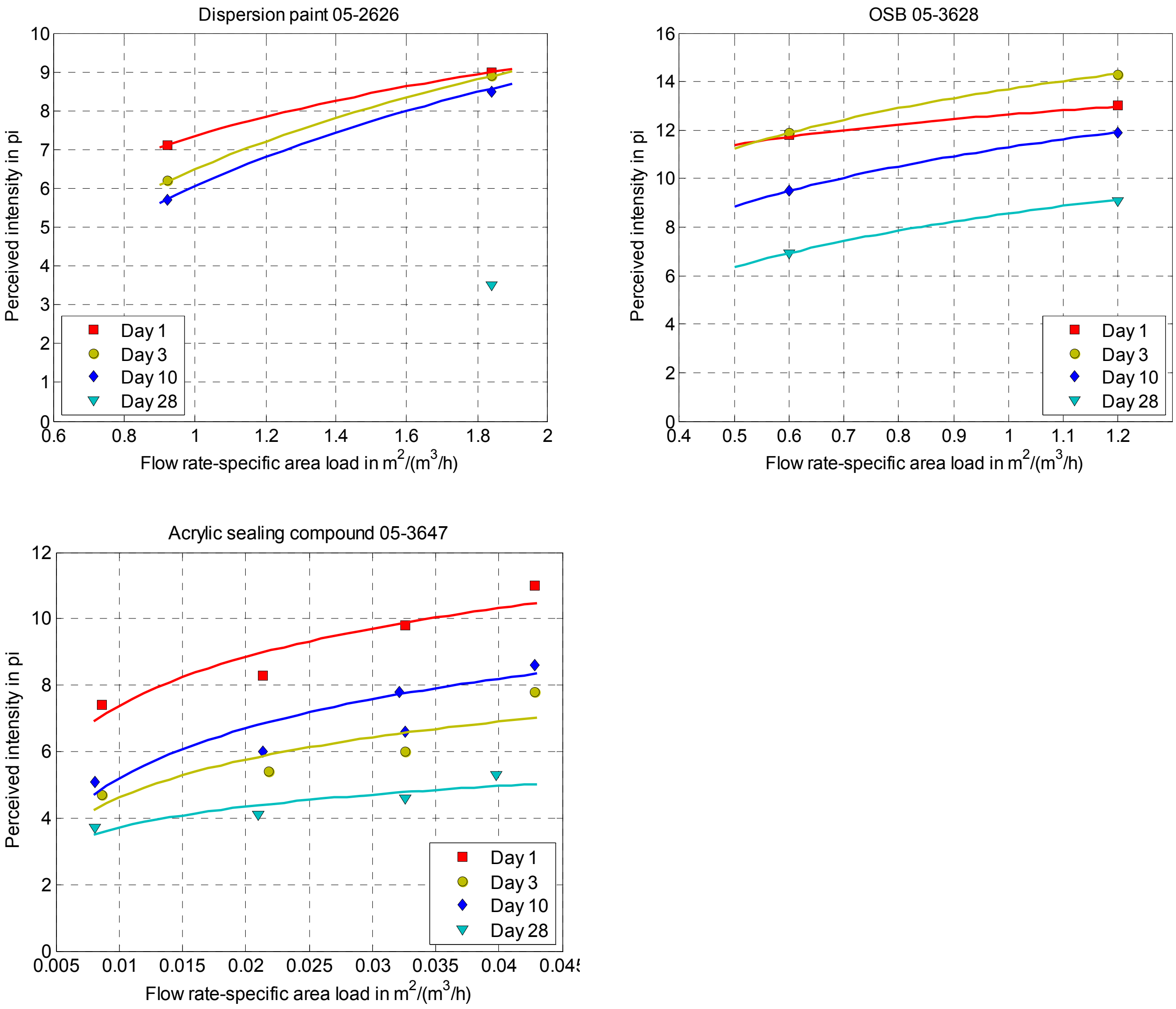


Figure 4-19: Odour intensity characteristics of other building products on four different measurement days

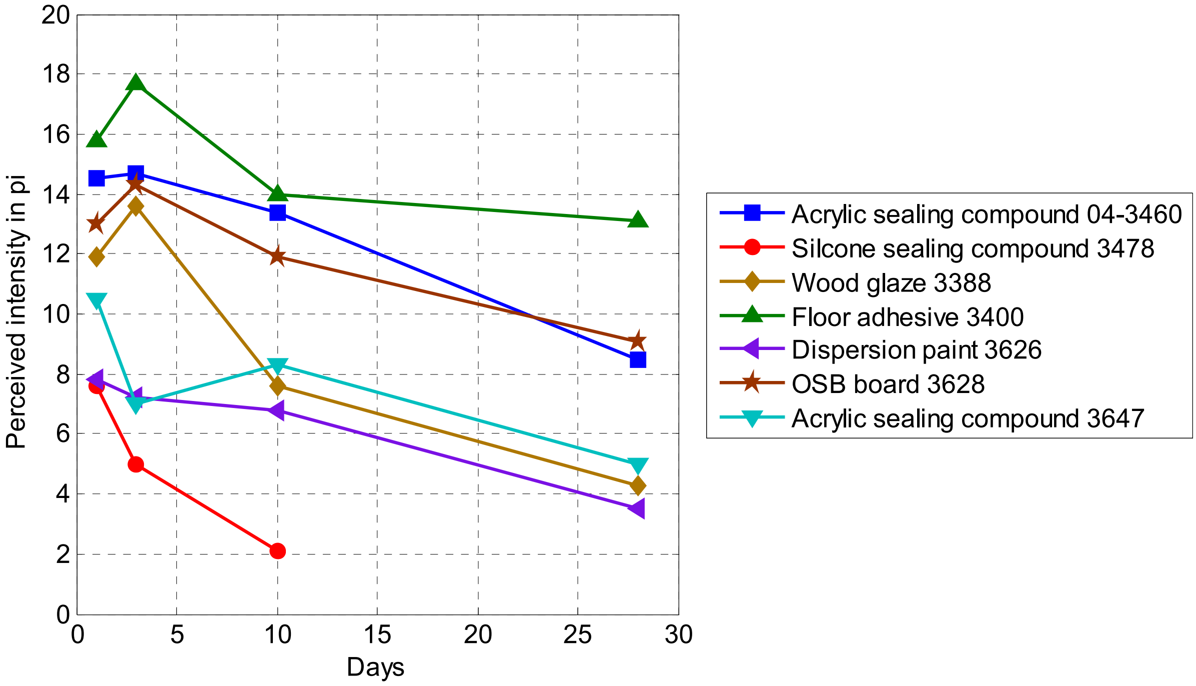


Figure 4-20: Assessment of odour intensity in the CLIMPAQ tests of undiluted sample air over 28 days

Graphical illustration of the measured values of the multi-gas sensor system is no longer reasonable in the evaluation due to the large number of sensors. The amount of data provided by 38 sensors has to be reduced in order to determine the odour intensity. Since the sensors react with different sensor patterns to different substance compositions, an unique correlation of the measured values to odour intensity is not possible. The determination of odour intensity is performed via a two-stage method. A classification into odour classes takes place in the first stage, in which the sensor pattern is assessed and the measurement is attributed to an odour class with a similar pattern. A transfer function to odour intensity is established for each of these classes. In the second stage the intensity of the unknown sample can be determined based on its class affiliation using the transfer function.

Classification of odours can be performed using suitable statistical analysis methods, which enable the multidimensional data space created by the sensors to be mapped onto two or three principal components, and this facilitates a graphical illustration. The data space is transformed in such a way in these methods that the variances in measurements are maximized. Two methods were used in the current investigation programme. In the Principal Component Analysis (PCA) the transformation is performed without taking into account the target values, i.e. odour intensity or odour class. The separation into classes takes place exclusively based on the measured values. In the Linear Discriminant Analysis (LDA) the transformation algorithm is determined from calibration data. Discriminant functions are looked for which can best separate the specified classes of the calibration data, so that the measurement points within a class move closer to each other and the centres of different classes are as far away from each other as possible.

The measurements are not expressed in terms of sensor values after the transformation in either method, but by the newly determined components. These components are sorted according to their relevance related to the information content to distinguish the measurement points. Since the method comprises a coordinate transformation, exactly the same number of new components is obtained as there are sensors are in the sensor system. One great advantage of the method is that the variances of the sensor patterns can almost completely be expressed by two or three components. Higher component numbers do not noticeably contribute to distinguishing the patterns. A graphical illustration of the results is possible.

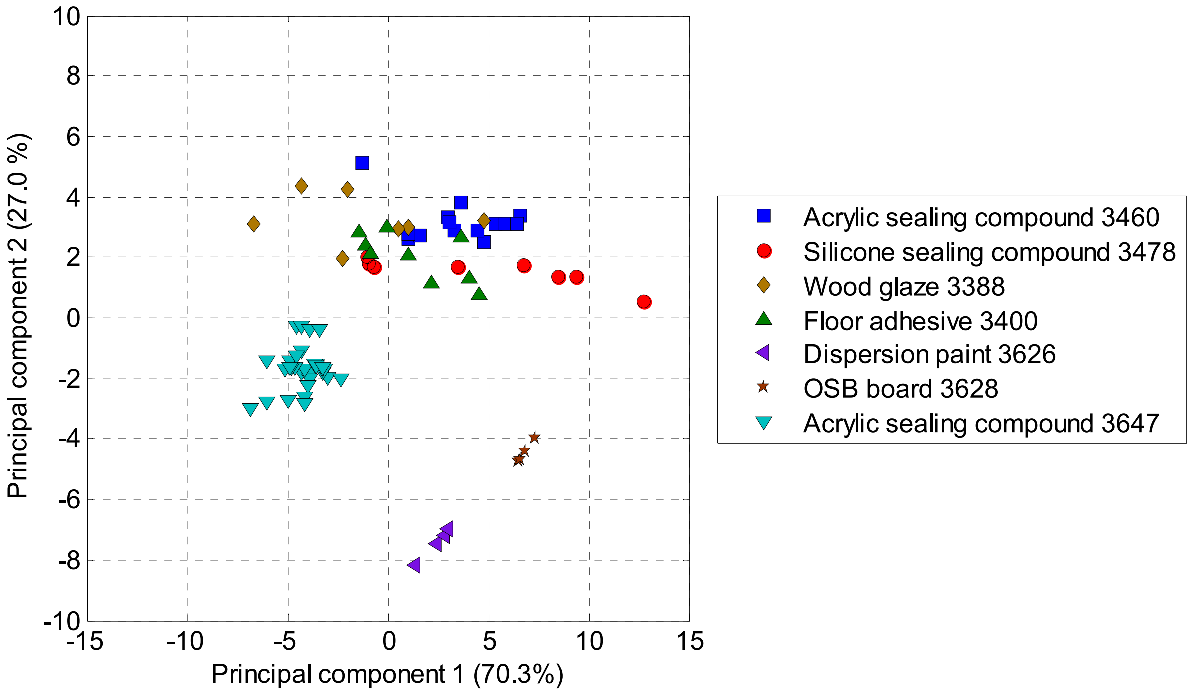


Figure 4-21: Principal component analysis of the performed measurements for 7 building products.

Figure 4-21 shows the result of the principal component analysis for the measurements of the tested building products using the multi-gas sensor system. The first two principal components of the measurements are shown in the diagram. Different symbols and colours characterise different building products in order to understand how the measured values are distributed and grouped in the plane. The percentages in brackets indicate how much of the information on the variances of the measurements is expressed in the principal component.

The diagram of the PCA shows that a clear classification cannot be achieved for all building products. The measurement results of three products form closed groups and can be separated from the measurements of other building products. The other four building products cannot clearly be separated. However, the intensity assessments of these materials are so different that they cannot form an odour class of their own. It has also to be noted that the measurements of the silicone sealing compound do not form a compact group, but produce an elongated row. This means that the sealing compound changes its pattern very strongly in the first days. This can be attributed to the fact that individual substances show different decay behaviour in the hardening process of the sealing compound or chemical reactions that take place, thus the emissions may change.

Since the transformation in the PCA is based on the measurement data of the sensor system, the measurements used have an influence on the result. In order to obtain a better classification of the four building materials that cannot be classified unambiguously, a second analysis was carried out including only data from these building materials. Additionally, measurements on pure supply air, i.e. with no contamination by the samples, were performed on the measurement days shown in Figure 4-22. The diagrams show the results of the first three principal components. Each diagram shows the plane spanned by two principal components. The acrylic sealing compound (3460) forms a group on the periphery, but a clear attribution cannot yet be established.

Regarding the measurements on pure supply air, it can be seen that PCA cannot distinguish between the measurements of wood glaze (3388) and floor adhesive (3400) and that of air. The measurements of silicone sealing compound (3478) in the first days can be distinguished from other measurements, but they tend to shift towards the region of air. This is in agreement with intensity assessment, which is 2 pi closer to the area of air on the tenth day.

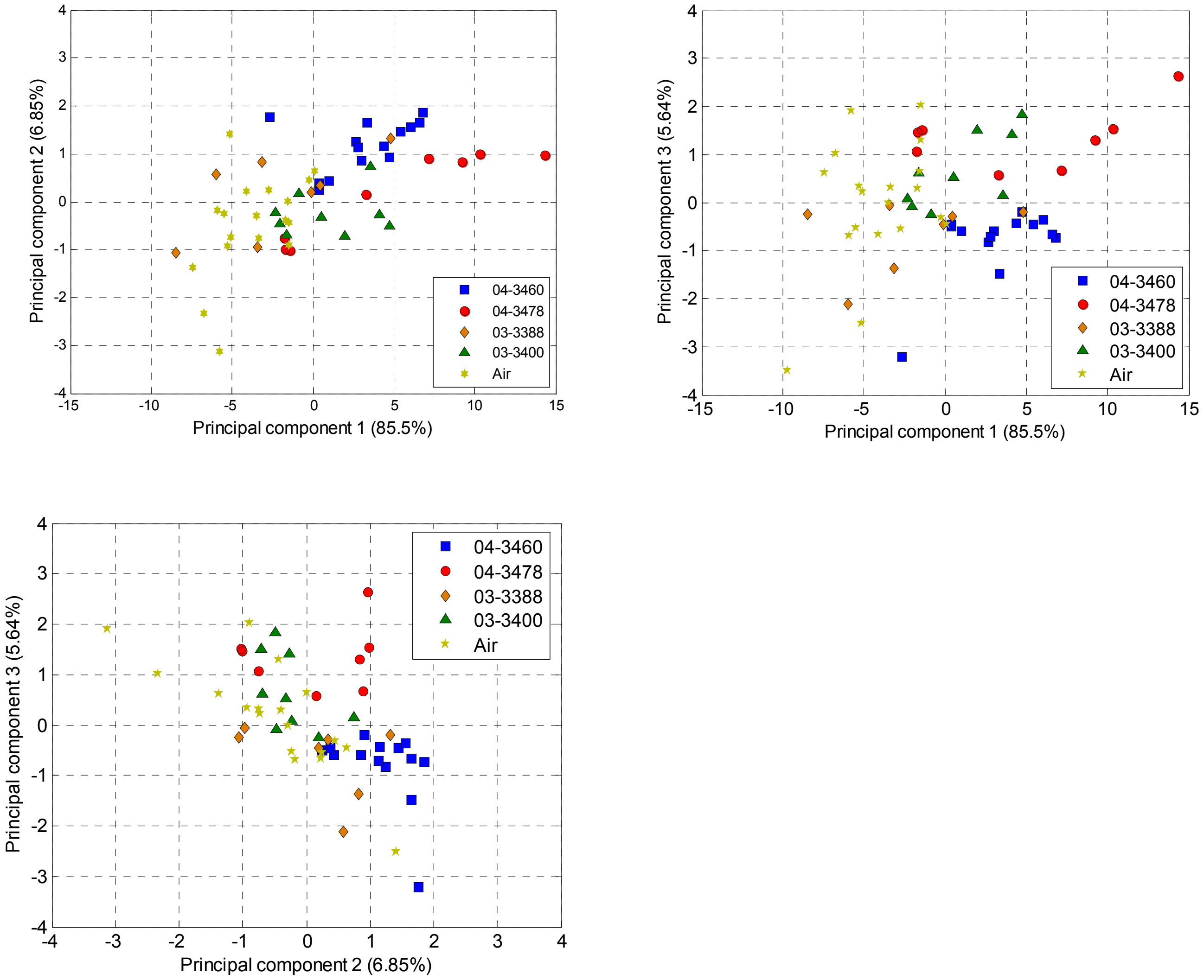


Figure 4-22: Principal component analysis of the measurements on four building products and uncontaminated odour-neutral air

The principal component analysis does not allow a clear classification of the building materials. In order to achieve a better grouping of the data, a linear discriminant analysis (LDA) was carried out. LDA may achieve a better distinction since the classes are optimised based on their class attribution.

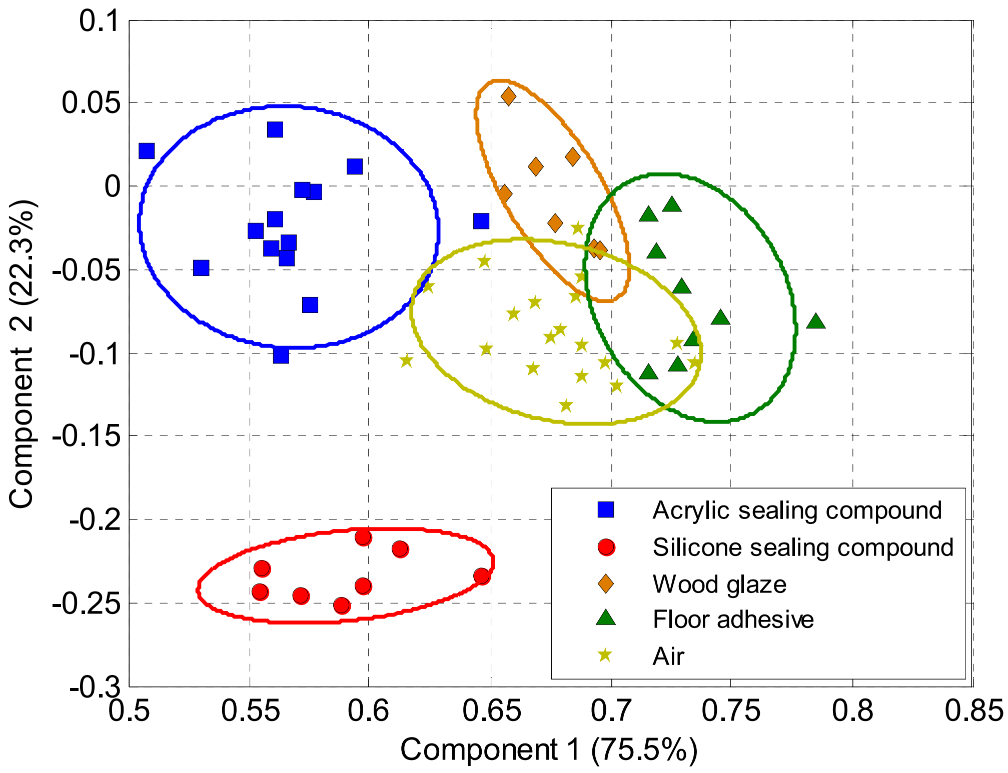


Figure 4-23: Linear discriminant analysis of the measurements on four building materials and odour-neutral air

LDA was performed for all seven building products including measurements on air. The transformation algorithms were established using the kind of building product as classes. Figure 4-23 shows the result of the LDA based on the first two components. The diagram only shows an excerpt of the plane containing those measurement data which are difficult to differentiate. The other three building products could be distinguished clearly from the other groups with the LDA as it could be seen with the PCA. The percentage in the parentheses behind the component again indicates the relevance of the respective component.

LDA enables a better separation of the building product classes. Measurement data of the individual building products form more compact groups. However, overlaps of classes in the LDA can still be observed between the areas of air and floor adhesive and, to a lesser extent, wood glaze.

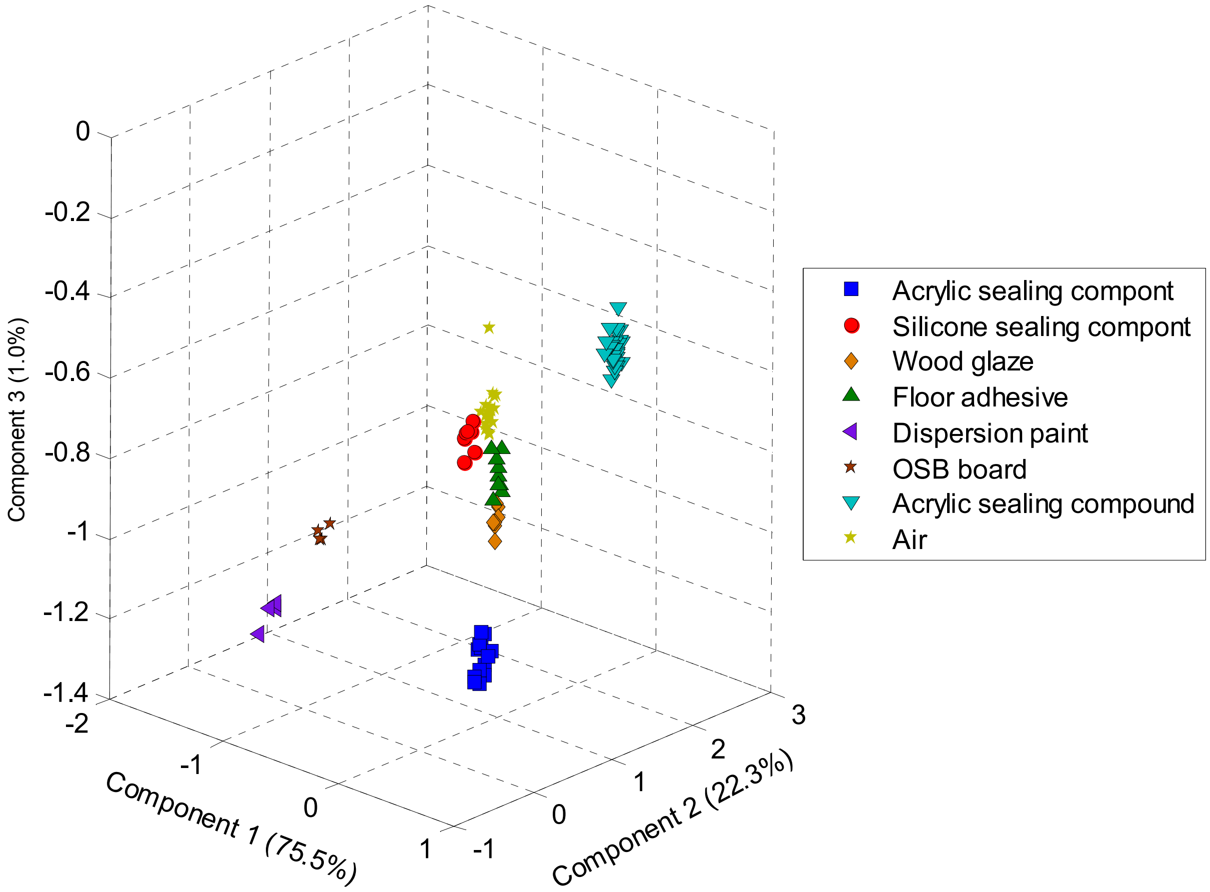


Figure 4-24: Illustration of LDA with three components

When considering the first three components of LDA, all building products can be represented as separate classes. This is evident from the three-dimensional representation in Figure 4-24. However it has to be noted that the third component exhibits only a small portion, i.e. 1%, of the information content of the variance of the measured values.

A regression with the measurements of the respective class is performed in the second step of assessing the samples' intensity. The method of principal component regression (PCR), being a combination of principal component analysis and multiple regression, was used in this investigation.

For the regression assessment in an ideal case, the measurement data are divided into calibration data used to determine the regression parameters and into validating data which are not included in the regression. However, this requires a large number of data. Since only relatively few measuring data are available for each building product, the leave-one-out-method was used to validate the regression. In this method a measurement is separated for validation purposes from the other measuring data and the regression parameters are determined with the remaining data. The determination of the regression quality is based on the excluded validation measurement. Regression is repeated as often as each measurement has been subject to validation. Panellists then compare the calculated intensities from the validation of the regressions with the assessments. Figure 4-25 and Figure 4-26 show the results of the regressions for acrylic sealing compound and silicone sealing compound.

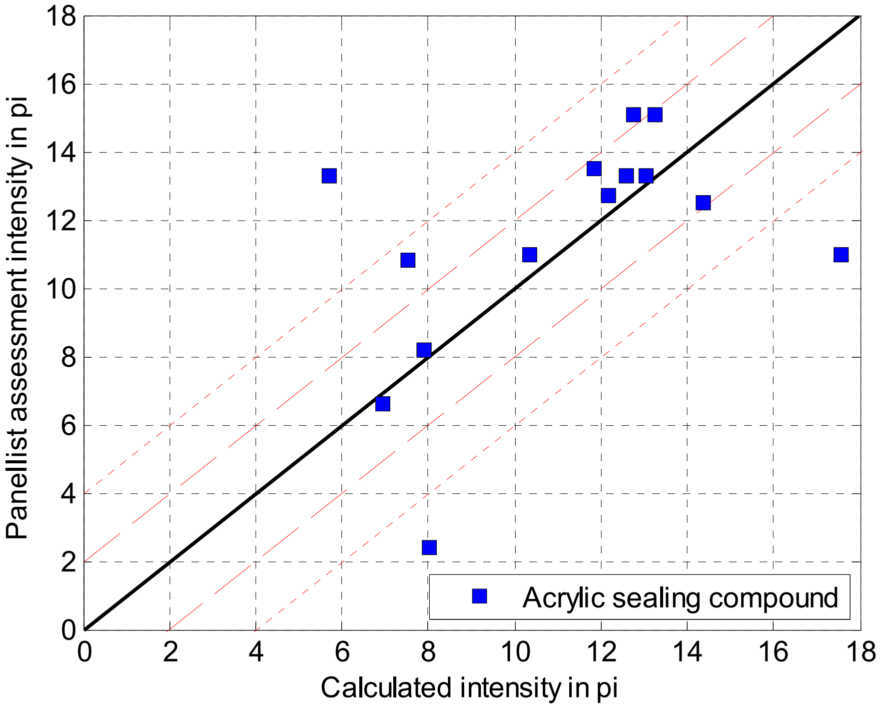


Figure 4-25: Principal component regression of the measurements of the acrylic sealing compound 3460

Intensities assessed by the panellists are plotted against intensities determined from sensor measurement data. If the two values agree, the points are on the first bisector. The ranges for a deviation of ±2 pi and ±4 pi are indicated in the diagrams by dotted lines. Most measurement points lie within the range of ±2 pi. However, the regression of the measurement data of the acrylic sealing compound shows 3 points that are far away from the assessed intensity. It is conspicuous that these high deviations occur in the periphery. The determined regression functions are only valid within the range of the intensities of the measurement values included for calculation of the regression parameters. If the validation measurements are in the boundary region of the regression, they are outside the valid intensity range of the regression. It has to be taken into account that the assessments by the panellists also exhibit a certain measurement inaccuracy and the deviations from the ideal profile can also be caused by these inaccuracies.

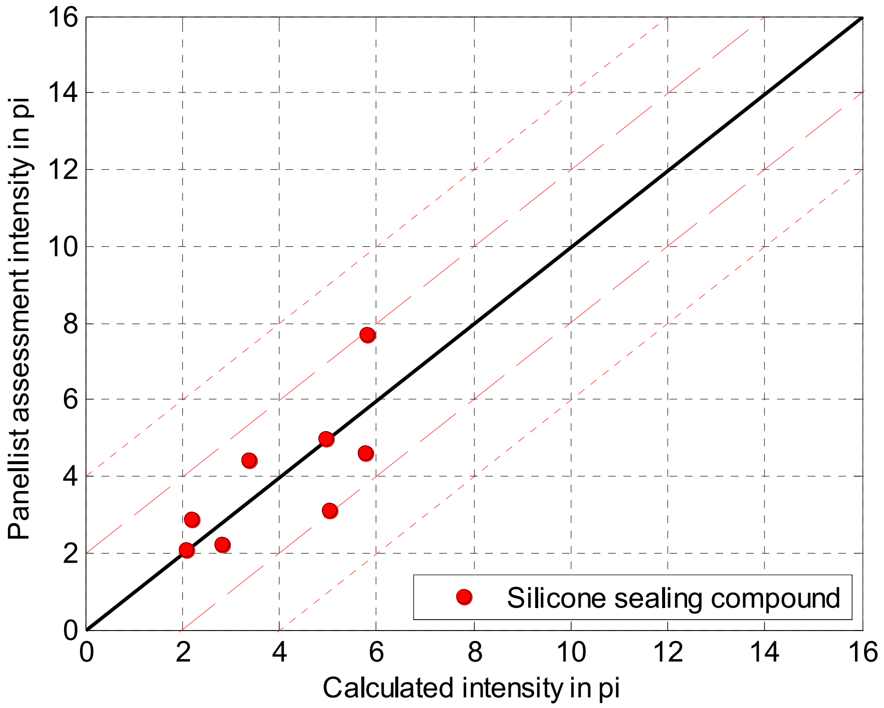


Figure 4-26: Principal component regression of the measurements of the silicone sealing compound 04-3478

Figure 4-27 sums up the results of the regression of all seven building products. Odour intensities of most building products can be calculated by the 2-step method with a classification and regression described here. High deviations for acrylic sealing compound (3460) and floor adhesive (3400) can be recognised in the boundary region of the regression range. The determined intensities of wood glaze (3388) deviate by 4 pi from the assessments in some cases. The classification of the measurement data for these building products also requires an increased effort and an attribution of the measurements to the correct class cannot always be performed unambiguously.

The investigations of building materials within this research project show that the use of sensor systems is feasible for the determination of odour intensity. However, sensitivity and selectivity of sensor systems must be increased in order to be able to distinguish between various building materials more efficiently. Follow-up investigations of combinations of building materials are necessary to facilitate the use of sensor systems in the determination of odour intensity of building materials. The extent at which odour intensity from new and unknown materials can be determined has to be investigated based on a calibration data set from selected materials of different material classes.

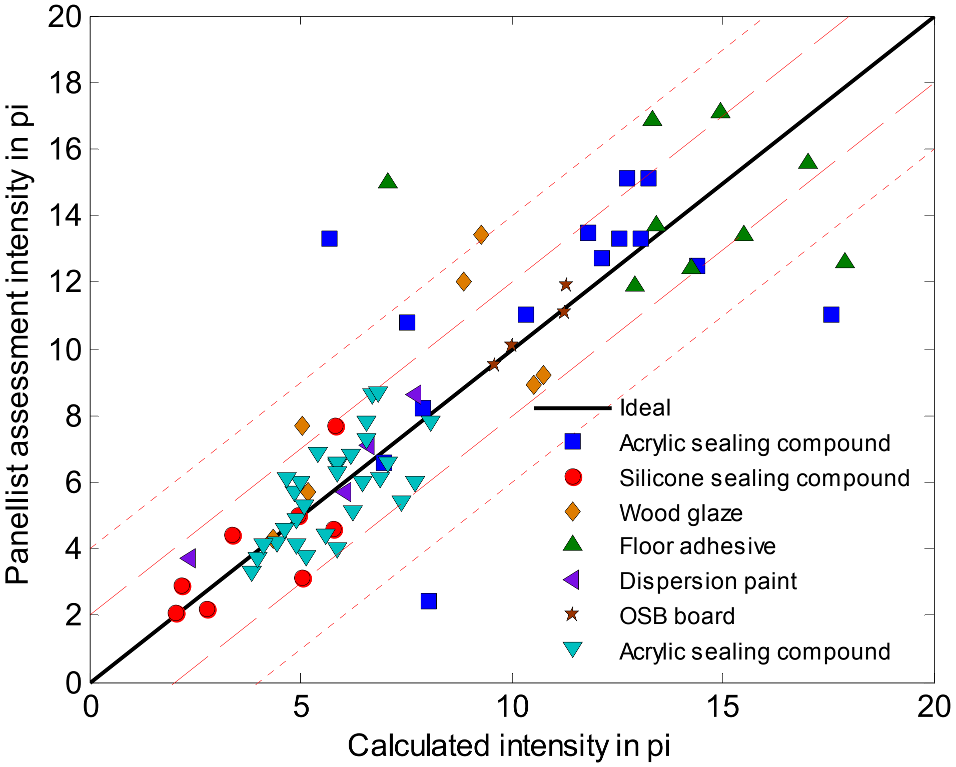


Figure 4-27: Principal component regression of the measurements of seven building products

4.3 ACCOMPANYING INVESTIGATIONS

4.3.1 COMPARISON OF VOC TESTS IN DIFFERENT CHAMBERS

As described in Section 3.5.1 (page 34), larger airflow rates are needed for odour measurements than usually obtained from emission measurements in chambers in accordance with the standards 16000-9-11. 1-m³ chambers or smaller chambers are mainly used, which at an air exchange rate of 1 h^{-1}, provide only about 1/3 of the flow rate which is needed for an unimpaired assessment. CLIMPAQ was specifically developed for the assessment of odours [15]. This only enables odour assessment of building products at a reduced load, and that requires a higher area-specific airflow rate. This is unfavourable for the simultaneous emission measurement in accordance with ISO 16000-9, since the measurements are performed with clearly smaller loads and the results are difficult to verify. The emissions were measured in several simultaneous tests both in emission test chambers and CLIMPAQ, using at least the same area-specific air flow rate in each case. Though the comparison of odour measurements was the key target, VOC measurements were also compared. They showed good agreement for the results of some materials. Measurement conditions in CLIMPAQ and in the emission test chambers also differed in the respect that air-conditioned external air was only used in CLIMPAQ, opposed to the emission test chambers which used compressed air cleaned several times. This leads to a somewhat increased blank value in CLIMPAQ, which was taken into account in the assessment of the measurements. Figure 4-28 shows examples of relative ethanediol and butanol concentrations from an acrylic sealing compound. The results showed good comparability for these very volatile components.

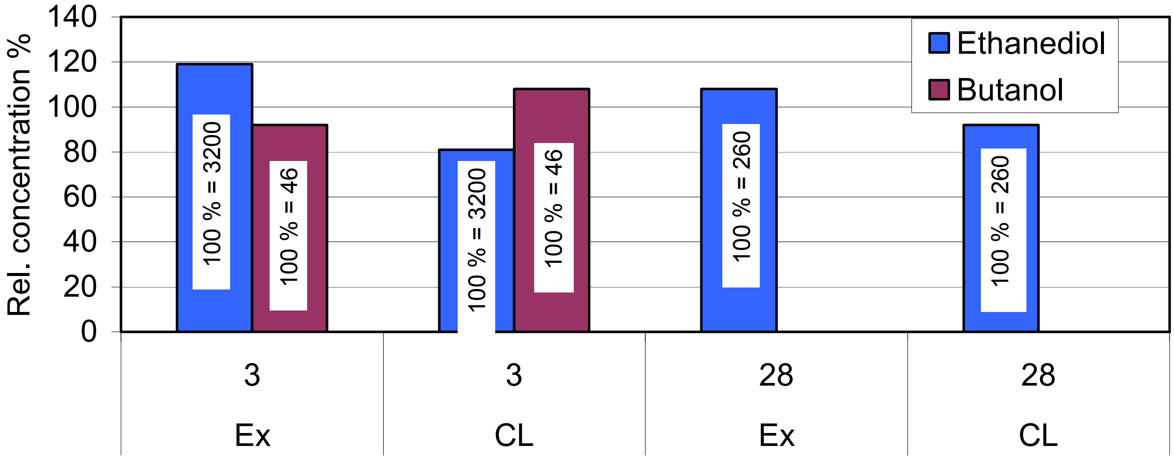


Figure 4-28: Comparison of selected compounds of an acrylic mass 3460 tested in the 23-litre chamber (Ex) and in CLIMPAQ (CL) on the third and 28th day (figures are given in relative concentrations, the average value is 100 % in each case)

Figure 4-29 illustrates two rather semivolatile compounds from a wood glaze. Here a shortfall was observed in CLIMPAQ in comparison to the 23-litre chamber.

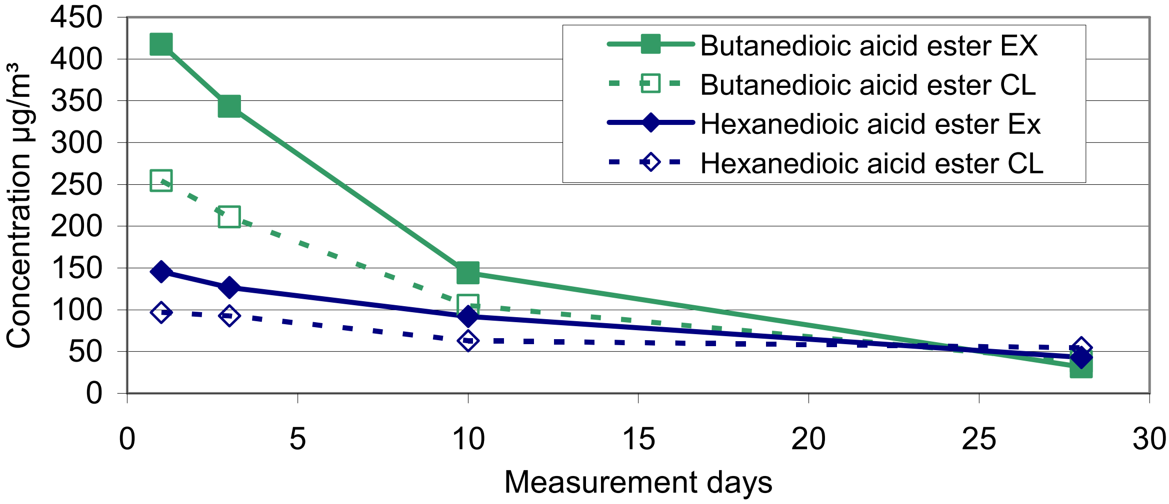


Figure 4-29: Concentration performance of selected compounds of a wood glaze 3388 tested in 23-litre chamber (Ex) and in CLIMPAQ (CL)

In addition to the comparison of emission test chambers as per ISO 16000-9 with CLIMPAQ, multiple determinations were also performed in this project using emission test chambers in accordance with ISO 16000-9. Such comparative tests can be used to determine sample homogeneity. The comparative measurements were carried out on an OSB of which several samples were tested. The results indicate an inhomogeneous sample material. Figure 4-30 shows the differences on the third and eighth and/or tenth day for two compounds. Sample 2 was only assessed over ten days, so that longer comparisons are not available. Δ_3-carene and other terpenes show very different values, while the concentrations of aldehydes and carbonic acids showed better agreement. The excellent comparability of the results of test chamber measurements was already proved in earlier projects [56].

A laboratory comparison to check the odour measurement method was also performed in the project (Section 4.4, page 109). The same type of sample was tested nine times within this comparison for the sake of quality assurance. For this purpose seven different cartridges of an acrylic sealing compound batch were tested over a period of six months. All TVOC values and most VOC values showed very little fluctuation in the tests. The standard deviations of VOC are displayed in Table 3-2 (page 33) clearly showing the differences: some compounds, chiefly polar ones, show deviations between 10 and 20 per cent and the few polar VOCs are below 10 per cent. The TVOC values are shown in Figure 4-31 in greater detail, exhibiting standard deviations less than 10 %. Thus a high degree of homogeneity was proved in the tested samples.

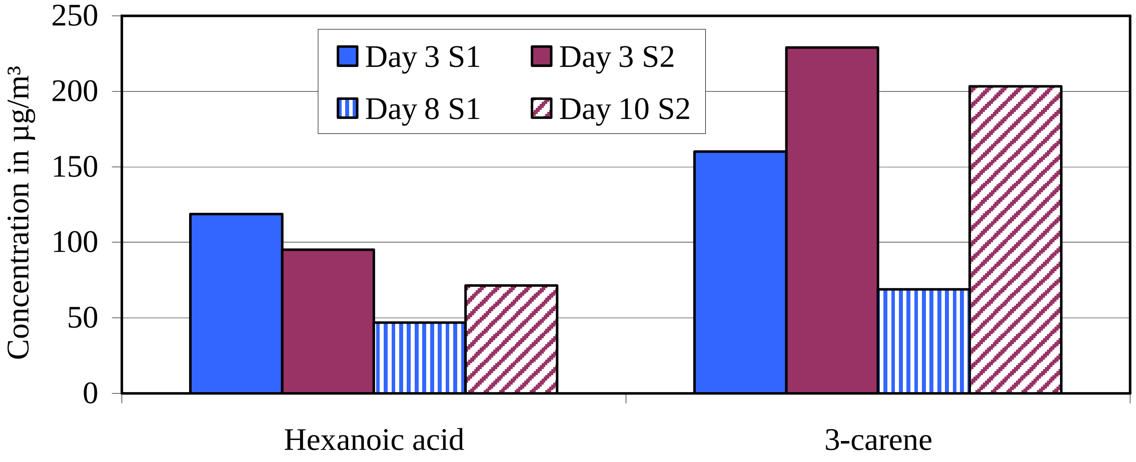


Figure 4-30: Comparison of concentrations of selected compounds of an OSB 3628 tested in two different 23-litre chambers (Sample1 (S1) and Sample 2 (S2))

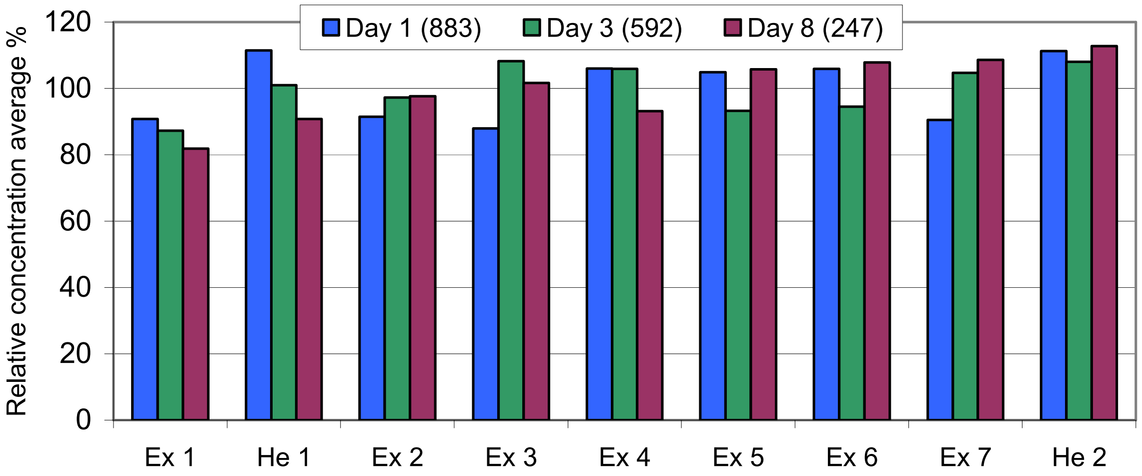


Figure 4-31: TVOC values of an acrylic mass 3653 tested nine times in 23-litre chambers (Ex) and in a 1-m³ chamber (He)

4.3.2 VOC COMPARISON: TEST CHAMBER AND ODOUR TRANSPORT CONTAINER

In addition to analysing the chamber air, odour transport containers were also tested by the Hermann Rietschel Institute before transport in all emission tests. Good agreement was found for most VOCs between the concentrations in the 23-litre chamber and those in the container. Figure 4-32 clearly indicates that there is hardly any difference between measurements in the chamber (Ex for short) and the transport container (Sa for short) over a large concentration range and also for rather polar components such as ethanediol. However, differences were found between the determined concentrations in other test series, especially on the first measurement day. This can be explained by the circumstance in which the transport containers were dynamically filled over night. The contained air also may have been several hours old since these containers only had an air exchange rate of approx. 0.3 h^{-1}. Since the VOC emissions from the building products decreased very quickly especially in the first hours, this longer period of dwell of the air in the container may have resulted in an increased concentration in comparison to the chamber. Sampling corresponds to a period of only a few minutes while the container represents a considerably longer period.

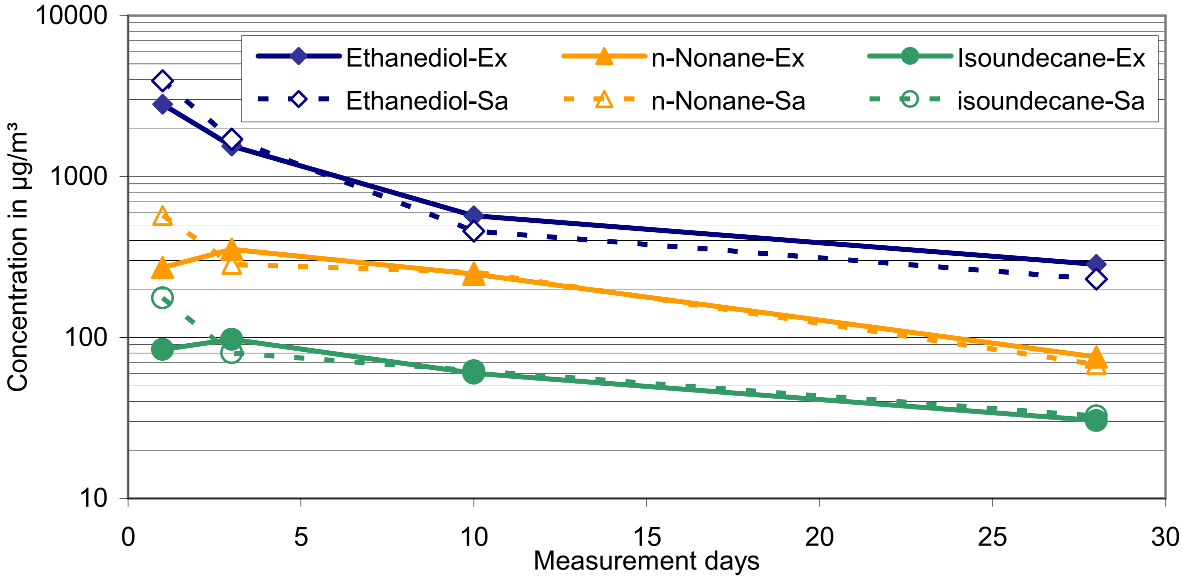


Figure 4-32: Comparison of concentration performance of selected compounds of acrylic sealing compound 3351 tested in the 23-litre chamber (Ex) and transport container (Sa)

The good agreement of the results was proved both in high and low concentration ranges, as indicated in Figure 4-33. Higher boiling points (around hexadecane) may lead to minor shortfalls. This behaviour is clarified by the example of the two dioic acid esters in Figure 4-34. The esters elute briefly before butanedioic acid ester or shortly after hexadecane. The concentrations in the transport container are in both cases less than the values measured in the emission test chambers.

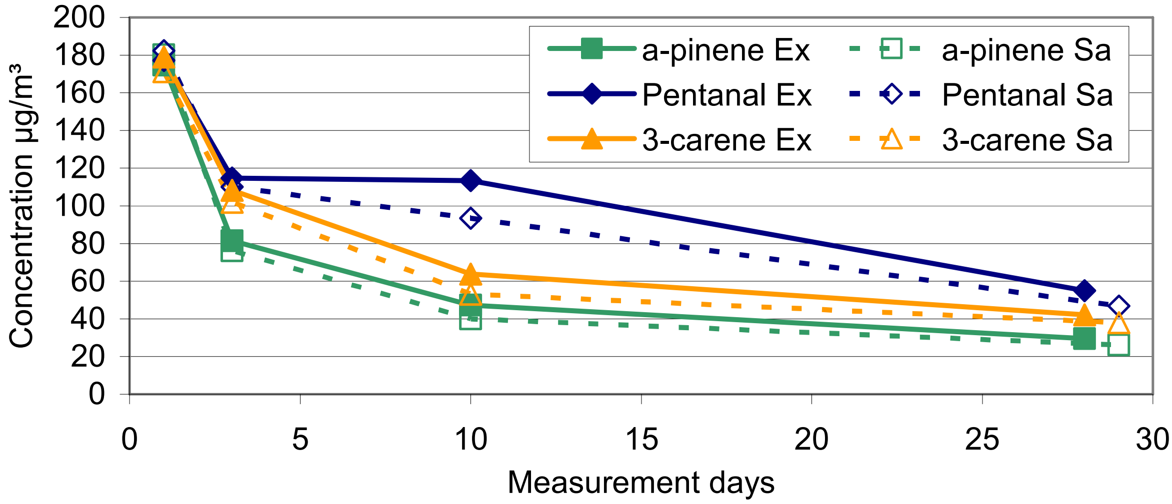


Figure 4-33: Comparison of concentration performance of selected compounds of OSB 3488 tested in 23-litre chamber (Ex) and transport container (Sa)

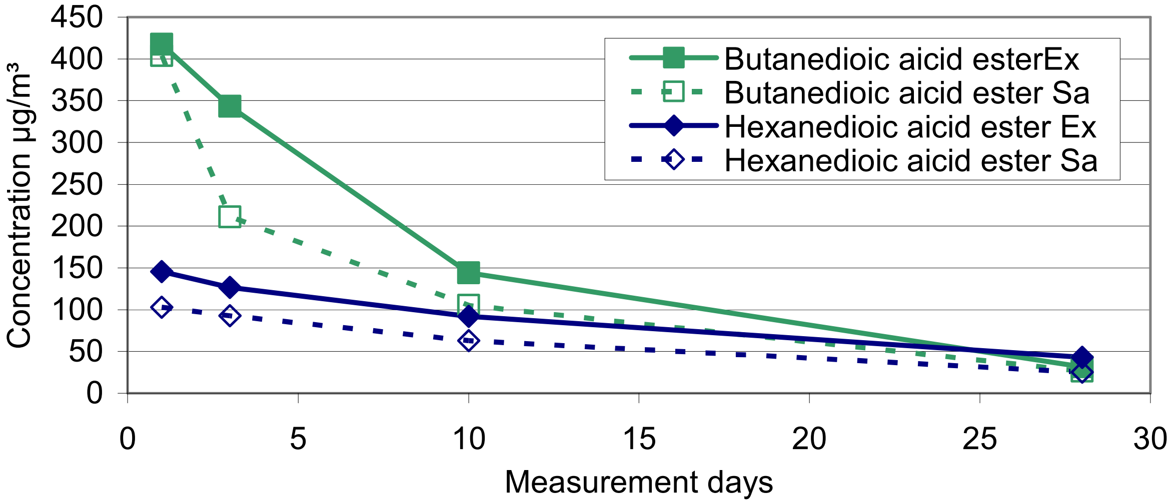


Figure 4-34: Concentration performance of selected compounds of a wood glaze 3388 tested in the 23-litre chamber (Ex) and in transport container (Sa)

4.3.3 HEDONICS AND INTENSITY

One of the key questions in sensory assessment of laden air samples by panellists is what information is queried and assessed. The methods presented in Chapter 2.3.1 provide an overview of the existing questions. Since in the two-stage method initial source strength is exclusively assessed by trained panellists, the question arose as to whether or not the assessment of hedonics of an odour (very pleasant … extremely unpleasant) furnished any additional information. For this purpose, test results obtained by preliminary investigations prior to the current research project were initially available. In addition to assessing two building materials (carpet, linoleum), over 100 untrained panellists assessed air samples that were produced from natural vegetable fragrance oils (vetiver, carnation, grapefruit and rose). Figure 4-35 shows a comparison of the assessments of hedonics by untrained panellists with the assessments of odour intensity by trained panellists determined directly before the untrained panellists.

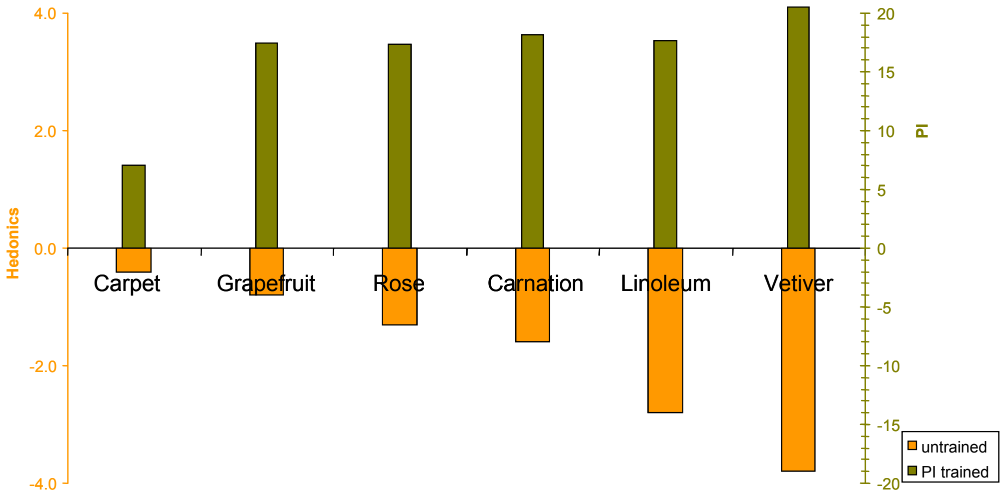


Figure 4-35: Intensity and hedonics: assessment by trained and untrained panellists

On average, none of the substances was given a positive hedonics assessment by untrained panellists. Conspicuous is a relationship of the hedonics with odour intensity. High intensity values are obviously connected with an unpleasant to extremely unpleasant odour effect.

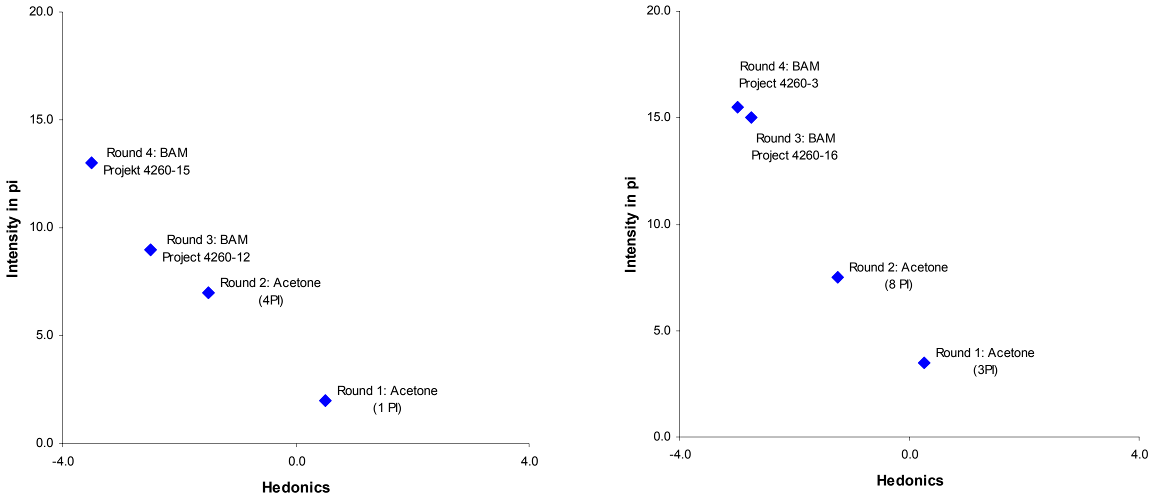


Figure 4-36: Intensity and hedonics: assessment by trained panellists

In addition to perceived odour intensity Π, the hedonic odour effect was also determined for building material assessment within the research project. Figure 4-36 illustrates the assessment of some selected building materials and acetone. Hedonics is plotted on the abscissa and perceived intensity Π on the ordinate.

The assessment by trained panellists shows even more clearly the relationship intensity vs. hedonics. An assessment of 'pleasant' can only be expected when the panellists have determined very low intensities.

Figure 4-37 summarises 164 hedonics and intensity assessments of building materials. Each individual point in the diagram represents the average of an assessment of hedonics and intensity on a particular test day. A clear relationship between increasing intensity and decreasing hedonics can be observed here too. It has to be principally stated that an existing odour impression is always assessed as a negative hedonics by a panel.

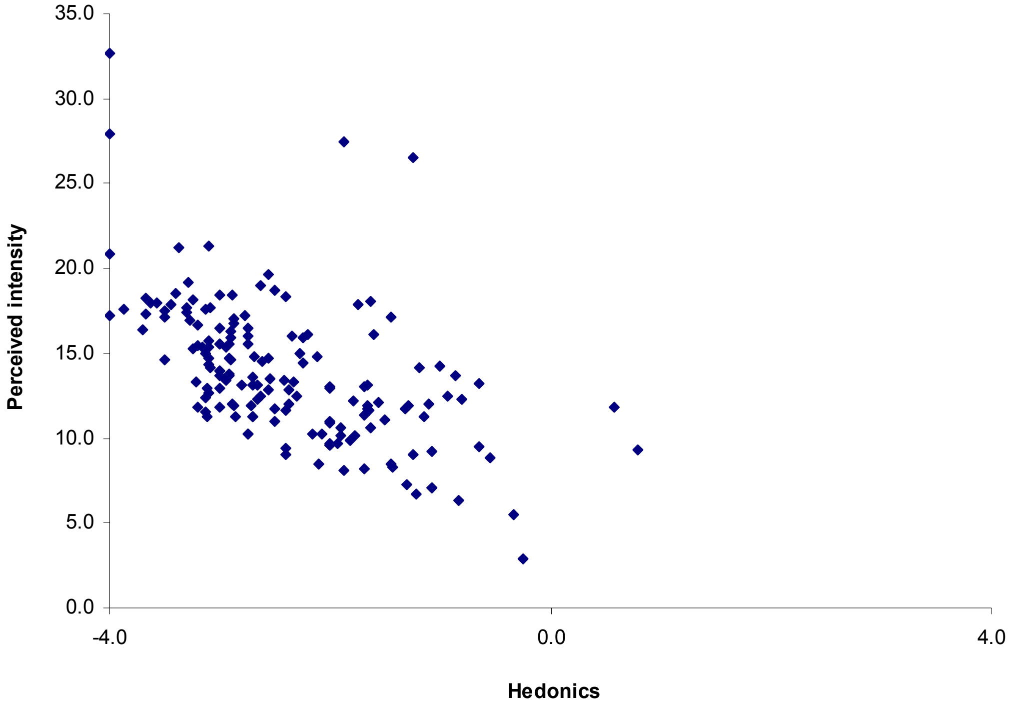


Figure 4-37: Summary of hedonics and intensity assessment

The wide dispersion of the value pairs hedonics/intensity within the range between 10 and 20 pi shows that using hedonics does provide additional information about odour impression. However, the standard deviation of the answers is considerably larger than that of the assessment of odour intensity due to the very individual estimates of odour impressions. Medium and maximum standard deviation for perceived intensity and hedonics is compiled in Table 4-19.

Table 4-19: Medium and maximum standard deviation of perceived intensity and hedonics

	Medium standard deviation, relative	Maximum standard deviation, relative
Perceived intensity	24 %	66 %
Hedonics	61 %	424 %

Large panels can only provide reliable values for hedonics when dispersion of the answers is so high.

4.3.4 ODOUR COMPARISON: CLIMPAQ AND SAMPLE BAG (EMISSION CHAMBER)

Selections of building material samples were simultaneously loaded into CLIMPAQs in the Hermann Rietschel Institute and emission test chambers in BAM for the comparative CLIMPAQ – sample bag tests. The area-specific airflow rate q was determined as suggested by Nordtest NT Build 482 and the same value was adjusted in both experimental set-ups (also see Chapter 3.5.2, Sample provision). The assessment of the samples from the odour transport containers was performed on the same day as the direct assessment of the samples from the CLIMPAQs took place.

The results of intensity assessments on an acrylic sealing compound are compared in Figure 4-38. The basic performance of intensity assessment is similar in both evaluation series. Intensity decreases from the first to the third day, moderately increases in the assessment on the tenth day and clearly drops toward the 28th day. It is conspicuous that intensity assessments of air from CLIMPAQ provide lower values than those samples from the sample bag.

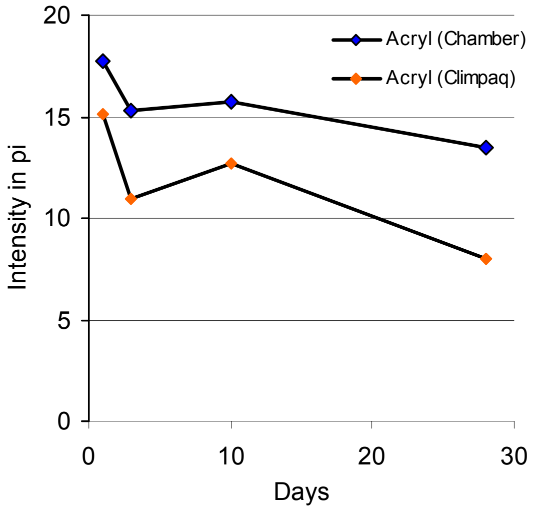


Figure 4-38: Comparison of intensity assessments for Acryl 3460 in Climpaq and chamber

The differences in the intensity assessment are even more expressed for the silicone sealing compound (Figure 4-39). The curves of the assessments on the first, third and tenth day are nearly parallel, but the assessments from CLIMPAQ provide significantly lower values.

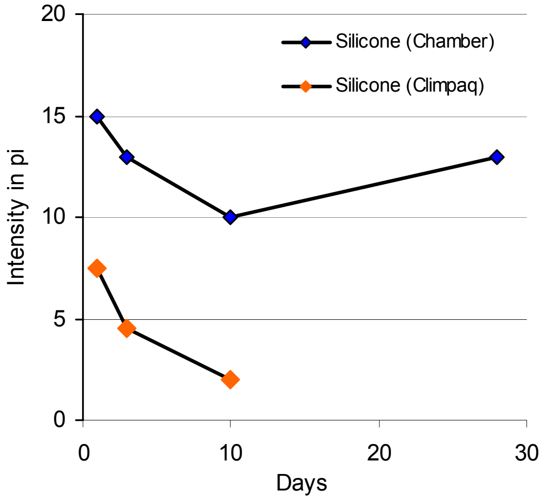


Figure 4-39: Comparison of intensity assessment for silicone 3478 in Climpaq and chamber

Acryl and silicone constitute a group of building materials which, as sealing compounds, are exposed on a relatively small surface in the interior. If the building materials represent a large area in the room, the values of perceived intensities from

CLIMPAQ and emission chambers are much closer to each other (Figure 4-40 and Figure 4-41).

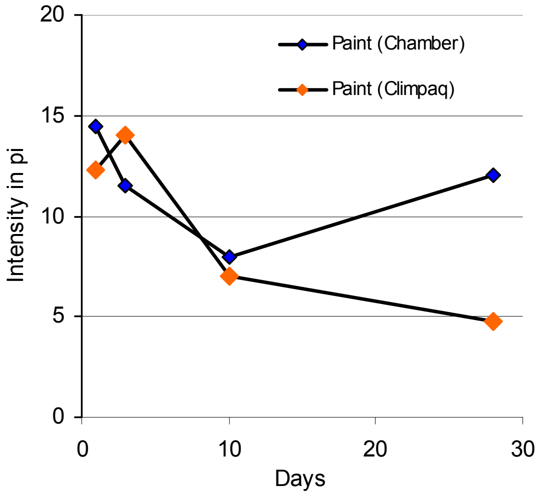


Figure 4-40: Comparison of intensity assessment for paint 3388 in Climpaq and chamber

The different assessments on individual days may have several causes. In addition to the influence of sample bags on sample air, air supply to the CLIMPAQs has also to be considered: as opposed to the high-purity air supplied to the emission chambers of BAM. CLIMPAQs at the Hermann Rietschel Institute are supplied with air from the air quality laboratory air conditioning system. This special equipment is manufactured from low-emission components such as high-grade steel and glass, but is not capable of compensating for changes in ambient air humidity and temperature. These fluctuations may have an influence both on emission behaviour of the building materials and on assessment by trained panellists.

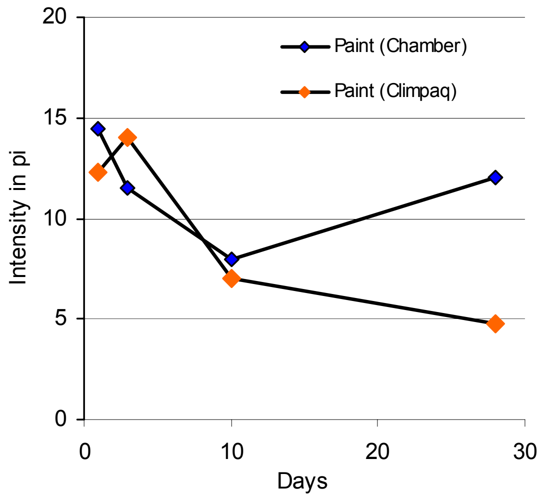


Figure 4-41: Comparison of intensity assessments for adhesive 3400 in Climpaq and chamber

4.3.5 ASSESSMENT OF LOW INTENSITIES

Assessments of building materials altogether provided higher values than expected. Laminate flooring was in particular assessed with high perceived intensities - contrary to experience and observations of the institutes participating in the group of experts.

A purposeful assessment of clean or minimally laden air samples from the comparative scale and sample bags was used to test whether trained panellists can detect low intensities and assess them accordingly and whether or not the sampling and sample provision system contributes to an additional contamination of sample air.

For this purpose the panellists must first assess clean air in an initial experimental set-up relying on the comparative scale. The micro-metering valve used to adjust acetone supply is fully closed. The panellists are thus provided exclusively with clean supply air of the comparative scale for assessment. The remaining five funnels with intensities 1, 3, 6, 9 and 12 pi are available to them for comparison. Figure 4-42 shows the assessment by the panellists.

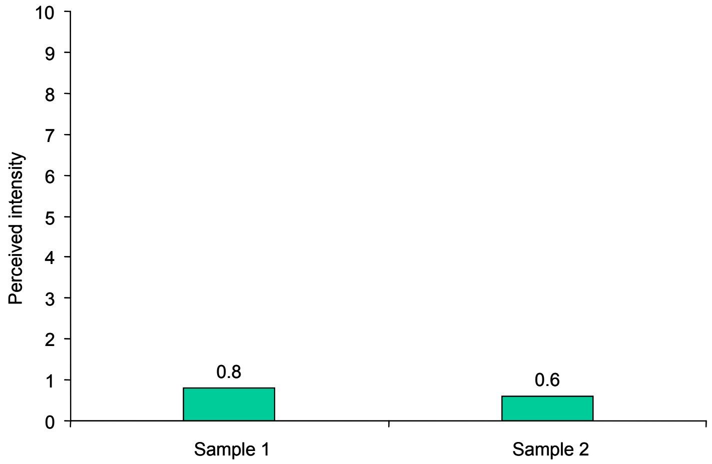


Figure 4-42: Assessment of clean sample air from the comparative scale

An average assessment of intensity of 0.6 and/or 0.8 pi indicates that the panel can recognise non-existing smells and assess them accordingly. Assessments of less than 1 pi are below the average odour threshold of acetone in this experimental set-up.

Two sample containers are filled with clean air from the air conditioning system of the air quality laboratory in another test. One sample container is filled 12 hours ahead of the assessment and another one directly before the assessment. A third sample container is filled with fresh external air directly before the assessment. It can be seen that air-conditioned air from the sample bags is assessed clearly higher with 2.1 pi, than clean sample air from the comparative scale (Figure 4-43). With a delay time of 12 h the assessment increases to 5.1 pi. External air is evaluated slightly higher with 2.3 pi than air-conditioned air.

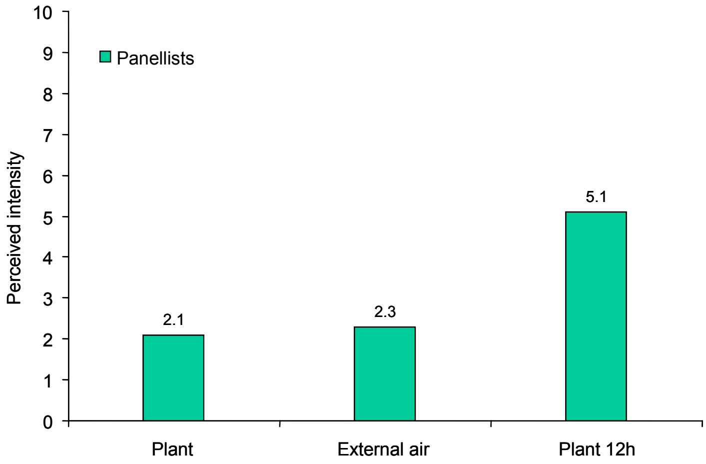


Figure 4-43: Assessment of low intensities from sample bags

There is an influence of the sampling and sample provision system on odour load of the air sample. However, when the existing provisions for the production and thermal treatment are carefully observed and waiting times reduced, the influence of the sampling and sample provision system can be kept to a minimum.

4.3.6 ODOUR DETECTOR MEASUREMENTS

Some of the chamber tests were additionally tested using a combination of thermodesorption with gas chromatography and odour detector port (GC/ODP) simultaneously to mass selective detection (MSD). The sealing compound (3653) used in the laboratory comparison was the one most intensively tested using this method. The procedure and the results are described in the following.

A sample of ten litres was usually drawn through the Tenax tube in these measurements. Thus the sensitivity of the measurements was enhanced, without having to change to another sampling procedure e.g. liquid desorption with increased sample enrichment. The eluate of the GC column was split before odour detection in the ratio of 1:1, part being fed into MSD and another part into ODP. For each run, a panellist had to smell the eluate in the analysis run (Figure 4-44). Since this is a very demanding activity where one must pay attention to and concentrate on the signals from the nose, it is important to devise short analysis runs. Experience shows that running times between 15 and 20 minutes are ideal and a panellist should participate in the tests for a maximum of twice a day. Depending on odour intensity, the panellist gives a signal during the analysis run using a potentiometer which then records a chromatogram simultaneously to that of the mass spectrometer.

Figure 4-44: A panellist smells the eluate of the chromatograph (smell funnel and potentiometer)

Assessment of the ODP chromatogram is complex since the result can be impaired by external influences. For instance, not each panellist is equally sensitive to all odours, and the result may be affected by their performance on the day, odour quality in the ambient air and room climate. For a sufficient reliability of the results it is important that several panellists test the same sample in order to be able to make statements about the odour at a high confidence level. In the investigations performed here at least six panellists tested the same sample. For this purpose all necessary Tenax pipes were loaded with chamber air on a particular day and were tested within two to three days.

Figure 4-45 shows an excerpt of the result of the superposition of the two chromatograms. The black chromatogram in the foreground shows the MSD measurement and the red one in the background depicts the ODP test. As the diagram indicates, there are good agreements in the retention times of ODP and MSD, but there are also strong ODP signals which do not correspond to any MSD peak (odour-generating substances). There are also MSD signals to which there are no corresponding ODP signals (less odour-generating substance). In addition, humans have a breath rate of 15 breaths per minute at rest, each of which lasts about 1 second. Thus humans only smell every 4th second which corresponds to about 0.07 units in the chromatogram. Therefore the retention time of the ODP signal deviates from that of the MSD signal by this time. When one calculates an additional uncertainty, the ODP signal can deviate from that of the MSD by 0.1 units. This circumstance makes the evaluation more difficult. Therefore retention time ranges were used to compare the answers of the panellists.

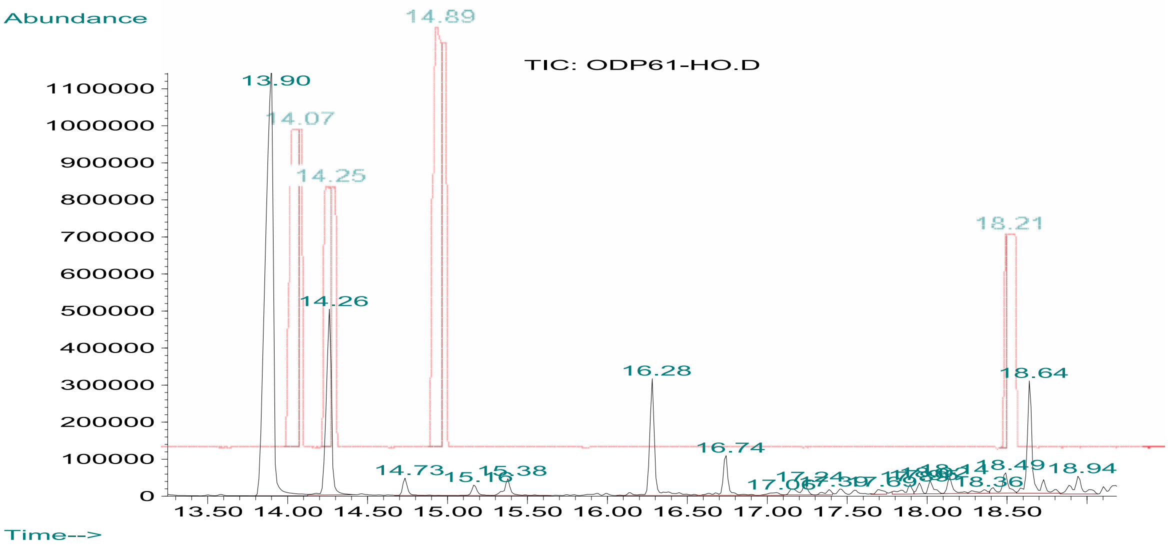


Figure 4-45: Two chromatograms of the same sample (acryl 3653): MS (black) and ODP assessment (red)

Table 4-20 displays the answers of nine, ten and/or 13 panellists for the emissions from an acrylic sealing compound. The first column contains the components and their retention times that were determined as emissions. Those retention times where more than half of the panellists smelled something on the first day are indicated in bold type face. It is worth mentioning that no pre-selection of the panellists took place, therefore it is not absolutely sure whether they are capable of performing reproducible tests. It was possible to give unambiguous answers to some compounds which was corroborated by checking the relevant standards. Those components belonging to this group include n-butylether, propionic acid butylester and butyric acid butylester.

Table 4-20: ODP answers in % for acryl 3653 sample on the first, 16th and 28th day of the chamber test

		Number of panellists		
		10	**13**	**9**
Compounds	**RT range**	**Day 1**	**Day 16**	**Day 28**
	2.10 - 2.40	40	54	78
	2.80 - 3.30	40	38	22
	3.47 - 3.90	-	38	44
	4.00 - 5.08	-	23	33
	5.30 -5.60	40	23	11
	5.70 - 5.80	**50**	**31**	**11**
1-butanol (RT 5.98)	6.00	20	15	22
	6.34 - 6.65	**90**	**69**	**33**
	6.83-7.10	**-**	**69**	**44**
	7.23 - 7.81	40	38	44
	8.20	-	-	11
	8.50 - 8.90	10	23	11
Propylene glycol (RT 9.18)	9.10 - 9.38	10	31	11
	9.55 - 9.90	40	31	-
	10.00 -10.70	30	15	44
Acetic acid butyl ester (RT 11.47)	**11.3 - 11.5**	**60**	**31**	**11**
	12.70	-	15	-
	13.00 - 13.30	20	8	33
n-butyl ether (RT 13.88)	**13.40 - 14.00**	**80**	**77**	**56**
	14.10 - 14.28	20	15	44
Propionic acid butyl ester (RT 14.24)	**14.37 - 15.00**	**90**	**85**	**89**
	15.57 - 16.00	**60**	**54**	**56**
Butyric acid butyl ester (RT 16.25)	16.30 - 17.80	40	31	22
Decane (RT16.35)	18.00 - 18.50	30	31	33
Undecane (RT18.6)	18.60 - 19.25	40	46	33
	19.37 - 19.87	40	23	22
Dodecane (RT 20.06)	20.00 - 20.50	10	-	44
Tridecane (RT 21.22)	20.50 - 21.50	10	-	44
Tetradecane (RT 22.51)	21.60 - 22.80	10	-	33

In particular on the first day, nearly all panellists were able to identify a very clear odour after about 6.5 minutes. However, the measurement from a mass spectrometer was not able to detect any compound that could have been assigned to this odour. Only increased sample quantity enabled small amounts of ethyl acrylate to be identified. Then different panellists performed recovery tests on this component. Table 4-21 shows the results of these investigations. Individual minute concentrations were obtained in at least two measurement runs and a blank value determination. This assessment enables the identification of the individual sensitivity of the panellists for this compound. Three panellists were able to easily and reproducibly recognise ethyl acrylate in a very small absolute concentration of 0.1 ng absolute on a Tenax tube - this would correspond to 0.01 µg/m³ in a sample of 10 litres. Three other panellists were only able to identify 1 ng absolute. These results correspond to the identification in the sample: 90 % of the panellists detected the component on the first day, 70 % on the 16th day and 33 % on the 28th day (Table 4-20).

Table 4-21: Recovery tests for the component ethyl acrylate at different absolute concentrations on Tenax pipe (x = positive answer, - = not smelled, empty = not participated)

Absolute concentration of ethyl acrylate in ng	**Panellists**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	-	x	x		x	x	-	
0.5	-	x	x	(x)	-	-		
0.1	-	x	x	-				x

ODP tests can supply good additional information for VOC emissions. However, a good result depends largely on ambient influences in smelling and the sensitivity of the panellists for individual components. As expected, there is rarely a good agreement between an odour and a properly identified VOC concentration, therefore the experience of many years is helpful in the assessment of ODP signals, and a very strong enrichment in concentration of the samples is necessary. This enrichment cannot be increased at will in adsorptive sampling over Tenax, since long sampling periods lead to a breakthrough of the components. A complete determination of all odour-active compounds may sometimes not be feasible if these compounds are very volatile or especially semivolatile and Tenax is therefore not the appropriate adsorbent. Stronger or weaker adsorbents might be used but this would make the method of odour assessments even more expensive.

4.3.7 NIK (LCI) LIST AND C SUBSTANCES

A key component of the AgBB scheme (Section 2.2, page 6) is the NIK (LCI) list which illustrates health-related, substance-specific data of individual substances. They are components that are frequently used in and emitted from building products. Based on their MEL (Maximum exposure level) (German: MAK, Maximale

Arbeitsplatz-Konzentration) or other toxicological information, concentration values – so-called NIK (LCI) values – are determined and included in the list.

Detection and determination limits of these NIK (LCI) substances were ascertained in the project by tests with standard solutions. A determination limit of ≤ 1 µg m^{-3} was determined for 78 % of the NIK (LCI) substances based on the column used in the project and an assumed sample volume of five litres on Tenax. The determination limit is ≤ 5 µg m^{-3} for another 18 % and a determination limit above 5 µg m^{-3} was only determined for 4 %. This last group mainly includes polar components, for which a much smaller determination limit may be obtained on a more polar column with high probability. However, the ISO 16000-6 standard envisages that a nonpolar column should be used.

Another requirement of the AgBB scheme is the adherence to very close limits, as far as the demonstrability of carcinogenic substances (C substances) is concerned. Thus the sum of C substances must be less than 10 µg m^{-3} after three days and less than 1 µg m^{-3} after 28 days. However the C substances are not represented by a list in the AgBB scheme. The CMR list (carcinogenic, mutagenic, reproduction-toxic) of the Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, BAuA) [58] can be used as a guide, which is based on the lists of the EU Guideline 67/548/EWG and TRGS 905 and 906. C substances marked by 1 and 2 have been integrated from these lists in the evaluation mask, which is used by the German Institute for Construction Technology (DIBt) for the application of the AgBB scheme. Based on this list, a selection was compiled depending on plausibility, relevance to building products and potential detectability of the substances. Detectability of these CMR substances was tested within this project.

First the components were acquired for the investigations, and then standard solutions and their mixtures were prepared right down to concentrations of 0.05 ng per injection. These solutions were tested using the selected ion mode (SIM) which enables very sensitive detection. A special method was developed for the 38 carcinogenic materials, which enabled their simultaneous determination in a run. Detection limits listed in Table 4-22 were determined from the results. If a sample quantity of five litres on Tenax is assumed, a detection of limit less than 1 µg m^{-3} can be determined for 89 % of the components.

Table 4-22: Determination limits in ng absolute for 38 carcinogenic components of the CMR list of substances of the BAuA assessment based on the AgBB scheme

Determination limit in ng	**Number** Total 38	**Component**
< 1	21	Azobenzene; 2-methoxy-5-methylbenzene amine; 4-chlorine-2-methylbenzene amine; 1-methyl-2,4-dinitrobenzene; 1-methyl-2-nitrobenzene; 2-methyl-1,3-dinitro-benzene; benzoic trichloride; benzyl chloride; 1,2-dibromoethane; 2,3-dibromopropan-1-ol; 1,3-dichloro-2-propanol; 1,2-dichloroethane; 2,3-dinitrotoluene; hydrazobenzene; 2-methoxyaniline; 1-nitrosopyrrolidin; o-toluidine; (R)-1-chlorine-2,3-epoxypropane; 1,3-dichloropropene (1); trichloroethylene; 1,2,3-trichloropropane
1 – 5	13	2-methyl-5-nitrobenzene amine; 4-methyl-1,2-dinitrobenzene; benzene; 4-chloroaniline; diethylsulfate; 3,3-dimethoxybenzidine;dimethyl sulfate; furan; 2-nitroanisol; 2-nitropropane; o-tolidine; 2-propenenitrile; styrene oxide
> 5	2	Dimethyl carbamyl chloride; 4-methyl-m-phenylenediamine
unknown	2	Bis-(4-aminophenyl)-methane; tetranitromethane

4.3.8 VVOC TESTS

In addition to the known methods for VOC, such as sampling using Tenax and DNPH, other adsorbents were tested in the project in order to extend the spectrum towards very volatile components (VVOC). The DNPH method enabled the determination of aldehydes and ketones emitting within the VVOC range. VVOCs indicated chiefly in the result section of the report includes formaldehyde, acetaldehyde and acetone. Thermoextraction of the products (Section 4.3.9) gave an initial overview of whether VVOC emissions from the products could be expected. Due to their high volatility a large part of these components evaporated during the usual waiting period of 24 hours before the test and could not be determined. Building products which are known to emit fairly large amounts of very volatile components include most foamy insulation materials such as EPS, phenolic resin or PU foam [59], which however were not tested in this project.

The ISO 16017 standard [60] describes numerous adsorbents which can be used for the most diverse volatility ranges. Apart from Tenax, three other adsorbents were used. Blank values, break-through behaviour and possibilities of standard feeding were tested. Carbotrap, Carbotrap C and Carboxen were used: the first two were loaded into empty adsorbent tubes for two-phase tubes and all three in the indicated sequence for three-phase tubes. The sequence of the adsorbents is very important in these tubes: the first one must have the weakest adsorption capability and the last one of the strongest. Thus it is ensured that semivolatile components are separated first and so the stronger adsorbents are protected and only exposed to very volatile compounds.

In the two-phase tubes, which are comparable to Tenax tubes, standards dissolved in methanol can be used since methanol has a very small break-through volume. Carboxen however, hardly releases adsorbed methanol at ambient temperature, therefore an alternative method must be sought for three-phase tubes in order to be able to introduce standards. A few components, e.g. pentane and acetone were introduced into the tubes via the gaseous phase. For this purpose about one gram of the pure component was loaded into an empty headspace glass (20 ml) which was adjusted to a specific temperature by placing it in an ice bath to ensure a well defined vapour space above the liquid level. This vapour space concentration and the removed gas volume determine the quantity that is to be transferred in the gas flow into the adsorbent tube. In this way VVOCs can be applied without any solvent.

As already mentioned, hardly any VVOCs were detected in the building products. However, the method was successfully used to check concentrations of acetone at the comparative scales for odour tests. The three-phase combination tube could alone be used for this purpose because a statement about the available Brühl & Kjaer on-line measurement instrument had to be checked for laboratory comparison (Section 4.4, page 109). In addition, the measurement results were checked by DNPH cartridges. The very short sampling time is a possible source of error in both collecting procedures since only 100 or 200 ml sample volumes were used on the combination tubes and 400 ml to 1 litre on the DNPH cartridges. The differences between the measurements were surprisingly small under these conditions (Figure 4-46). Thermodesorption has advantages over the DNPH method concerning processing since the measurements can be assessed without any delay.

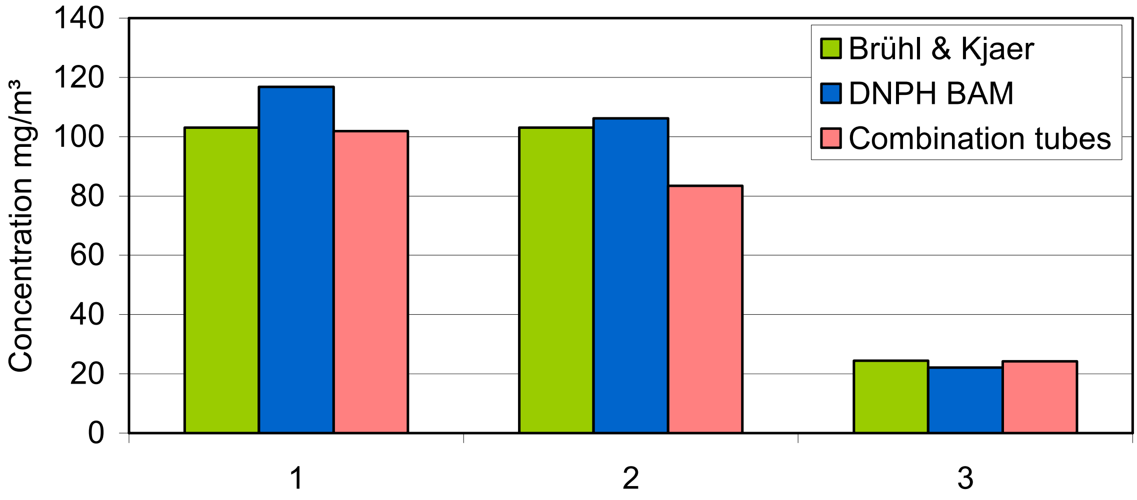


Figure 4-46: Acetone concentrations measured using three different methods for the calibration gas (1) and two comparison standards (2, 3)

4.3.9 DIRECT TDS, TERMOEXTRACTION

All pastes and liquid products, e.g. paints, lacquers, sealing compounds and plasters were tested using thermoextraction or direct thermodesorptions (TDS) before the emission chamber tests [61]. A method is now available which might provide results comparable with chamber tests due to the introduction of different commercial thermoextractors with a temperature control down to an ambient temperature [62, 63]. In order to obtain such results (assuming that the tests are performed at 23 °C), these samples must be stored for a long time and measured only on the third or 28th day. This method can be successfully used for a qualitative statement about which materials are emitted from a product.

The basic principle of all thermoextractors is the same: a small piece of sample of a few square millimetres to a few square centimetres is placed in an oven. A carrier gas (helium or nitrogen) flows continuously above the sample, which remains either isothermal or slowly warms up. At the exit of this "oven" the emitted VOCs are collected e.g. using a desorption tube or are led directly into a cold trap. Subsequently they are normally analysed with the help of a GC/MS combination.

The pastes or liquid products were spread in thin layers on an aluminium foil in this project. After a normal 24-hour drying period a small sample (approx. 2 mm x 15 mm) was cut out and placed into a TDS tube. Figure 4-47 shows an example of the test of a silicone sealing compound. The TDS tube is then placed directly into the thermodesorption system and treated at a reduced temperature of 40 or 60 °C - but otherwise in the same way as a Tenax tube in an analytical sense. Semivolatile components are driven out more vigorously in this procedure, but it provides a good overview of potential emissions.

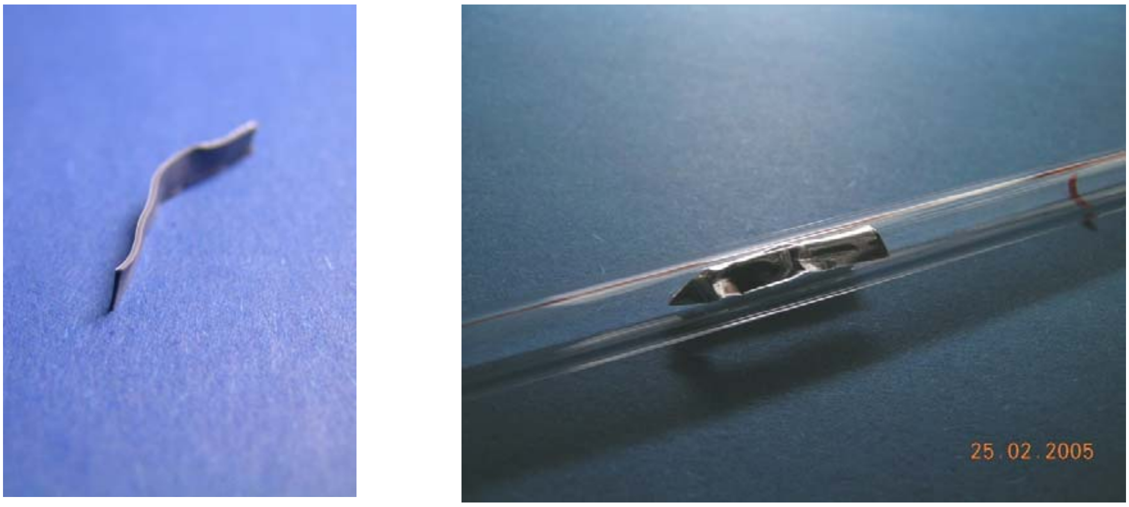


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Figure 4-47: Direct thermodesorption. Left: cut-out sample (silicone) with aluminium foil; right: sample placed in a TDS tube

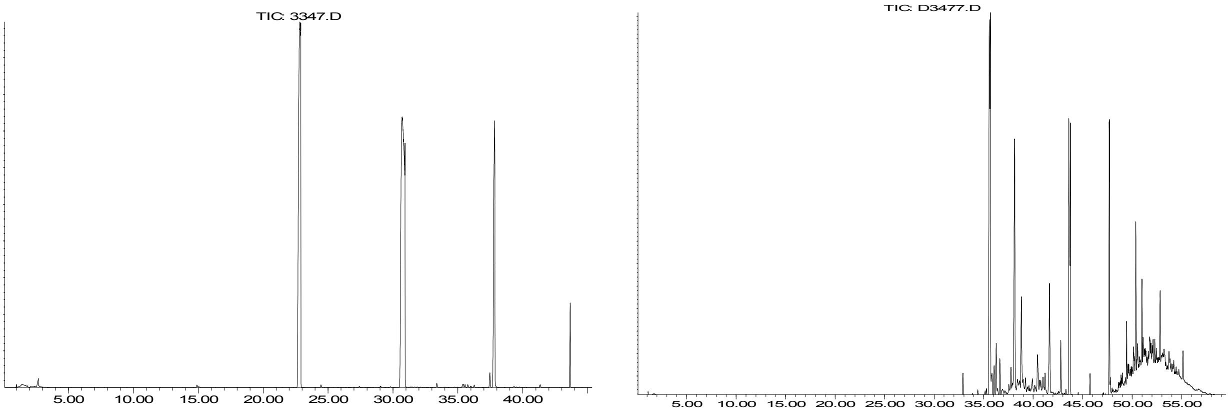

Figure 4-48: Chromatogram of direct TDS of silicone 3347 (left) and silicone 3477 (right) - both are acetate-cross-linking

Figure 4-48 shows the chromatograms of two typical representatives of acetate-cross-linking silicones. The left-hand chromatogram shows only a few peaks usually representing exclusively cyclic siloxanes (it must be determined that analysis is performed within the correct mass range to 500 A (mass number)). The right-hand chromatogram additionally shows a small alkane ‘hill’ which frequently indicates that a TVOC limit is exceeded in the emission tests.

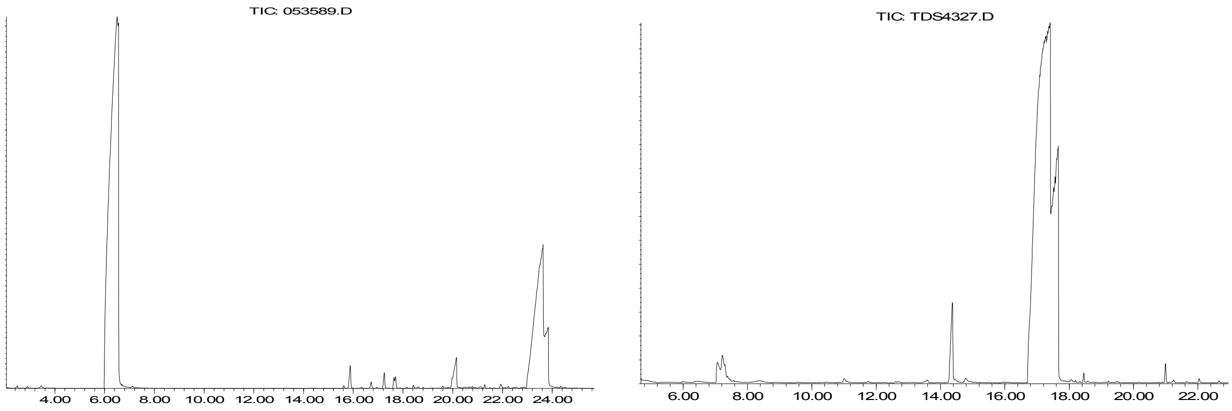

Figure 4-49: Chromatograms of direct TDS of parquet lacquer 3589 (left) and the same sample in chamber test (right) after 24 hours

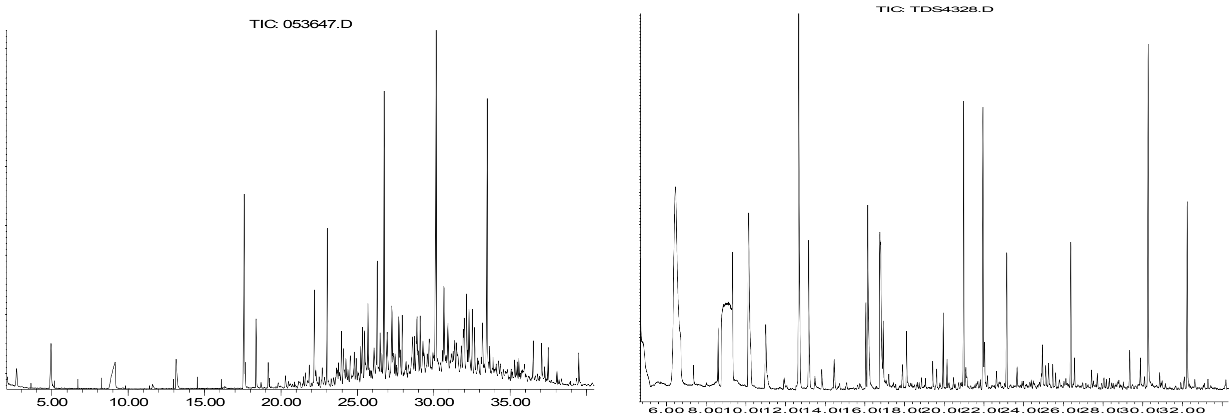

Figure 4-50: Chromatograms of direct TDS of acryl 3647 (left) and the same sample in chamber test (right) after 24 hours

Figure 4-49 and Figure 4-50 show a chromatogram of thermoextraction on the left and the corresponding product in a chamber test for comparison on the right after 24 hours. The first example of parquet lacquer shows good agreement between the two chromatograms. Though the first peak (triethylamine) is clearly underrepresented in the chamber test, the other VOCs of the emission tests are properly verified. In the second example (acrylic sealing compound) the semivolatile components are over-represented in the direct TDS. The outstanding peaks of the left chromatogram are higher alkanes, of which only rather small concentrations were found in the emission test. The method of thermoextraction is in essence well suited for the selection of the samples to be tested before an emission test. Samples with equal emission usually show a very similar behaviour in thermoextraction. In some cases however thermoextraction failed to indicate relatively important emissions, e.g. methylisothiazolinone.

4.4 INTERLABORATORY COMPARISON

In the project a laboratory comparison was planned to test the odour measurement method. However, none of the other institutes possessed the same odour measurement instruments as the Hermann Rietschel Institute, therefore a suitable procedure had to be found. The construction of the facilities in the institutes involved would have been a feasible way, but could not be realized for different reasons. Thus a timely graduated process was planned. A transportable version of the comparative scale was designed, and the AirProbe was completely rebuilt. The equipment was sent from participant to participant. The experimental setup only remained with each participant for three weeks. In this time an eight-day chamber test combined with chemical analysis and sensory testing of sample air was performed. Because of the new sensory testing the participants were instructed in a one-day introductory course in the handling of devices and the measurement technique. In addition to the air quality manual, extensive documentation and detailed guidance on the test methodology were available to the participants. Brief device-related descriptions were compiled during the tests for quick orientation.

4.4.1 EXPERIMENTAL SETUP

Chamber test

In addition to the innovative odour tests, an emission chamber test was also performed in accordance with ISO 16000-9 to -11 and/or -6 within the interlaboratory comparison. Planning the emission chamber tests was a challenge, since all participants had to carry out the tests under the same conditions over a longer period. Thus a roll or stacked commodity, which would age in the course of time, had to be rejected. Instead, a sample had to be selected which remains stable during a period of at least six months. Furthermore the sample had to exhibit good measurable emissions and at least a clear, well identifiable odour. The choice finally fell on an acrylic sealing compound, which can be prepared very reproducibly for the tests. The acrylic sealing compound was placed in an aluminium standard channel, levelled with a trowel and placed into the chamber after a short waiting period. The details of material preparation for this laboratory comparison are described in the Annex.

Emission and odour tests on air from the chamber were carried out on the first, third and eighth days. Double sampling took place on Tenax on each measurement day. The odour transport containers were filled at the chamber exit. When this was done in chambers smaller than 1-m^3, the container had to be filled dynamically over night. At the 1-m^3 chamber it was easy to exchange the tank contents three times within one hour, so that the odour sample could be taken directly before the assessment. For the third measurement day additional tubes were sent, which the participants loaded simultaneously to their sampling. They were then analysed by BAM to decide whether the chamber influences or analysis caused deviations between the results of the institutes. Each participant additionally received another standard solution, which could be used for the quantification of the emissions.

AirProbe

In view of the need of mobility, the AirProbe was further developed for the laboratory comparison. To achieve a better and more constant provision of sample air, the operational principle was fundamentally changed (Figure 4-51).

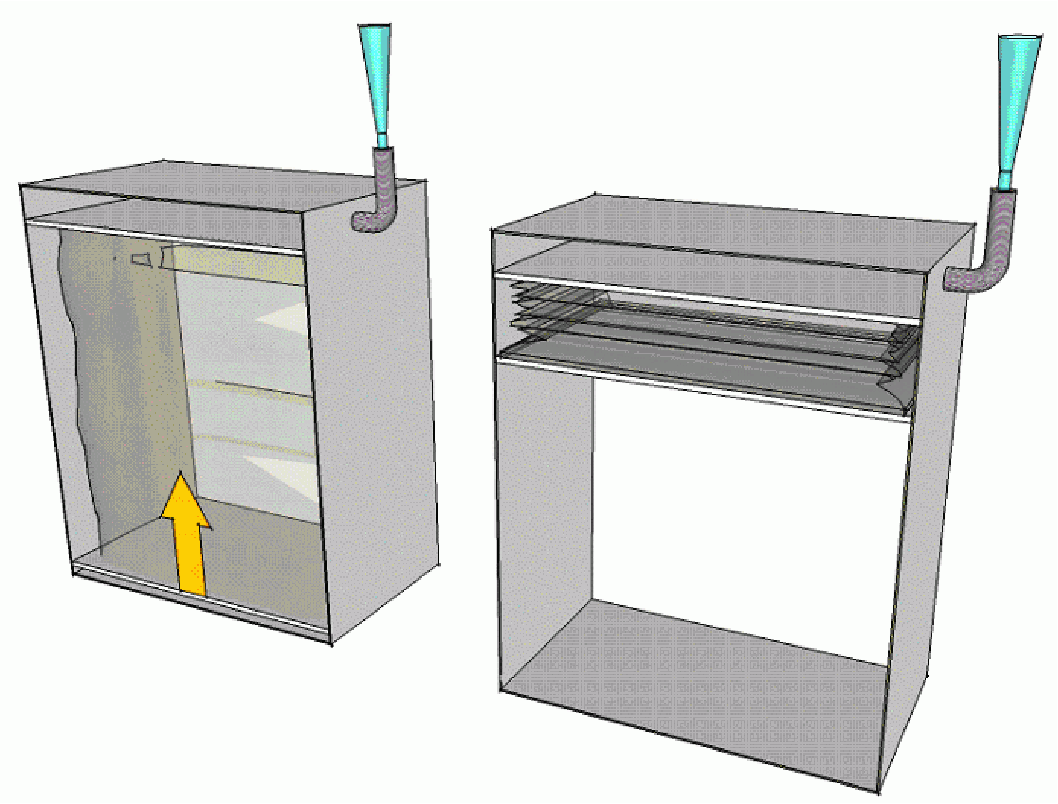

Figure 4-51: Operational principle of sample provision in AirProbe II

The sample provision in AirProbe II is based on the principle of a press (Figure 4-51). The sample container in AirProbe II is between an upper fixed plate and a mobile lower plate or piston. When the lower plate is moved at a constant speed, a constant flow rate is produced from the sample container, which is attached to a high-grade steel pipe leading to the glass assessment funnel. Based on a pressure difference measurement at an orifice, the flow rate can be calculated and indicated on a display. The piston velocity can be changed with a potentiometer over a wide range. The panellists have a longer time for assessment, since only the operation of a switch is needed during the smelling procedure to provide the full flow rate. In the period between two smelling procedures the flow rate is reduced to a minimum to prevent a back flow. Due to a smaller average flow rate up to 12 panellists can perform an assessment at the glass funnel.

The body of AirProbe II consists of a light aluminium transportation box with the external dimensions 1200 x 800 x 510 mm. Castors are attached to the body which enable it to be moved on smooth surfaces. The sample containers have a similar geometry to AirProbe I, but can have smaller dimensions due to an improved utilization of sample air for sample provision. A detailed description of the equipment can be found in the Annex "Laboratory Comparison".

Comparative scale

The comparative scale (see Figure 2-3, page 15) was equipped with its own fan unit for an independent mobile operation. An electronic fan control unit enables the exact adjustment of the total flow to provide a supply for the comparative scale. A seventh evaluation funnel helps a faster adjustment of the training values. A detailed description of the equipment can be found in the Annex "Laboratory Comparison".

4.4.2 VOC

Numerous tests were carried out within the interlaboratory comparison in order to provide the same sample quality for all participants. Several investigations are described in Section 3.4.7 (page 32) and in Figure 4-31 (page 88). The selected sealing compound exhibited a very high reproducibility in the values measured in the chambers. The accompanying standards were also checked and showed standard deviations under five per cent. Only polar substances showed somewhat higher standard deviations, but this also occurs in multiple tests of a standard within an institute on the same day. It was also checked which deviations arose when different people produced standard solutions from the same pure standard components (Section 3.4.7, page 32). Since these tests provided good reproducibility, it is possible to compare results obtained over a period of six months.

Figure 4-52 shows the TVOC values for all institutes and measurement dates. Even if this is not reflected by the TVOC values, the third day produced the highest reproducibility and the standard deviations of the test results on this daily were usually below 15 %. Only very polar components exhibited higher values up to maximum 40 % (see Table 4-23).

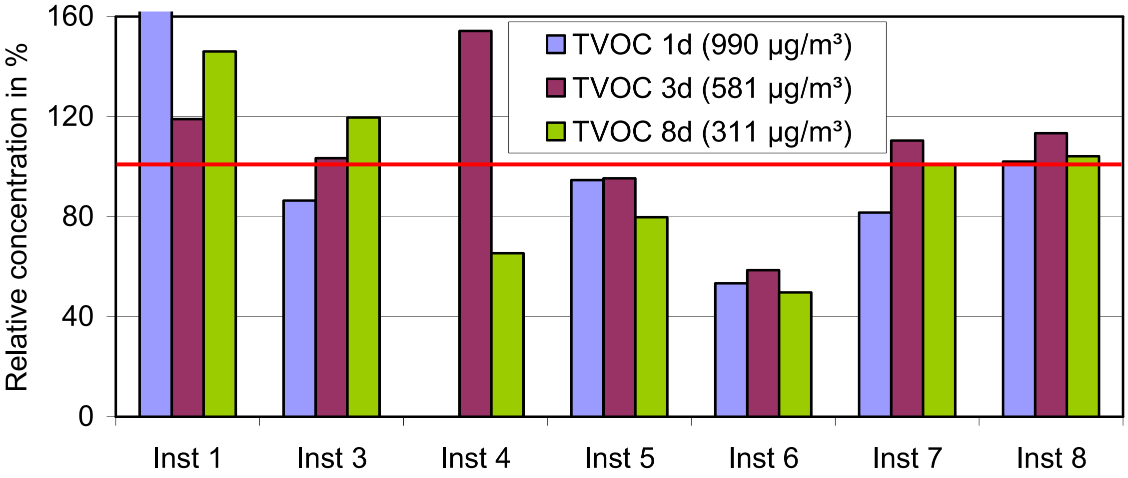

Figure 4-52: Sum of the detected VOC in the chamber tests of the participants over the test period. (Figures in µg m^{-3} in brackets correspond to 100 % relative concentration (red line))

Table 4-23 gives information about the deviations of individual components: it is conspicuous that the largest differences, in particular in relative standard deviations, occurred on the first day. This can probably be attributed to the fact that, in the initial phase of a chamber investigation, the system had not reached equilibrium.

Table 4-23: Average values and relative standard deviations for selected components in the laboratory comparison of all participants

	Butanol	**Propylene glycol**	**n-butyl acetate**	**n-butyl ether**	**Propanoic acid butyl ester**	**Butoxy-ethoxy ethanol**	**Do-decane**	**TVOC**
	71-36-3	57-55-6	123-86-4	142-96-1	112-34-5	112-40-3		
Average Day 1	**330**	**340**	**34**	**63**	**23**	**98**	**15**	**990**
RSD %	*38*	*69*	*30*	*23*	*15*	*80*	*13*	*44*
Average Day 3	**140**	**230**	**20**	**40**	**13**	**53**	**13**	**600**
RSD %	*27*	*13*	*27*	*20*	*13*	*28*	*10*	*13*
Average Day 8	**47**	**88**	**12**	**31**	**9**	**24**	**10**	**300**
RSD %	*28*	*59*	*26*	*31*	*31*	*61*	*26*	*35*

RSD % = relative standard deviation

The system is more stable on the third day and the concentrations were still sufficiently high, thus errors played a much lesser role. This is clearly indicated in the examples of Table 4-23. The values approached more difficult detection ranges for polar components on the eighth day, thus the differences were greater. The different column types used by the participants may have made a major contribution to the deviations, since more polar columns enable higher reproducibility in the detection of some components. Apart from this, there were further sources of error. Despite these well-known sources of error the interlaboratory comparison supplied markedly reproducible results.

Table 4-24: Average values of the third day - summary of the results of the participants, dispatched tubes and the individual values

	Butanol	**Propylene glycol**	**n-butyl acetate**	**n-butyl ether**	**Propanoic acid butyl ester**	**Butoxy-ethoxy ethanol**	**Dodecane**	**Tridecane**
General mean	**147**	**187**	**18**	**39**	**14**	**53**	**12**	**12**
RSD %	*34*	*29*	*24*	*17*	*18*	*28*	*12*	*13*
Participant average	**143**	**226**	**20**	**40**	**13**	**61**	**13**	**13**
RSD %	*27*	*13*	*27*	*20*	*13*	*24*	*10*	*10*
Dispatch tubes average	**147**	**162**	**17**	**38**	**14**	**47**	**12**	**12**
RSD %	*38*	*31*	*19*	*14*	*21*	*23*	*12*	*14*

RSD % = relative standard deviation

An important check on the results was performed using the tubes dispatched by BAM to the participants on the third day. Table 4-24 illustrates the average values for some components of this comparison. First the common means of all results, those of participant results and of dispatch tubes as well as their relative standard deviations for all tests were summed up. Afterwards these were divided into the values provided by the participants on the one hand and into those of the dispatched tubes analysed by BAM on the other. This compilation revealed hardly any differences between the respective average values, which were usually less than ten per cent. Figure 4-53 and Figure 4-54 show detailed results of these comparisons for n-butyl ether and propylene glycol. Unproblematic components, such as n-butyl ether, show very good agreement between the tests (Figure 4-53). The tests from the participants themselves and the dispatch tubes show good agreement with the exception of a single outlier. Those two participants, who used their own standard solutions (indicated with ‘own standard’ in Figure 4-53), are specifically labelled. These also show good agreement with the other results.

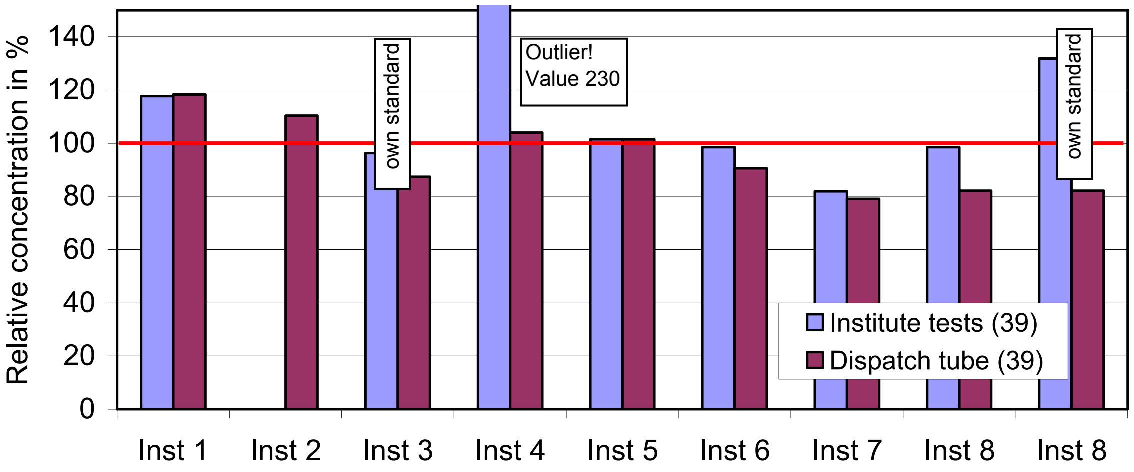

Figure 4-53: Comparison of the tests on the third day for the well reproducible component n-butyl ether. (Figure in brackets: 39 µg m^{-3} corresponds to 100 % relative concentration (red line))

Greater deviations can be recognised in the propylene glycol test components, which also show the highest differences in pure standard tests. In this case, however, the values of the participants tests are very different from each other in some examples compared with the results in the dispatch tubes (e.g. Institute One and Four). It is difficult to find the reason for these differences, based only on this one single test. Sampling pumps may have played a role if they were not specifically adjusted for the dispatch tubes. So, if the tube type deviated from those usually used, pumps without mass flow control could not guarantee the correct quantity was really drawn into the tube. However, only n-n-butanol and propylene glycol exhibited such a significant difference.

Summing up, the laboratory comparison was successful since the results overall exhibited good agreement, despite the many differences between the participants. This is all the more remarkable as the test method is very complex and a number of factors, e.g. sampling, sample preparation, emission chamber parameters and calibration, may cause deviations.

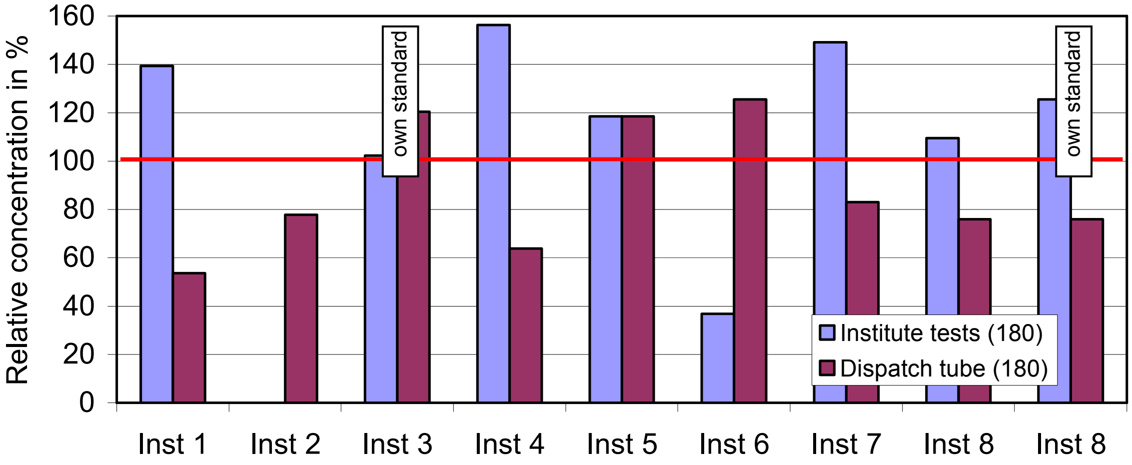

Figure 4-54: Comparison of the tests on the third day for the strongly varying component propylene glycol. (Figure in brackets: 180 µg m^{-3} corresponds to 100 % relative concentration (red line))

4.4.3 ODOUR

After completing the tests in the institutes, the data sets were conveyed to the Hermann Rietschel Institute for assessment. All laboratories involved managed to complete the sensory assessments despite the short time. Six to 18 panellists per laboratory participated in the tests. Between 69 and 76 individual values were produced each test day.

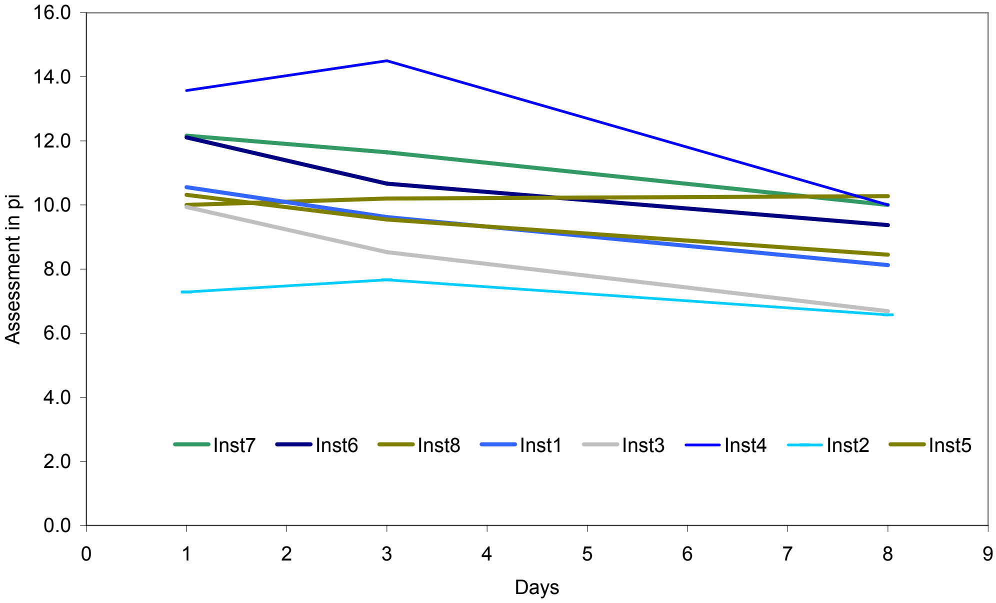

Figure 4-55: Intensity of all laboratories

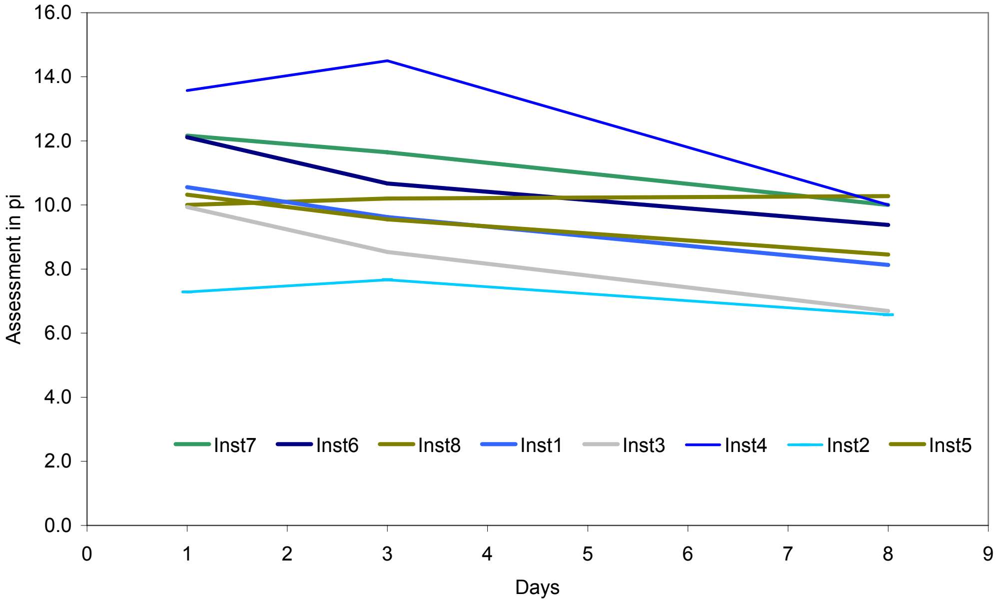

Figure 4-55 illustrates the results from the laboratories. The test days are plotted on the abscissa and the perceived intensity Π on the ordinate. The results of each institute were calculated as an arithmetic average of the individual answers for each test day.

The results of Institutes 2 and 4 were excluded from further consideration in the assessment. Technical problems in the test procedure in one of the institutes and deviation from the procedural regulations in the second institute provided results under non-comparable test conditions. Technical problems in AirProbe2 forced Institute 8 to do a short-term modification to AirProbe1 during the test run, which may be an explanation for the horizontal profile of intensity assessments. Since all other boundary conditions were adhered to in this Institute and AirProbe1 is in principle suitable for the execution of the tests, the results were included in the overall assessment. Figure 4-56 shows the cleaned laboratory results and the average value of all laboratory results.

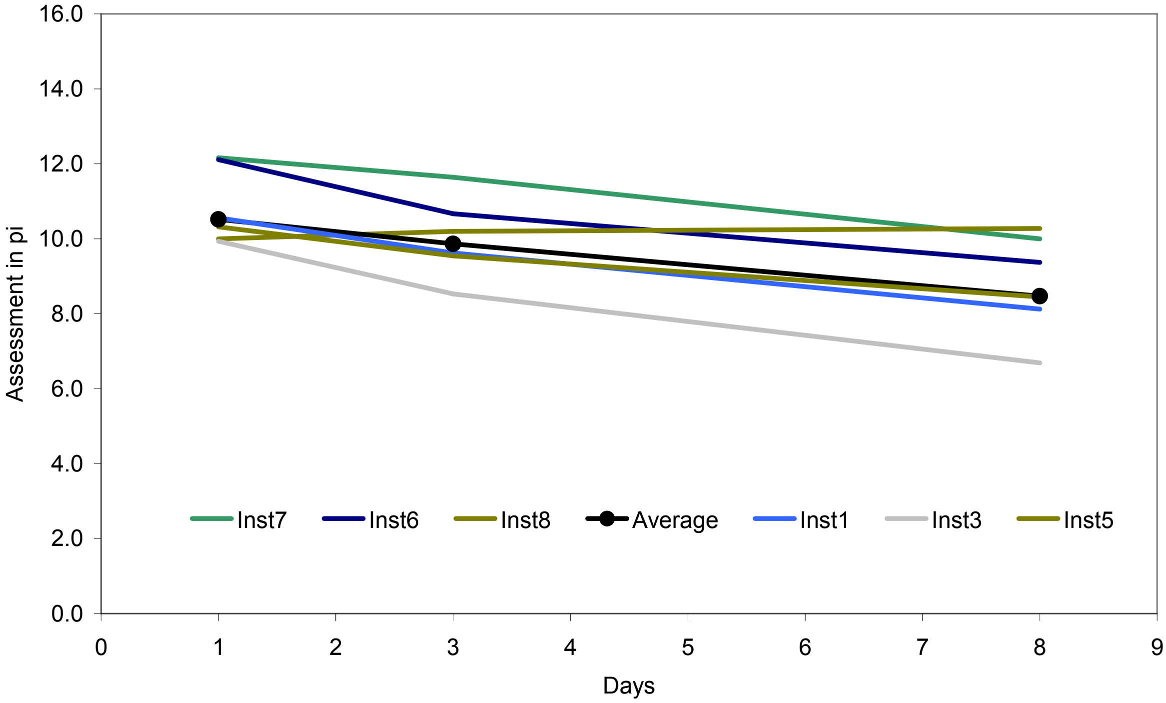

Figure 4-56: Cleaned intensity, average of all laboratory results

In addition to the medium standard deviation, Figure 4-57 also shows the maximum deviation of the laboratories from the average value of all laboratory results for a better assessment of the test results. Deviations of the Hermann Rietschel Institute are also indicated for a comparison.

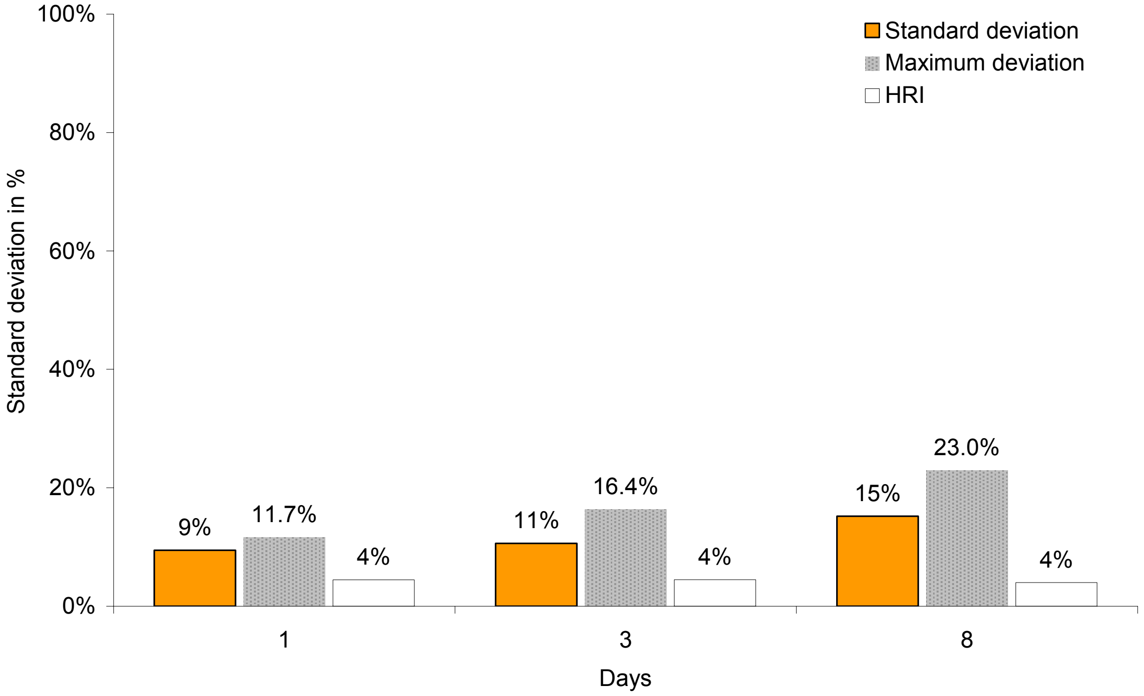

Figure 4-57: Medium standard deviation and maximum deviation of the laboratories from the average of all laboratory results, deviation of the Hermann Rietschel Institute

The medium standard deviation is between 9% on the first test day and 15% on the last test day. The maximum deviation is between 11.7% and 23%. These reasonably good values from a first interlaboratory comparison could be improved by a focused selection of the panellists. Figure 4-58 shows the medium standard deviation of the individual answers from a laboratory and the maximum deviation over the test days. It provides information as to how large the dispersion of the individual answers of the panellists of a laboratory is on a particular test day. The maximum standard deviation here shows the enhancement potential of the results if a focused selection of the panellists was undertaken.

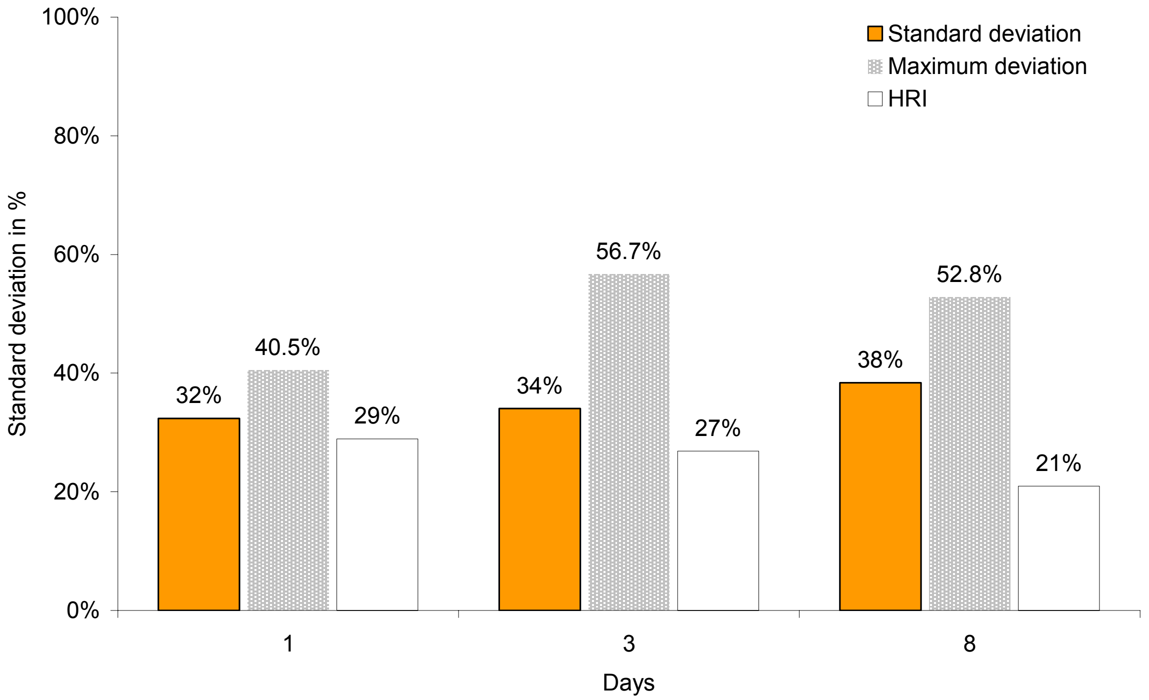

Figure 4-58: Medium standard deviation and maximum deviation of the individual answers of the individual laboratories, standard deviation of the Hermann Rietschel Institute

The standard deviations of the Hermann Rietschel Institute, which works with a focused selection of trained panellists under optimised ambient conditions and whose staff members have been familiar with the method for years, are accordingly well below the medium standard deviation.

Since the laboratories involved exclusively used 1-m³ chambers for test execution, the Hermann Rietschel Institute carried out additional tests in 1-m³ and 23-litre chambers.

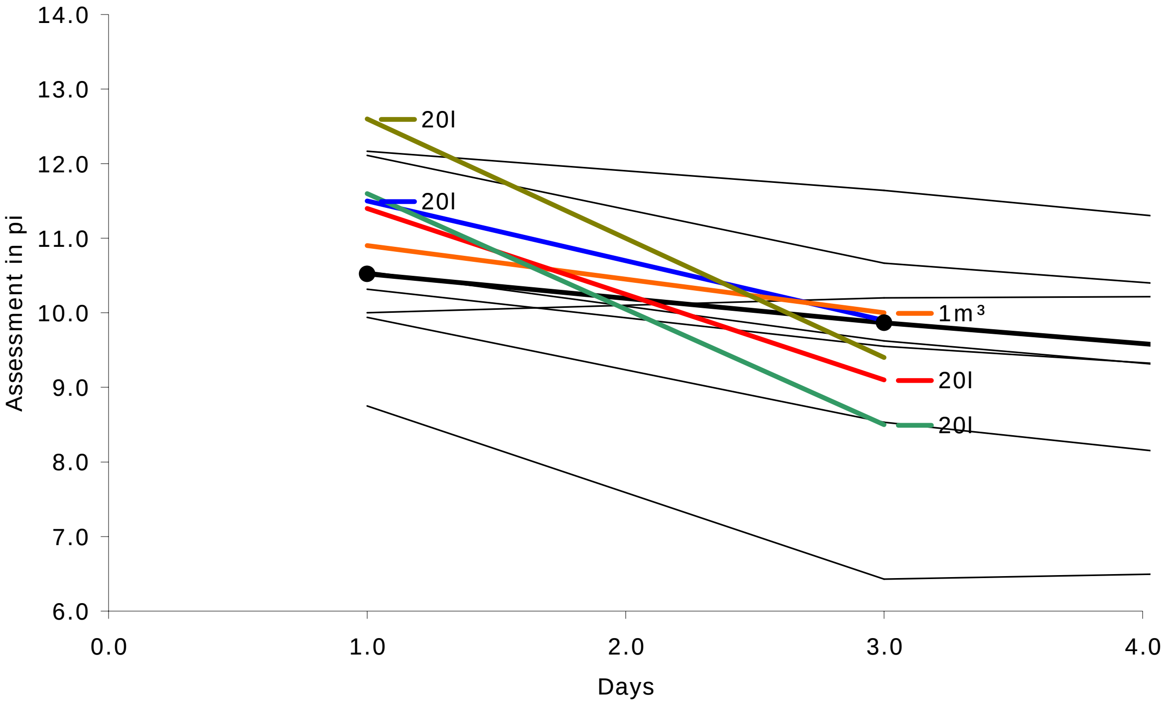

Figure 4-59: Intensity assessment of samples from the 23-litre and 1-m³ chambers

The investigations are limited to the first and third test day. Figure 4-59 shows an enlarged excerpt of the two test days. The curves show that the chamber size obviously has no influence on the sensory assessment.

5 SUMMARY AND CONCLUSIONS

The building product directive of the European Union defines the term ‘building product’ as “a commercial product that is manufactured with the purpose of remaining in the building over a long period of time”. Standard and certification authorities have the task of achieving a high level of health and environmental protection in technical specifications for building products based on the principles of precaution and prevention - in addition to other goals of the building product guideline. The assessment scheme of the Committee for Health Evaluation of Building Products (AgBB scheme) is an important contribution to the assessment of environmental and health properties during the use of building products and describes the protection level aimed at in Germany in the implementation of the building product directive.

The objective of the project was to test and extend national and international test methods and to assess building products according to this scheme. For many building products the understanding of the emission behaviour was completely missing or there were not enough measurements available to describe the range of emissions adequately and perform a comprehensive assessment in accordance with the AgBB scheme.

The measurement methods (emission test chamber in combination with Tenax sampling and gas chromatography/mass spectrometry analogous to ISO 16000-6 and ketones and aldehydes analogous to ISO 16000-3), which the AgBB scheme is based on, are capable of detecting low concentrations of volatile organic compounds (VOC) in chamber air. However, very volatile organic compounds (VVOC) and semivolatile organic compounds (SVOC) indicate that the method has its limits. Changes were introduced in sampling techniques to achieve better analytical detectability for those compounds that are difficult or impossible to measure.

Since VOC emissions are frequently accompanied with emissions of odour-generating substances, which may lead to impairment of health, sensory testing was included in the AgBB scheme as an important aspect. However, it is currently not required for the assessment in view of the existing measurement uncertainties. Despite improved analysis methods and the development of artificial noses, it has not been possible to replace the human nose in the determination of perceived air quality so far. Odours develop from a number of chemical substances and many materials have been identified that trigger an odour perception in humans.

Figure 5-1: Building products and their emission tests in a 23-litre chamber

Methods used to determine odour emissions either lead to poorly reproducible results ("fruit jar method") or have not reached the level of practical application as far as VOC determination in emission test chambers is concerned. Urgent action was needed to develop an adequate test method to assess odour emissions from building products using a reasonable combination of several available approaches.

The objective of developing a method for sensory testing of building materials was to build on the methods of emission tests from building products which the AgBB scheme is based on. The available flow rates vary widely depending upon emission chamber size and are not suitable for direct sensory assessment by panellists in currently used emission chambers of volumes between 20 litre to 1m^3. Therefore a method has been further developed in which laden air is pumped from the emission chambers into 300-litres Tedlar bags. Thermally treated Tedlar exhibits low emission and has ideal characteristics concerning permeability and adsorption. The filled bags were transported for assessment to the air quality laboratory of the Hermann Rietschel Institute (HRI). The newly developed AirProbe 2 method can guarantee a constant airflow rate from a Tedlar bag. The minimum flow rate of 0.7 litre/s necessary for a sensory assessment by a panellist can thus be provided for approximately six minutes. At least eight panellists evaluated the perceived intensity Π of the sample air. The comparative scale based on different acetone concentrations enabled the panellists to classify unknown emissions. In addition to intensity, hedonics was also included in the sensory assessment and evaluated in the current test.

Test results of 50 building products

50 building products (see Table 5-1) were tested in this project in emission chamber tests according to the provisions of the AgBB scheme. Those products that failed to meet the provisions after three days nevertheless remained in the chamber until the 28th day. VOC emission tests were performed in each case on the first, third, tenth and 28th day and, in addition, odour emission tests were conducted on selected products. At the beginning of the investigation, screening tests were carried out on 90 building products using thermoextraction (direct test for potential emissions of building products in the thermodesorption system coupled with a gas chromatograph (TDS/GC system)). The results of these tests were used for product selection.

Table 5-1: Overview of building products tested in screening test, number of emission chamber tests derived and their result in the AgBB assessment.

Building products	**Screening tests**	**Chamber tests**	**Passed AgBB selection**	**Failed AgBB selection**
Silicone sealing compounds	21	6	-	6
Acrylic sealing compounds	15	7 +	4	3
Lacquers and wall paints	17	11 +	10	1
Wood (OSB, pine, cork, parquet)	14	13	12	1
Synthetic resin premixed plasters, levelling screed, plaster boards	14	7	3	4
Adhesives, wall covering, primer	10	6	6	-
Sum	**90**	**50**	**36**	**14**

The + sign behind some chamber tests indicates that some products were tested more than once.

Emission test results

Table 5-1 shows a brief summary for all products tested in accordance with the AgBB scheme. The measurements were performed in each product group at a characteristic area-specific airflow rate q in accordance with ISO 16000-9 [24] and/or Nordtest NT [15]. A more detailed comparative assessment of the products is illustrated in Table 5-3.

Table 5-2: Area-specific air flow rate q in the tests of various building product

Building product	**Area-specific air flow rate** q [m^3/m^2h]	
	23-litre chamber	CLIMPAQ
Sealing compounds	44	83
Paints, lacquers, primer	1	3 (2)
Wood, OSB, plaster board	1	3
Synthetic resin premixed plaster	0.5	n.m.
Adhesives, floor materials	1.25	3

n.m. = no measurement

Table 5-3: All products tested in the project in accordance with the provisions of the AgBB scheme

Criterion /	**$TVOC_3$**	**$TVOC_{28}$**	**$\Sigma SVOC_{28}$**	**R**	**$VOC_{\text{without NIK}}$**	**AgBB**
material	**mg m^{-3}**	**mg m^{-3}**	**mg m^{-3}**		**mg m^{-3}**	**assessment**
Provision	**≤ 10**	**≤ 1.0**	**≤ 0.1**	**≤ 1**	**≤ 0.1**	
Acryl 3332	0.85	0.15	0.051	0.11	0.033	passed
Acryl 3351	4.7	*1.15*	0	*1.26*	0.047	failed
Acryl 3356	8.3	*2.8*	0	*5.11*	0.006	failed
Acryl 3460	7.2	0.53	0	*2.02*	0.06	failed
Acryl 3485	0.47	0.05	0	0.00	0.05	passed
Acryl 3647	0.58	0.09	0	0.09	0.032	passed
Acryl 3653	0.60	0.09	0	0.09	0.032	passed
Silicone 3333	5.6	*1.4*	*1.8*	0.09	*1.4*	failed
Silicone 3338	*10.3*	*1.7*	*0.18*	*0.04*	*1.0*	failed
Silicone 3353	*12.1*	*3.7*	*1.85*	*0.15*	*3.6*	failed
Silicone 3477[#]	7.6	0.41	0	0.00	*0.40*	failed
Silicone 3478	1.1	0.21	0	0.00	*0.20*	failed
Silicone 3707	7.9	0.37	0	0.00	*0.36*	failed

[#] 26 µg m^{-3} of benzene was detected for this silicone on the 3rd day while a maximum 10 µg m^{-3} of carcinogenic substances may be contained according to the AgBB scheme.

Criterion /	**TVOC $_3$**	**TVOC $_{28}$**	**ΣSVOC$_{28}$**	**R**	**VOC$_{withoutNIK}$**	**AgBB**
material	**mg m^{-3}**	**mg m^{-3}**	**mg m^{-3}**		**mg m^{-3}**	**assessment**
Provision	**≤ 10**	**≤ 1.0**	**≤ 0.1**	**≤ 1**	**≤ 0.1**	
Adhesive 3400	0.58	0.09	0.09	0.17	0.02	passed
Adhesive 3405	0.19	0.01	0	0.00	0.01	passed
Adhesive 3445	0.10	0.05	0	0.00	0.005	passed
Adhesive 3461	0.03	0	0	0.00	0	passed
OSB 3382	1.4	0.45	0	0.41	0	passed
OSB 3383	0.4	0.17	0	0.16	0	passed
OSB 3488	1.5	0.40	0	0.98	0	passed
OSB 3543	1.9	0.55	0	*1.04*	0	passed
OSB 3559	0.9	0.39	0	0.73	0	passed
OSB 3628	2.9	0.57	0	*1.30*	0	passed
OSB 3689	1.3	0.68	0	*1.26*	0.013	passed
Pine bd. 3384	0.37	0.21	0	0.13	0.022	passed
Cork p. 3479	0.19	0.11	0	0.00	0.10	passed
Chipbd. 3560	1.61	0.79	0	*1.52*	0.003	failed
Cork bd. 3561	0.28	0.07	0	0.03	0.04	passed
Laminate 3562	0.05	0.01	0.003	0.00	0.003	passed
Beech bd. 3625	0.14	0.06	0	0.11	0	passed
Fl lacquer 3385 G$^{\#}$	6.72	*1.18*	0	0.00	*1.18*	failed
Fl lacquer 3385 S$^{\#}$	4.11	0.76	0	*1.84*	*0.22*	failed
Wd glaze 3388	4.75	0.14	*0.14*	0.00	*0.14*	passed
Mc lacquer 3392	0.37	0.21	0	0.13	0.022	passed
Fl lacquer 3587	0.48	0.16	0	0.43	0.01	passed
Pa lacquer 3589	2.11	0.29	0	0.22	*0.13*	passed
W paint 3463	0.04	0	0	0	0	passed
W paint 3463$^{\$}$	0.11	0	0	0	0	passed
W paint 3558	0.21	0	0	0	0	passed
W paint 3584"	0.06	0	0	0	0	passed
W paint 3586	0.14	0.02	0	0	0.02	passed
W paint 3626	0.19	0.004	0	0	0.004	passed
W paint 3690	0.36	0.07	0	0	0.07	passed
SR-PP 3342	0.88	0.11	0	0.01	0.09	passed
SR-PP 3345	*214*	*34.5*	*0.19*	0.34	*33.9*	failed
SR-PP 3357	0.41	0.02	0	0.00	0.003	passed
SR-PP 3487*	*52.7*	*5.35*	0	0.48	*3.14*	failed
SR-PP 3614	0.98	0.27	0	0.07	*0.22*	failed
SR-PP 3623	6.31	1.28	0	*2.46*	0.10	failed
NWF + A 3444	0.20	0.03	0	0.07	0.01	passed
P 3544	0.05	0	0	0.00	0	passed
GC 3546	0.06	0.01	0	0.02	0	passed

* Also contained 11 µg m^{-3} benzene (carcinogenic) after 3 days.
SR-PP = synthetic resin premixed plaster;
$^{\#}$ G = glass plate, S = screed; $^{\$}$ on non-woven fabric wallpaper; " on plaster board with primer
Pine bd. = pine board.; Cork p. = cork parquet; Chipbd. = chipboard; Beech bd. = beech board;
Fl lacquer = floor lacquer; Wd glaze = wood glaze; Mc lacquer = multicoloured lacquer; Pa lacquer = parquet lacquer; W paint = dispersion wall paint; NWF + A = non-woven fabric + adhesive; P = primer; GC = plaster board

The results of the individual product groups are summarised in the following.

Sealing compounds: Silicone and acrylic sealing compounds are the two main groups of these building products. Silicones harden by cross-linking with the separation of organic compounds such as acetic acid or methanol, whereas acrylic compounds dry through evaporation of water. Glycols and n-butanol were the main polluters emitted in acrylic sealing compounds. Since low-molecular glycolic components such as ethanediol have a low NIK value, the emissions of these components caused two products to exceed the R value. None of the silicone sealing compounds met the provisions of the AgBB scheme, since concentrations of cyclic siloxane was detected well above 100 µg m^{-3} in all products. They do not have any NIK value, except D4 (octamethyl cyclotetrasiloxane), and failed to adhere to the provisions for the $VOC_{without\ NIK}$ value. Some neutral cross-linked silicone sealing compounds exhibited emissions of the VVOC methanol in excess of 1 mg m^{-3} in the initial phase. No emissions of phthalate softeners from acrylic sealing compounds, whose contents were qualitatively determined using extractive methods, were detected. The detection method using PU foam sampling was not sensitive enough which could possibly be optimised by a modified TDS method. Both silicone and acrylic sealing compounds meet the emission provisions for sealing materials with Blue Angel (awarding basis RAL UZ 123) since the provisions for the $VOC_{without\ NIK}$ value are not considered as an exclusion criterion in the first period of the awarding basis.

Synthetic resin premixed plasters: So far only limited information is available about the emissions from synthetic resin premixed plasters in the literature. Emissions from six different samples were tested in this project, four products failed to meet the provisions of the AgBB scheme, while the other two did not have any problem in doing so (Table 5-3). Glycols are the ones that are most likely to exceed the provisions, but the in-can preservative, methyl isothiazolinone (MIT), also exhibited a high emission. Compared with other aqueous products (such as wall paints), the relatively high emissions of in-can preservatives were conspicuous. If MIT was present, the concentration exhibited a maximum after 10 days, although the exact apex is not known since only four measurements were taken over 28 days.

Wood and wood-based materials: The tested products of this group met the provisions of the AgBB scheme except for one product. One chipboard alone showed unusually high acetic acid emissions which exceeded the R value. OSB boards exhibited high emissions of n-aldehydes and corresponding carbonic acids, whereby the provisions on the R value - with values just over unity – have just been met.

Therefore the analysis of unsaturated aldehydes with their low NIK values requires the utmost care. Five of seven OSB exhibited a formaldehyde concentration of over 10 µg m^{-3}. In one case clearly more than half of the permissible limiting value of 0.1 ppm (124 µg m^{-3}) was detected. Thus the tested OSBs emit larger quantities of formaldehyde than the other tested wood-based materials.

For the comparability of the emissions from wood-based material products the production time is important, which was not considered in this project, since all products were to be tested in the same manner as the consumer can acquire them for example in building material stores. If the production date is several weeks before, then some of the emissions, for example terpenes and aldehydes, may have already faded away. The production time is less relevant for pastes or liquid products since they had been in closed sales units until the beginning of the tests.

Lacquers and paints: Dispersion wall paints, with an annual consumption in Germany of approx. 500,000 tonnes, only emit VOCs, and to a very small extent. Only one of the floor lacquers failed to meet the AgBB provision among other lacquer systems tested. Emissions of other lacquers in the TVOC range lay at approx. 200 µg m^{-3} after 28 days. The in-can preservative MIT was found in three dispersion paints similar to synthetic resin premixed plasters. More than 300 µg m^{-3} was detected at the beginning in one case, but the emission had decreased to a concentration of 16 µg m^{-3} by the 28th day. Emissions of the two other dispersion paints fell to below the detection limit.

Adhesives and other products: Emissions from adhesives and other products tested in the project were low. The two floor adhesives tested met the provisions of the AgBB scheme without any problem and one of them also met those of Blue Angel (awarding basis RAL UZ 113). Other tested products – plasterboard, glass fibre non-woven fabric and primer – also exhibited very low concentrations.

Table 5-4 summarises those VOCs detected in this project which led to objections according to the AgBB schemes. The products concerned failed to meet the provisions of the AgBB scheme due to concentrations of these substances being too high in test chamber air. The substances mentioned led to the most diverse excesses in the TVOC, ΣSVOC or the R value or the $VOC_{\text{without NIK}}$. In all tested product classes, in addition to those that failed to meet the AgBB-provisions, there are products that fulfil the provisions - except the building materials group of sealing compounds. In principle, adherence to the AgBB scheme is to be regarded as state of the art for the tested product groups.

Table 5-4 Volatile organic compounds which led to objections according to the AgBB scheme and mitigation actions

Volatile organic compounds	**Detected in the products**	**Possible mitigation actions**
Mixes of n- and isoalkanes $C_7 – C_{16}$ or $C_{14} – C_{18}$	Synthetic resin premixed plaster, silicone sealing compound	Use of high-quality raw materials
Benzene	Silicone sealing compound	Use of aromatics-free raw materials
Dipropylene glycol	Acrylic sealing compound, synthetic resin premixed plaster	Use of glycols with NIK values
Mix of various esters	Floor lacquer synthetic resin premixed plaster	Use of well-specified solvents
Acetic acid	Wood chip board	Adjustment of the manufacture conditions or use of other raw materials
Ethanediol	Acrylic sealing compound, synthetic resin premixed plaster	Use of glycols with NIK values
Methyl isothiazolinone	Synthetic resin premixed plaster	Reduction of quantities and/or use of other biocides
Propanediol	Floor lacquer	Use of other glycols (from the NIK list)
Siloxane	Silicone sealing compound	Establishing NIK values for further cyclic siloxanes by AgBB

Optimisation of the test method

In addition to the investigation of building products in accordance with the provisions of the AgBB scheme, some follow-up issues of the test methods were dealt with. Different chamber types, e.g. CLIMPAQ common in Northern Europe, were tested for their suitability to compare emission results from this chamber type with those of the chambers as in ISO 16000-9. The small size of CLIMPAQ appeared to be a problem because of the high air flow rate required, which only enabled a reduced loading and failed to reflect actual indoor conditions. A further nine repetition measurements were performed on an acrylic sealing compound in 23-litre and 1-m^3 chambers. These tests showed a very good agreement between the chambers, both in repetition within a chamber type and in sample homogeneity. They were performed alongside an interlaboratory comparison. Relying on this good comparability, reproducible preparation of the samples and high quality of the analytic detection, it can be assumed that the assessments in accordance with the provisions of the AgBB scheme will prove highly reliable.

An odour detector (ODP), installed parallel to an MS system at the exit a GC column, was used in some examples to try to correlate odour impressions with VOC tests. This is a very important instrument for clearing-up assessments of odour emissions but whose application should however be further refined. This method also enabled the detection of emissions of the highly odouriferous ethylacrylate from an acrylic sealing compound for which GC analysis failed to detect the concentration available.

The analytic determination of NIK (LCI) substances and carcinogenic materials (C substances) was also tested. The internal standards method was used in chromatographic detection of the components to achieve high quality results. Detection sensitivity in the analysis of some NIK materials can be improved, possibly by using other GC columns. Within the project expert group, an exchange ring of chemical standards was initiated among the participating institutes to ensure a proper allocation in comparative tests for all compounds in the NIK list. Selective methods in mass spectrometry such as selected ion monitoring (SIM) is recommended for a safe detection of C substances. For this purpose a second Tenax pipe must be tested parallel to the TDS/GC/MS system for C substances.

This SIM method enables detection limit well under 1 µg m^{-3} to be achieved for a number of C substances. Figure 5-2 displays the absolute values in µg m^{-3} for the detectability of carcinogenic substances for a 5 litre sample volume on Tenax.

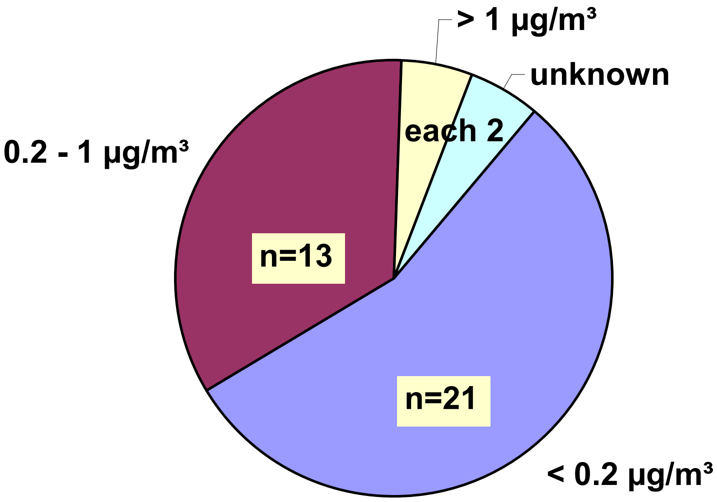

Figure 5-2: Detectability of 38 different volatile carcinogenic substances.

An extension of the analytical spectrum outside the range C_{22} does not seem to be necessarily based on current data. The range below C_6 should be further considered even if only very little information about VVOCs was found in this study. Some compounds such as formaldehyde, acetaldehyde and acetone were detected using the DNPH method.

The screening method using direct thermoextraction of the products in TDS used in this study enables good preliminary information to be gained about potential emissions. It does not enable a direct comparison with chamber tests, for this purpose thermoextractors are suitable which are currently being introduced to the market. Initial studies were performed that substantiate this suitability [62, 63].

Results of the sensory tests

In the current project a method was developed and tested, which enables the simple and safe integration of sensory tests into current test procedures under the AgBB scheme. The method developed in the Hermann Rietschel Institute can provide a proper amount of sample air to the panellists for assessment, regardless of the size of the emission test chamber.

Perceived intensity Π is determined as an arithmetic average of the individual values in the sensory assessment of building materials by panellists. The average values of all 164 single answers related to perceived intensity ranged from 2.7 pi to 32.9 pi, the average values of the individual answers referring to hedonics were between -4.0 and 0.4 (see Table 5-5). Odour intensity is considerably easier to differentiate than hedonics by panellists due to the available scale, besides an existing odour impression is usually connected with a negative hedonics.

Table 5-5: Use of available scale ranges – intensity and hedonics from 164 assessments

	Perceived intensity	Hedonics
Available scale	0 – 18 PI	-4 .. 0 .. 4
Average values of assessments	2.7 to 32.9 PI	-4 to 0.4
Medium standard deviation	24 %	66 %

The medium standard deviation in the intensity questions is only 24%, while the medium standard deviation is 66% in hedonics assessment. The comparative scale used is based on increasing acetone concentrations and enables orientation for the panellists in the assessment of perceived intensity, whereas an intuitive scale without absolute familiarization points leads to increased scattering of the answers.

Altogether the results of the sensory tests based on perceived intensity were much higher than expected. Several factors may have contributed to this:

1. The laboratory environment at the Hermann Rietschel Institute separates the panellists from the building materials to be evaluated. Certain building materials evoke an attitude of expectation: for instance, it does not surprise the laboratory assistant or panellist that wood-based building materials smell of wood. Odour perception is perhaps superimposed on the positive

expectation attitude and reduces the odour impression. Therefore building materials are possibly assessed differently and more strictly in a laboratory situation.

2. The panellists may connect an additional expectation attitude with the assessments of the sample bags in AirProbe. Usually unknown, strong odours were offered for assessment. Random provision of clean neutral air from Tedlar bags may prevent this negative expectation attitude.

3. The Tedlar bags require a very careful thermal treatment. The baking procedure is still in the testing phase.

Based on intensity assessment of emissions from building materials, an individual, independent quantity has been introduced which cannot be derived from chemical analyses.

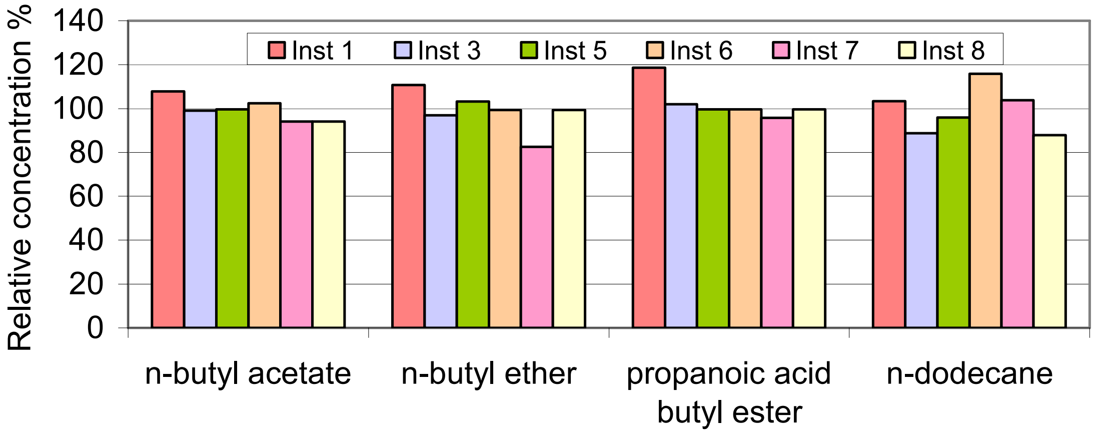

Figure 5-3: Comparison of selected VOC concentrations (relative to average values) determined on the third measurement day in the emission chamber of six institutes, two were omitted (outliers)

To validate the methodology of sensory assessment, an interlaboratory comparison with seven laboratories was carried out in Germany. In addition to chemical analyses, a building material was assessed using sensors over three days. The comparison of the VOC data of the chamber test shows good agreement between the participating laboratories when the conditions are well specified. Figure 5-3 shows an example of the good comparability for easy-to-analyse components among six different institutes. The medium concentrations for the components were 18 µg m^{-3} for n-butyl acetate, 39 µg m^{-3} for n-butyl ether, 18 µg m^{-3} for propanoic acid butyl ester and 13 µg m^{-3} for n-dodecane. When the compounds are more difficult to analyse, the deviation is greater, but the good comparability of the results proves that the different participants largely had the same test conditions in the chambers.

The results of odour assessment show that newly developed devices, guidelines and test descriptions allow comparable intensity assessments to be obtained between the laboratories for the selected building material, although the laboratories involved had little or no experience with sensory assessment of building materials. Figure 5-4 shows the summary of the intensity assessment of the individual institutes. Two institutes were omitted in the summary because of technical problems in sample preparation.

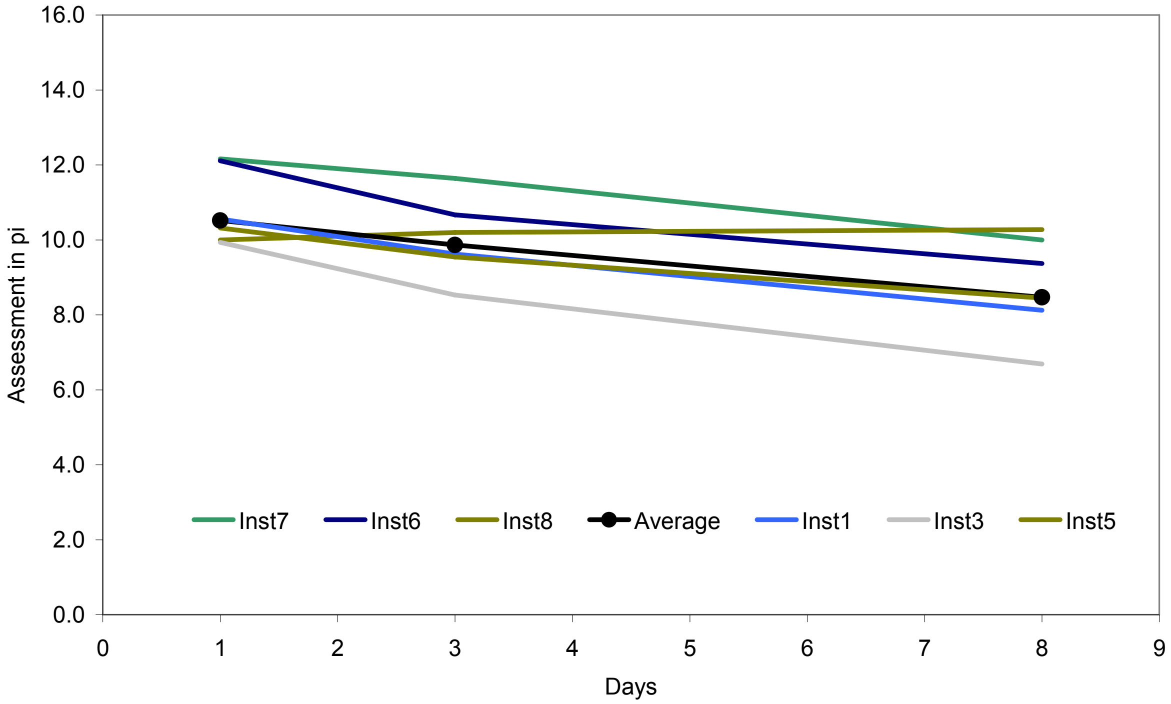

Figure 5-4: Interlaboratory comparison, summary of the intensity assessment

The good overall result of the interlaboratory comparison is illustrated in Figure 5-4. In addition to the standard deviation of the laboratories from the overall mean, the maximum deviation of the individual laboratories over the entire test period is also shown (Figure 5-5) for a better assessment. With a standard deviation of 9% (first test day) to 15% (eighth test day) very good results were obtained under the conditions specified above.

The Hermann Rietschel Institute achieved a very constant deviation of only 4 % from the general mean with trained panellists under optimised laboratory conditions over the entire test period.

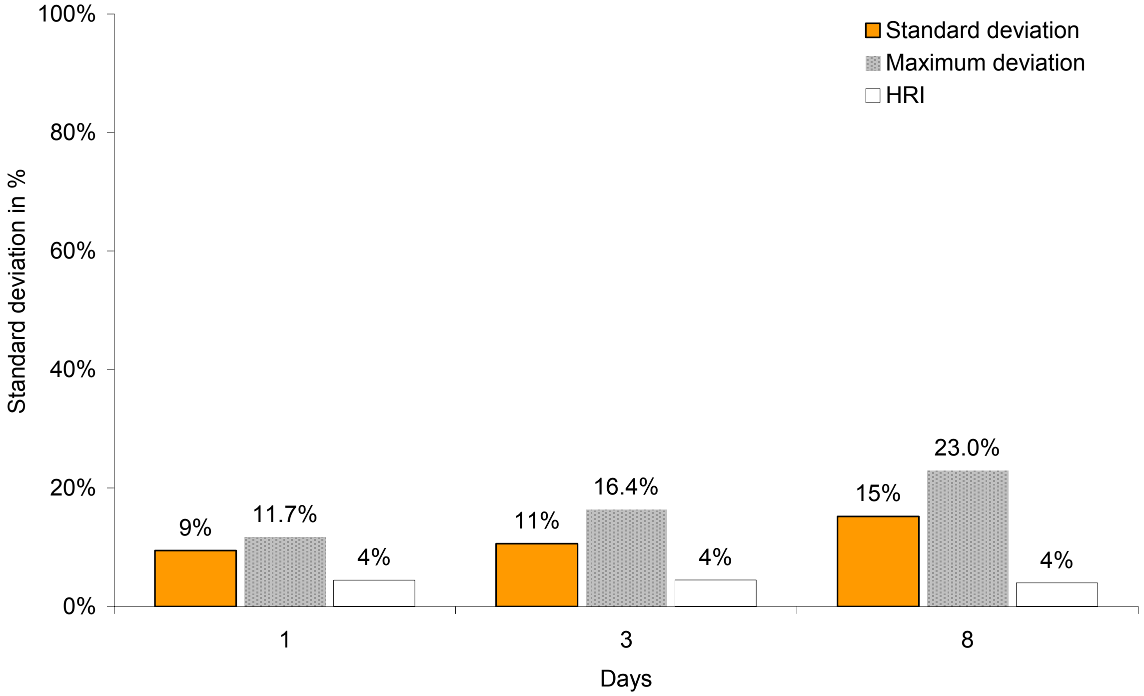

Figure 5-5: Standard deviations of the laboratory results

Conclusion and outlook

The technical progress has already led to a clear reduction in the emission of different building product groups, for example floor covering adhesives, dispersion paints and carpet linings. The results of this project also show that certain building products do not yet meet the provisions of the AgBB scheme. The manufacturing process of these products has to be changed or the composition must be adjusted, which – as experience from the above product groups shows – should be technically feasible.

The emissions of volatile organic compounds (VOC and SVOC) from building products can be justifiably determined using the available methods. However, test chamber measurements over 28 days are rather expensive. The AgBB scheme therefore plans the premature termination of measurements for building products that only produce small emissions. Thermoextraction might contribute to making the tests cost-effective for some building products and also provide an important contribution to production control.

Emission of very volatile organic compounds (VVOC) should be taken into account in the future. Not only formaldehydes, but also other VVOCs can increasingly be emitted from some products. Thus reliable detection of methanol is very desirable, particularly since initial results indicate early emissions within the range of some milligrams per cubic meter. For some components, such as carcinogenic materials, it is even now reasonable to carry out another analysis run.

Rooms in which strong, unpleasant odours occur, are barely tolerated by the occupants any longer. Therefore owners have to build as low-odour buildings as possible. For this purpose they need reliable information about the odour loads caused by building products. Such information is not available so far. The results of this project have established the basis for the sensory assessment required by the AgBB scheme. Since the AgBB scheme is an evaluation concept for building products within building law, it can only differentiate between odours to be tolerated and those that should not. The necessary criteria must be developed in further projects. It should also be investigated as to how intensity assessments can be transferred from emission chambers into a real room. For the positive labelling with the Blue Angel for instance, other and more ambitious criteria are necessary.

Technical improvements in the odour measurement procedure are also possible. The analytical determination of the adjusted acetone concentrations at each individual funnel in the comparative scale is very time-consuming and cost-intensive. A reproducible constant source of acetone providing controlled flow rates of the enriched acetone would greatly shorten the preparation times before odour tests and the measurement technique for acetone determination could be omitted.

A method (AirProbe) was successfully developed and tested to collect and provide sample air. In addition, CLIMPAQ described in the literature is also suitable as a test chamber for certain building products. It would also be interesting to perform the sensory assessment directly at a 1-m^3 emission chamber. It should be proved that an increased air exchange rate in the chamber could be compensated for by an increased loading factor, or that lower sample air flow-rates could also be suitable for odour assessment under certain conditions. In addition, it should be guaranteed that sensory assessment can be performed without being considerably impaired by the laboratory conditions.

Since the interlaboratory comparison was only performed on a single building material sample due to time constraints, other interlaboratory comparisons would be necessary for a possible validation of the method where several building materials were tested by sensors.

The project has shown that a reliable health-related assessment of building products is possible with the help of the AgBB scheme. A suitable method was developed for the sensory assessment already envisaged by the AgBB scheme, but which has so far been suspended. This method must be further developed and validated for implementation in practice.

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Annex

Final Report

Environmental and Health Provisions for Building Products

Identification and evaluation of VOC emissions and odour exposure

Environmental Research Programme
of the Federal Ministry for the Environment,
Nature Conservation and Nuclear Safety

Project No (UFOPLAN) 202 62 320

Annex 1
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Annex 2
Tables summarising analysed VOC and VVOC

The following tables contain all considerable VOC and VVOC from all products analysed using DNPH and Tenax. Table A-1 summarises all compounds from all products. The following tables (A-2 - A-5) are divided into separate groups of products.

Table A-1: Aldehydes and ketones identified using the DNPH method separated by the frequency of occurrence, mean and median from the chamber tests on day 28 of testing (in µg m^{-3})

Compound	**Amount**	**Max**	**Min**	**Mean**	**Median**
Formaldehyde	22	165	1	**22**	8
Acetaldehyde	14	23	1	**10**	8
Propanal	11	23	2	**8**	8
Acetone	10	107	2	**36**	17
Hexanal	9	130	2	**52**	35
Pentanal	7	31	3	**20**	22
Butanal	5	10	4	**7**	7
Heptanal	5	41	2	**21**	20
Octanal	5	24	2	**12**	12
Nonanal	5	18	6	**10**	8
Cyclohexanone	4	15	3	**8**	6
Benzaldehyde	4	12	2	**6**	5
Octenal	4	36	2	**21**	24
Decanal	4	5	3	**4**	4
Heptenal	3	4	3	**4**	4
Hexenal	2	3	3	**3**	3
Nonenal	2	18	2	**10**	10

Table A-2: VOC identified using Tenax separated by the frequency of occurrence, mean and median from the chamber tests on day 28 of testing (in µg m^{-3})

Compound	**Amount**	**Max**	**Min**	**Mean**	**Median**
Acetic acid	15	750	2	**68**	14
Hexanal	11	170	3	**63**	33
Benzaldehyde	9	18	1	**4**	1
Alpha pinene	9	130	2	**45**	35
3-carene	8	200	17	**52**	31
2-ethyl-1-hexanol	7	38	2	**13**	10
Butanol	7	24	2	**6**	3
Decamethyl cyclopentasiloxane	7	410	1	**63**	2
Hexanoic acid	7	86	6	**52**	60
Nonanal	7	20	1	**8**	2
Octanal	7	19	3	**11**	8
Pentanal	7	49	22	**32**	40
Pentanol	7	130	9	**35**	19
Beta pinene	6	5	1	**4**	4
Octamethylcyclotetrasiloxane	6	19	1	**6**	3
Heptanal	6	13	1	**6**	5
Longifolene	6	4	1	**3**	3
Dodecamethylcyclohexasiloxane	6	5600	43	**1177**	309
Phenol	5	5	1	**3**	2
Propanoic acid ester	5	2900	4	**870**	220
Tridecane	5	210	1	**49**	11
Acetophenone	4	4	1	**2**	2
C_4-benzene	4	35	2	**11**	4
Hexamethylcyclotrisiloxane	4	20	4	**10**	8
Ethanediol	4	280	17	**150**	140
Methylistothiazolinone	4	210	16	**97**	81
Tetradecane	4	86	1	**27**	10
2-2-butoxyethoxyethanol	3	76	2	**28**	7
2-octenal	3	9	7	**8**	9
C_3-benzene	3	59	1	**20**	1
Dipropylene glycol	3	1500	5	**738**	710
Dodecanoic acid methyl ester	3	5	4	**5**	5
Ethanol, 2-(2-butoxyethoxy)-acetate	3	120	1	**46**	15
Hexadecane	3	200	3	**76**	30
Limonene	3	9	2	**5**	4
Octanoic acid	3	13	6	**10**	11
Pentadecane	3	160	1	**64**	30
Pentanoic acid	3	12	0	**8**	11
Propylene glycol	3	120	16	**53**	19
Tetradecamethylcycloheptasiloxane	3	190	27	**102**	109

Table A-3: Frequency of occurrence, mean and median of emitted VOC from **acrylic sealants** identified using Tenax in chamber tests on day 28 of testing (in µg m^{-3})

Compound	Amount	Max	Min	Mean	Median
Butanol	5	24	2	**7**	3
Ethanediol	2	284	142	**213**	213
2-(2-butoxethoxy)ethoxy-ethanol	2	37	12	**25**	25
n-butyl ether	2	29	16	**22**	22
C4-benzene	2	35	4	**19**	19
Propylene glycol	2	19	16	**18**	18
1-hexanol-2 ethyl	2	12	10	**11**	11
Dodecane	2	15	1	**8**	8
Tridecane	2	11	1	**6**	6
Propanoic acid butyl ester	2	7	4	**5**	5
2-2-butoxyethoxyethanol	2	7	2	**4**	4

Table A-4: Frequency of occurrence, mean and median of emitted VOC from **silicone sealants** identified using Tenax in chamber tests on day 28 of testing (in µg m^{-3})

Compound	Amount	Max	Min	Mean	Median
Decamethylcyclopentasiloxane	6	410	1	**74**	14
Octamethylcyclotetrasiloxane	6	5600	43	**1177**	309
Dodecamethylcyclohexasiloxane	5	19	2	**7**	4
Tetradecamethylcycloheptasiloxane	3	190	27	**102**	109
Phenol	2	5	2	**4**	4
Tridecane	2	210	1	**108**	108
Tetradecane	2	7	1	**4**	4
Hexadecane	2	30	3	**17**	17
Pentadecane	2	30	1	**16**	16
Dodecamethylpentasiloxane	2	260	15	**138**	15
Hexamethylcyclotrisiloxane	2	20	9	**15**	15

Table A-5: Frequency of occurrence, mean and median of emitted VOC from **wood and wood-based products** identified using Tenax in the chamber tests on day 28 of testing (in µg m^{-3})

Compound	Amount	Max	Min	Mean	Median
Hexanal	11	169	3	**63**	33
α-pinene	8	64	2	**35**	33
Hexanoic acid	7	86	6	**52**	60
Δ3-carene	7	197	17	**51**	26
Pentanal	7	19	3	**11**	8
Acetic acid	6	745	3	**170**	61
Octanal	6	49	22	**38**	41
Pentanol	6	29	9	**18**	18
Heptanal	6	13	1	**6**	5
Unknown terpene	4	82	3	**24**	6
Nonanal	4	20	2	**13**	15

Annex 3
Structure of tables and illustrations in the annex

The following pages contain the test results from all chamber measurements which were performed in the project. The tables and graphics are listed according to the following pattern:

The ordinal numbers "3332, 3333, 3338" etc. are the laboratory sample identification numbers which also represent the principles for the following tables and figures when referring to a product. "Table 3333-1" contains the concentrations of the VOC determined in the chamber test mostly on the first, third, tenth and 28th day and in some cases even at a later time. Even if SVOC are contained in the tables, they are listed below **the thick** (red) **line** in the lower part of the tables. The listings above **the broken** (green) **line** correspond to VVOC. Usually the values of ketones and aldehydes obtained using the DNPH method are not included in the TVOC values. The DNPH values are, when available, indicated for all detected components. These values are separated by **a dotted** (blue) **line**. The TVOC values are in the last line which result from the summation of the individually quantified values. When TVOC values determined using toluene equivalents were available, they are listed in another line and marked as TVOC (toluene equivalent). A chromatogram for the respective product at day 28 follows. The last two figures and the final table are the results of the odour test when carried out.

n. d. in the tables is short for **non detectable** and applies to substances which were detected at an earlier time but later fell below the determination limit. Some components were **also non assessable** due to their quantity, such as acetic acid in acetate-releasing sealing compounds, they are then marked with **n. a.** Furthermore, where some compounds were not able to qualify exactly, then an attempt was made to use a likely selection from the spectrum library based on the fragments, or the component was considered as unknown VOC and denoted with **unknown VOC**.

The values of area-specific air flow rate q ($m^3m^{-2}h^{-1}$) used to perform the measurement, are indicated in the table headings. However, they were not considered in the AgBB evaluation or in the concentration values. But the comparative tables in the report text are converted to a common area-specific air flow rate.

The AgBB evaluation scheme is represented in the DIBt evaluation mask for the assessment of floor covering emissions which contains the key criteria for this evaluation. The LCI (NIK) values of the 2005 AgBB scheme were used for the calculation of the R value in all tables. Only formaldehyde, acetaldehyde and acetone in most cases belong to this group when indicating VVOC values.

Retention times (RT's) indicated in the tables are not always constant in different measurements. They reflect, among other things, a development in the laboratory measurement methods. The key difference is the conversion of a GC/MS system, based on an Agilent GC 5890/MS 5972 combination, to a new one which consists of an Agilent GC 6890 with MSD 5973. This is one of the reasons for different retention times of the same substance in the tables.

A peak in the chromatograms at an RT of 20.7 and/or 22.0 is usually due to the internal standard (cyclodecane), 20 ng of which was introduced in the Tenax tube in all chamber measurements before sampling. The signals of the measured compounds were corrected with the area integral of the internal standard for the quantification of VOC samples. Chromatograms, which show marked signals in the field of SVOC without being listed in the tables, result from a carry-over of high-contamination samples in the GC system. So-called spikes occur as blank values in a few chromatograms, they are indicated with a small arrow and the label ‘spike’ (problem of the older MS 5972 system). Furthermore, siloxanes originating from the Tenax tubes used most frequently occur in the foremost part of the chromatogram. The blank concentration values were subtracted from the measured values for quantification purposes. The retention times (RT) in the chromatograms do not always agree with the data in the tables, since the chromatograms shown were taken on day 28. The tables show the RT's of the first measuring day when higher concentrations can be measured, these deviations lead to a minor shift in the RT's.

All products tested in this study.

Sealants

3332 Acrylic sealant 1, manufacturer 1

Table 3332-1: Concentrations of organic compounds analysed from an acrylic sealant; 20-litre chamber, $q = 44\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Butanol	71-36-3	7.91	820	300	80	24
Propylene glycol	57-55-6	10.33	380	280	43	16
1-butyl acetate	123-86-4	12.12	38	25	11	3
n-butyl ether	142-96-1	14.97	120	66	35	16
Propanoic acid butyl ester	590-01-2	15.50	40	21	11	4
Decane	124-18-5	19.50	10	10	7	5
Butanoic acid butyl ester	109-21-7	15.54	10	5	3	1
Undecane	1120-21-4	23.13	42	33	21	14
Diethylene glycol monobutyl ether	112-34-5	25.47	91	47	16	7
Dodecene	112-41-4	18.44	28	23	15	10
Unknown alkane*		26.33	38	33	32	25
Dodecane	112-40-3	26.73	42	33	7	15
Tridecane	629-50-5	30.12	32	22	15	11
Butyl diglycol acetate	124-17-4	34.27	7	37	2	37
Unknown alkane*		34.99	22	12	8	6
Unknown alkane*		39.36	25	22	12	9
Unknown alkane*		36.34	30	22	17	12
Carbonic acid ester*		41.50	16	17	19	13
TVOC			1700	900	300	150

* Generalised name, no exact specification possible

Table 3332-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3332			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	0.848	<= 10	0.151	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0.051	<= 0.1
[C]	R (dimensionless)	no requirement		0.11	<= 1
[D]	Σ VOC without LCI	no requirement		0.033	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)		addit. inform.		addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	0.708	addit. inform.	0.118	addit. inform.

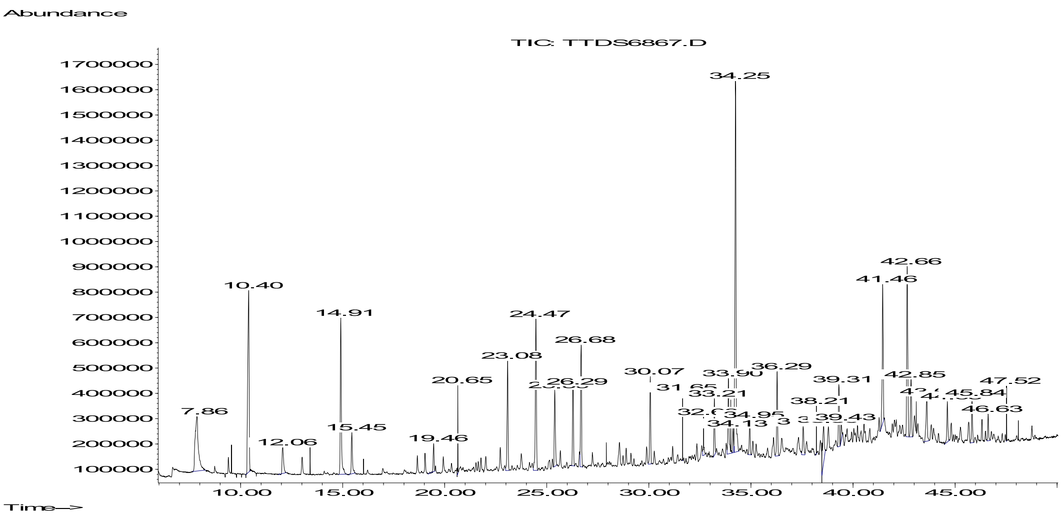


Figure 3332-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3332-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	14.3	1.1	-2.8	1.1
3	10	13.8	1.7	no data	no data
10	9	12.3	1.6	-2.7	0.9
28	11	10.1	2.0	-1.9	1.2

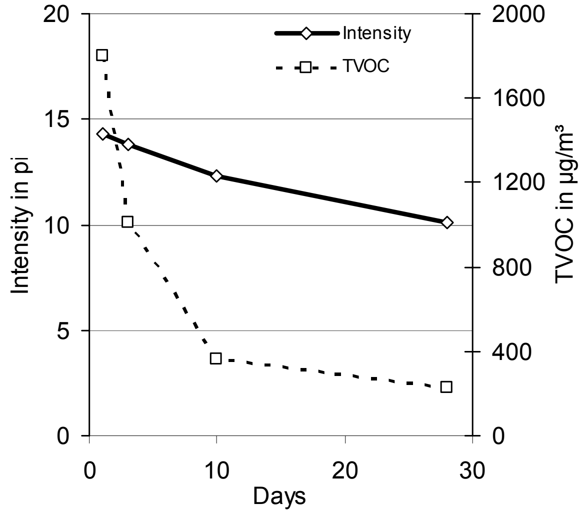


Figure 3332-2: Intensity and TVOC

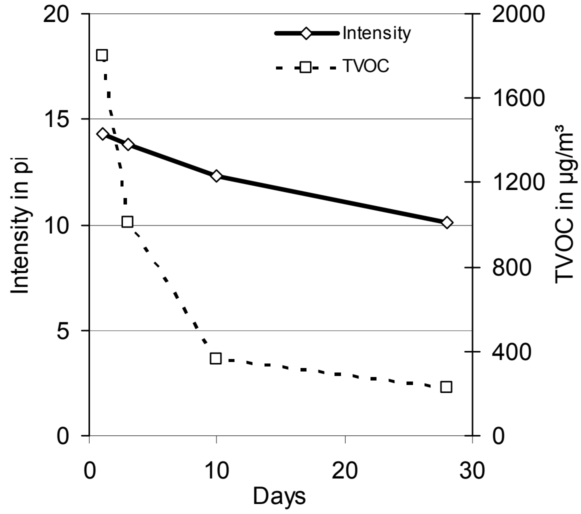


Figure 3332-3: Hedonics

3351 Acrylic sealant, manufacturer 3

Table 3351-1: Concentrations of organic compounds analysed from an acrylic sealant; 20-litre chamber, q = 44 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
n-butanol	71-36-3	7.9	190	110	34	10
Ethanediol	107-21-1	8.10	2800	1500	570	280
Octane	111-65-9	12.14	36	44	33	8
Ethylbenzene	100-41-4	14.00	15	15	9	3
Dimethylbenzene	108-38-3	14.32	29	30	19	7
Isononane*		14.61	45	57	40	14
Isononane*		14.87	42	46	33	12
Butylpropionate	590-01-2	15.54	62	57	32	11
Isopropylcyclohexane	696-29-7	15.41	33	38	26	10
Butylpropionate-2	590-01-2	15.55	37	36	23	8
n-nonane	111-84-2	18.44	270	350	250	76
Isodecane*		16.6	47	52	37	17
Isopropylcyclohexane	696-29-7	16.98	47	51	45	12
Isodecane*		17.21	69	83	60	26
Propylbenzene	103-65-1	17.49	39	44	30	15
3C-benzene*		17.74	31	33	20	9
3C-benzene*		18.02	39	43	27	14
Isodecane*		18.31	79	96	63	20
Isodecane*		18.33	46	42	67	20
Isodecane*		18.59	81	98	64	29
3C-benzene*		18.74	85	90	56	28
n-decane	124-18-5	19.56	560	750	470	180
3C-benzene*		19.95	30	24	17	9
Ethylhexanol	104-76-7	20.06	53	40	19	12
Isoundecane*		20.47	110	130	80	43
Isobutylcyclohexane	1678-98-4	20.73	45	56	35	17
Isobutylcyclohexane	1678-98-4	20.85	47	52	31	14
C4-benzene*		21.02	35	39	24	13
C4-benzene*		21.57	28	26	19	10
Isoundecane*		21.66	47	54	33	17
Isoundecane*		21.78	51	61	36	18
Isoundecane*		21.91	84	97	60	31
Isoundecane*		22	33	34	21	11
Isoundecane*		22.14	53	63	38	19
n-undecane	1120-21-4	23.24	340	410	260	120
TVOC			5700	4800	2700	1200

* Generalised name, no exact specification possible

Table 3351-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3351			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3]		Day 28 [mg/m^3]	
		Measured val.	requirement	measured val.	requirement
[A]	TVOC (C$_6$ - C$_{16}$)	4.705	<= 10	1.147 !!	<= 1
[B]	Σ SVOC (C$_{16}$ - C$_{22}$)	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		1.26 !!	<= 1
[D]	Σ VOC without LCI	no requirement		0.047	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C$_6$)	0	addit. inform.	0	addit. inform.
[G]	TVOC (C$_6$ – C$_{16}$) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	4.61	addit. inform.	1,09	addit. inform.

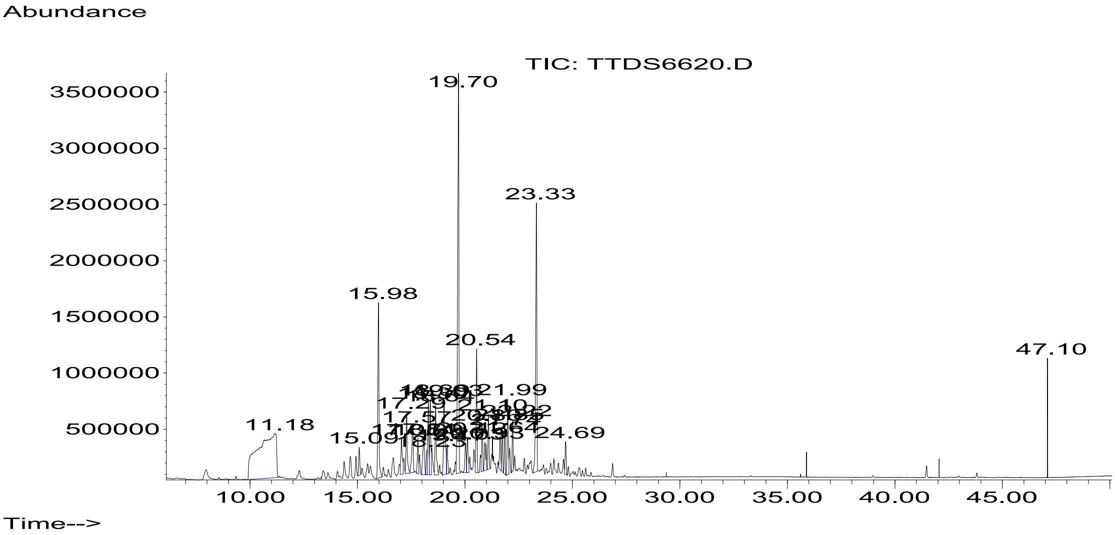


Figure 3351-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3351-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	no data	19.0	no data	no data	no data
3	no data	17.5	no data	no data	no data
10	9	11.2	3.6	-3.1	1.0
28	11	9.9	2.2	no data	no data

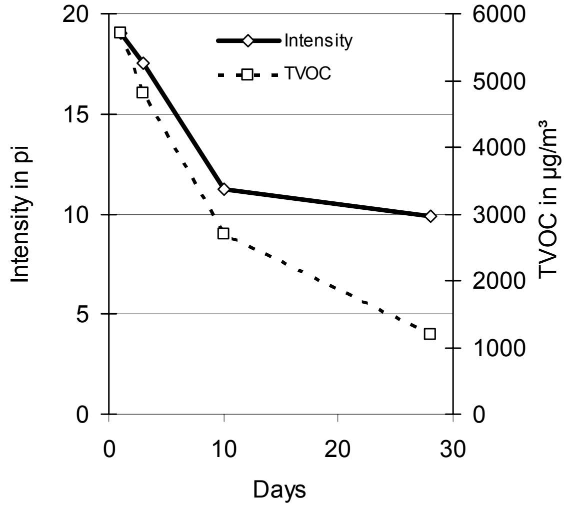


Figure 3351-2: Intensity and TVOC

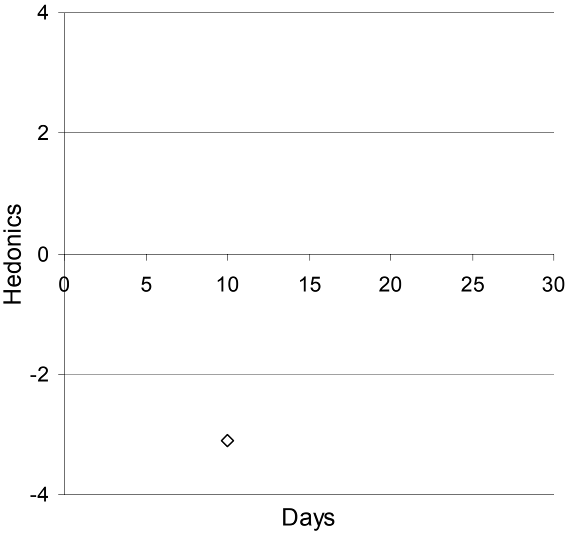


Figure 3351-3: Hedonics

3356 Acrylic sealant, manufacturer 7

Table 3356-1: Concentrations of organic compounds analysed from an acrylic sealant 20-litre chamber, q = 83 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
n-butanol	71-36-3	6.20	160	43	4	3
Acetic acid	64-19-7	6.87	35	11	n.d.	n.d.
Propylene glycol	57-55-6	8.74	220	78	13	n.d.
n-butyl ether	142-96-1	12.27	9	6	3	n.d.
Diethylene glycol	111-46-6	14.63	7	35	17	7
2-ethyl-1-hexanol	104-76-7	16.81	49	30	17	10
Benzaldehyde	100-52-7	14.01	5	3	1	n.d.
Nonanal	124-19-6	18.96	5	1	n.d.	n.d.
Dipropylene glycol	110-98-5	23.58	6900	4200	2300	1500
TVOC			7400	4400	2300	1500

Table 3356-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3356			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	4.412	<= 10	1.500 !!	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		2.71 !!	<= 1
[D]	Σ VOC without LCI	no requirement		0	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	4.403	addit. inform.	1.497	addit. inform.

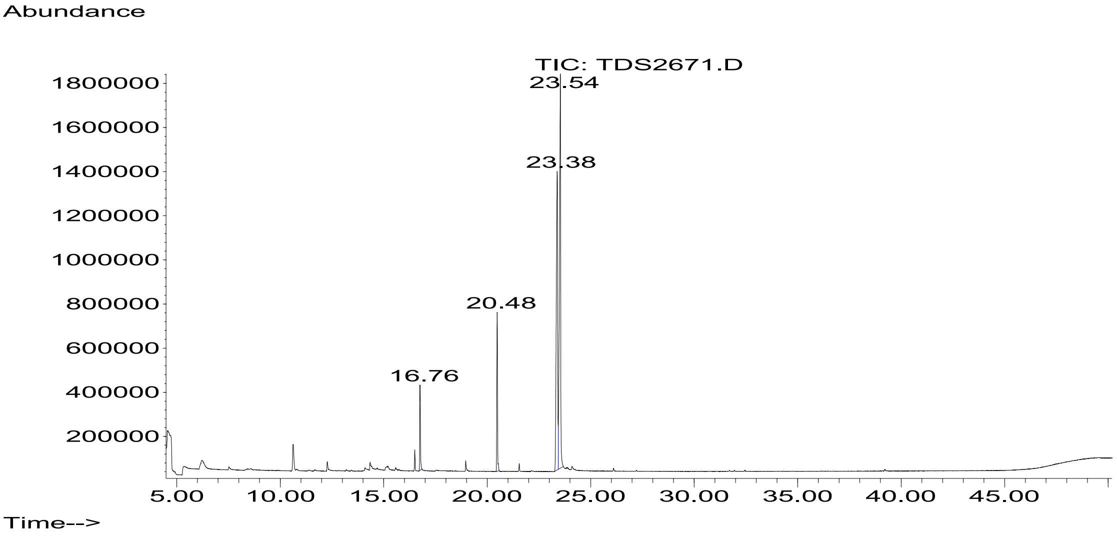


Figure 3356-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3356-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	7	9.6	4.4	-2.0	1.6
3	5	11.3	4.6	-2.7	0.7
10	8	10.3	3.8	-2.8	0.8
28	6	7.1	2.2	-1.1	2.1

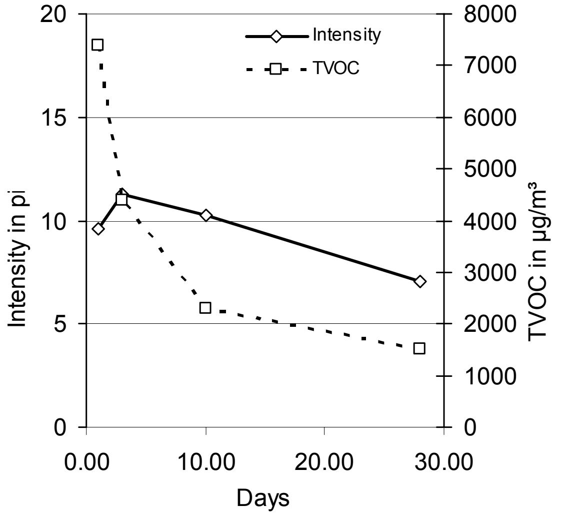


Figure 3356-2: Intensity and TVOC

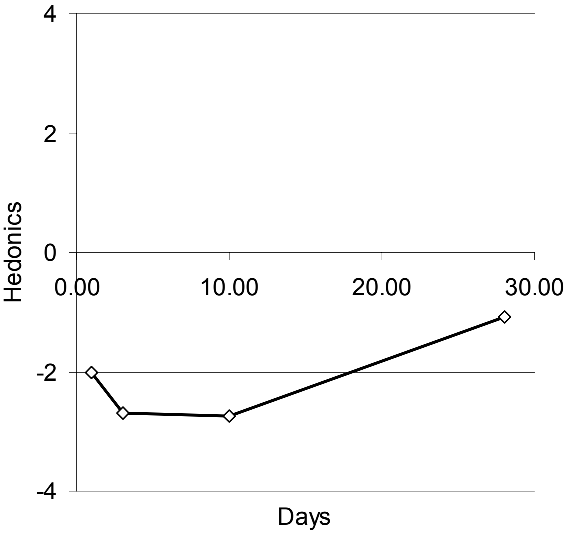


Figure 3356-3: Hedonics

3460 Acrylic sealant, manufacturer 13

Table 3460-1: Concentrations of organic compounds analysed from an acrylic sealant; 20-litre chamber, $q = 83\ m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m^3]**	**Day 3 [µg/m^3]**	**Day 10 [µg/m^3]**	**Day 28 [µg/m^3]**
Butanol	71-36-3	7.01	100	46	11	3
Ethanediol#	107-21-1	9.23	6200	3200	750	260
Butyl acetate	123-86-4	10.95	4	3	1	n.d.
Benzaldehyde	100-52-7	15.40	7	7	3	2
Phenol	108-95-2	16.2	1	1	n.d.	n.d.
Acetophenone	98-86-2	18.8	2	3	n.d.	1
Cyclohexane, 1,4-dimethyl-, cis-?*		21.4	3	2	2	1
Cyclohexane, 1,4-dimethyl-, cis-?*	624-29-3	21.8	3	1	1	n.d.
Tetradecane	110-98-5	30.4	1	1	1	n.d.
TVOC			6300	3200	780	270

* Suggestion of the mass sprectra library, no exact specification possible

Sample was tested for more than 28 days. Ethanediol can be measured in the following amounts (in µg/m^3):

Day of measurement	Day 86	Day 120	Day 133	Day 172
Ethanediol	140	110	67	74

Table 3460-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3460			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3]		Day 28 [mg/m^3]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	3.844	<= 10	0.284	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		1.069 !!	<= 0.1
[D]	Σ VOC without LCI	no requirement		0	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	3.837	addit. inform.	0.278	addit. inform.

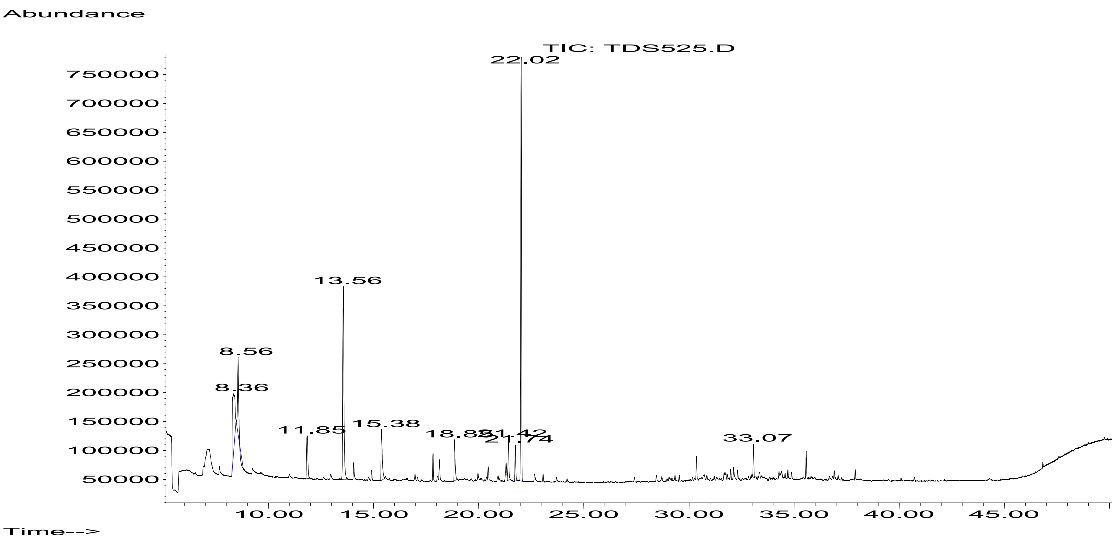


Figure 3460-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3460-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	12	17.7	4.1	-3.3	1.6
3	12	15.3	3.1	-3.3	0.7
10	10	15.7	2.5	-3.1	0.9
28	8	12.4	2.8	-3.1	0.8

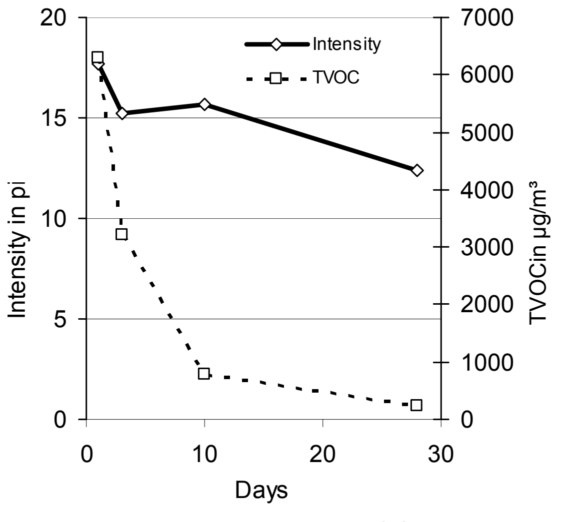


Figure 3460-2: Intensity and TVOC

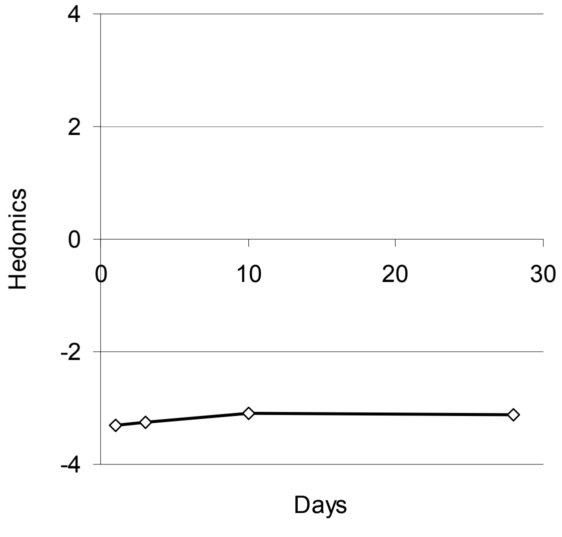


Figure 3460-3: Hedonics

3485 Acrylic sealant, manufacturer 15

Table 3485-1: Concentrations of organic compounds analysed from an acrylic sealant; 20-litre chamber, $q = 83\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]	Day 67 [µg/m³]
Butanol	71-36-3	7.33	69	15	5	2	4
Ethanediol	107-21-1	8.98	900	148	20	n.d.	n.d.
Acetic acid butyl ester	123-86-4	11.02	2	1	1	n.d.	n.d.
n-butyl ether	142-96-1	13.54	120	75	41	23	29
Propanoic acid butyl ester	590-01-2	14.03	31	15	9	4	7
Isopropylbenzene (cumene)	98-82-8	14.75	2	1	1	n.d.	n.d.
Phenol	108-95-2	16.39	2	1	1	n.d.	n.d.
TVOC			1100	260	78	30	40
TVOC*			290	140	64	39	28

* TVOC given as toluene equivalent

Table 3485-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3485			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	0.253	<= 10	0.027	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		0.00	<= 1
[D]	Σ VOC without LCI	no requirement		0.027	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent	0.139	key in the value manually!	0.039	key in the value manually!
[H]	Σ VOC with LCI	0.163	addit. inform.	0	addit. inform.

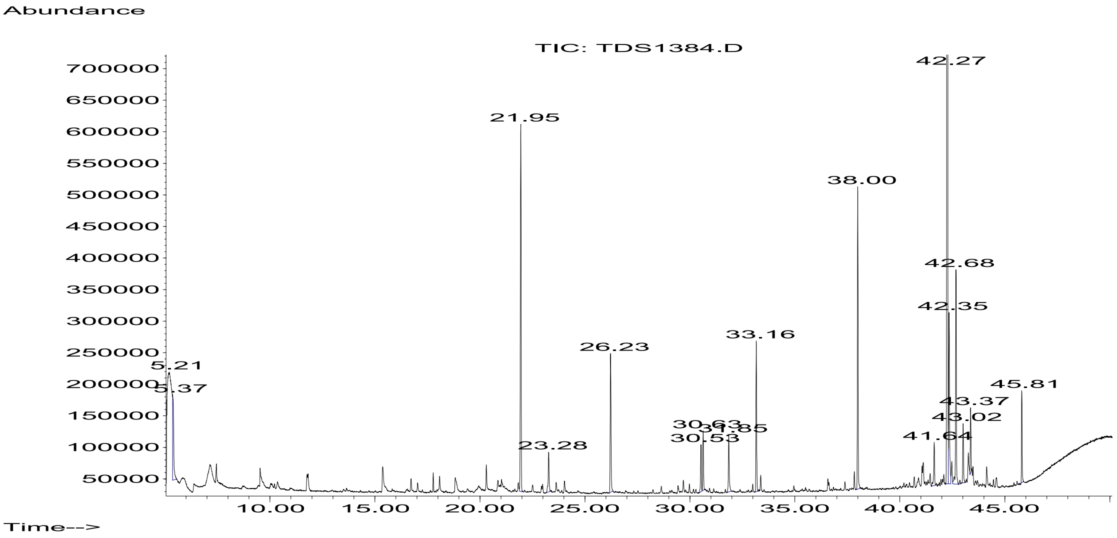


Figure 3485-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3485-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	15.4	3.5	-3.2	0.8
3	7	13.3	2.7	-2.7	0.5
10	9	13.0	2.9	-2.4	0.7
28	8	12.8	3.5	-2.3	1.3

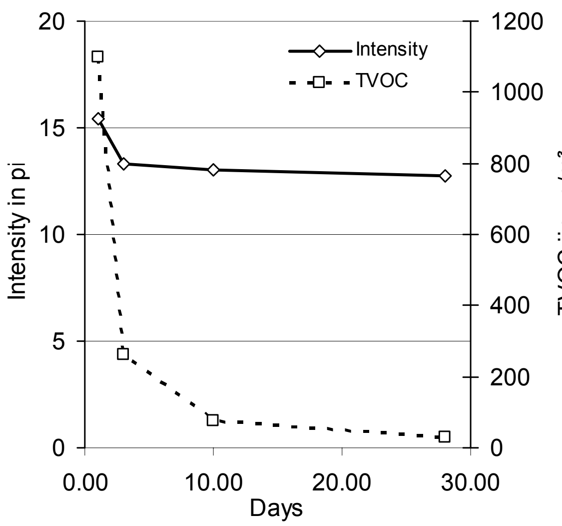


Figure 3485-2: Intensity and TVOC

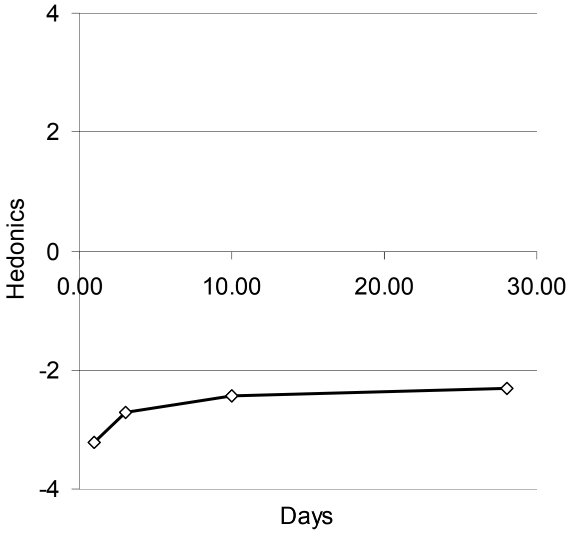


Figure 3485-3: Hedonics

3647 Acrylic sealant 2, manufacturer 1

Table 3647-1: Concentrations of organic compounds analysed from an acrylic sealant; 20-litre chamber, q = 83 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Butanol	71-36-3	6.29	160	38	10	3
Propylene glycol	57-55-6	8.8	390	140	50	19
Acetic acid	64-19-7	8.74	26	2	1	1
Acetic acid butyl ester	123-86-4	10.2	49	23	8	1
n-butyl ether	142-96-1	12.68	63	35	14	n.d.
Propanoic acid butyl ester	590-01-2	13.19	12	6	2	n.d.
Butanoic acid butyl ester	109-21-7	16.05	5	2	2	n.d.
1-methyl-2-pyrrolidinon	872-50-4	16.77	110	5	9	8
Undecane	1120-21-4	19.57	4	4	2	n.d.
2-(2-butoxyethoxy)-ethanol	112-34-5	21.93	34	15	4	2
Dodecane	112-40-3	23.14	9	8	4	1
Unknown VOC*		24.9	4	3	1	n.d.
Tridecane	629-50-5	26.38	8	7	4	1
Decanoic acid methyl ester	110-42-9	26.55	2	1	1	0
2-[2-(2-butoxyethoxy)ethoxy]-ethanol		30.28	22	35	17	12
Dodecanoic acid methyl ester		32.24	16	14	8	5
Acetone DNPH	67-64-1	9.9	21	3	n.d.	n.d.
TVOC**			910	340	130	52
TVOC***			526	245	107	49

* Generalised name, no exact specification possible
** Without DNPH values
*** TVOC given as toluene equivalent

Table 3647-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3647			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3]		Day 28 [mg/m^3]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	0.308	<= 10	0.049	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		0.05	<= 1
[D]	Σ VOC without LCI	no requirement		0.017	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0.003	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent	0.245	key in the value manually!	0.049	key in the value manually!
[H]	Σ VOC with LCI	0.240	addit. inform.	0.027	addit. inform.

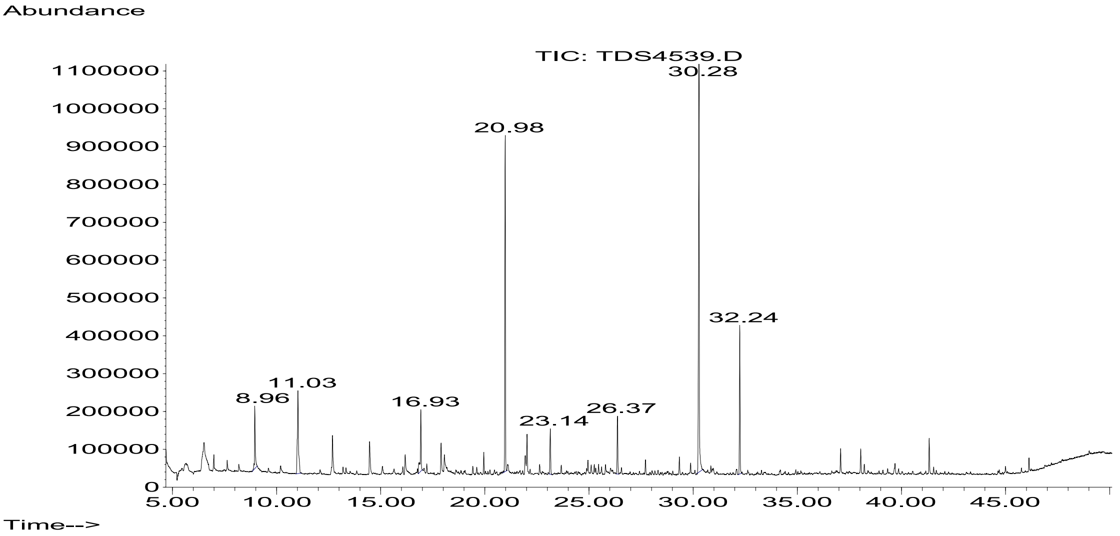


Figure 3647-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

Table 3647-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	11.4	1.7	-0.9	1.1
3	9	9.2	1.0	-1.4	1.0
10	8	8.8	2.2	0.8	1.2
28	10	6.1	1.9	0.5	1.3

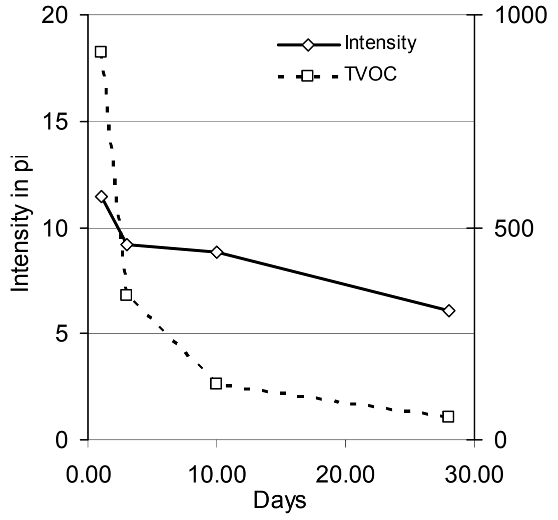


Figure 3647-2: Intensity and TVOC

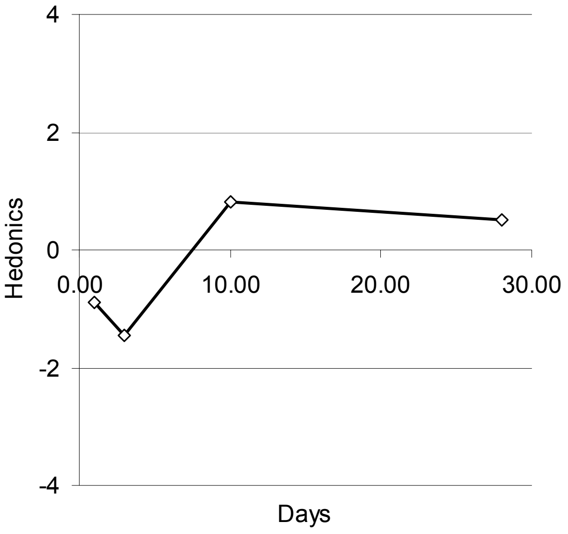


Figure 3647-3: Hedonics

3653 Acrylic sealant 3, manufacturer 1

Table 3653-1: Concentrations of organic compounds analysed from an acrylic sealant 20-litre chamber, q = 44 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
1-butanol	71-36-3	6.45	270	150	32	14
Propylene glycol	57-55-6	8.88	270	200	66	26
n-butyl acetate	123-86-4	10.14	24	32	8	3
n-butyl ether	142-96-1	12.65	51	41	22	11
Propionic acid butyl ester	590-01-2	13.14	22	16	8	3
Butyric acid butyl ester	109-21-7	16.03	9	7	3	2
Decane	124-18-5	16.75	3	3	2	1
Undecane	1120-21-4	19.93	8	8	5	3
2-(2-butoxyethoxy)ethanol	112-34-5	21.92	100	67	27	3
1-dodecane	112-40-3	23.12	14	15	8	5
Tridecane	629-50-5	26.35	14	15	8	5
Tetradecane	629-59-4	29.32	4	3	2	1
Ethanol, 2-[2-(2-butoxyethoxy)-ethoxy]		30.13	46	45	29	16
TVOC			840	600	220	90

Table 3653-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an acrylic sealant.

Sample		Acrylic sealant 3653			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	0.602	<= 10	0.091	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		0.09	<= 1
[D]	Σ VOC without LCI	no requirement		0.032	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0.000	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent	0.334	key in the value manually!	0.129	key in the value manually!
[H]	Σ VOC with LCI	0.487	addit. inform.	0.050	addit. inform.

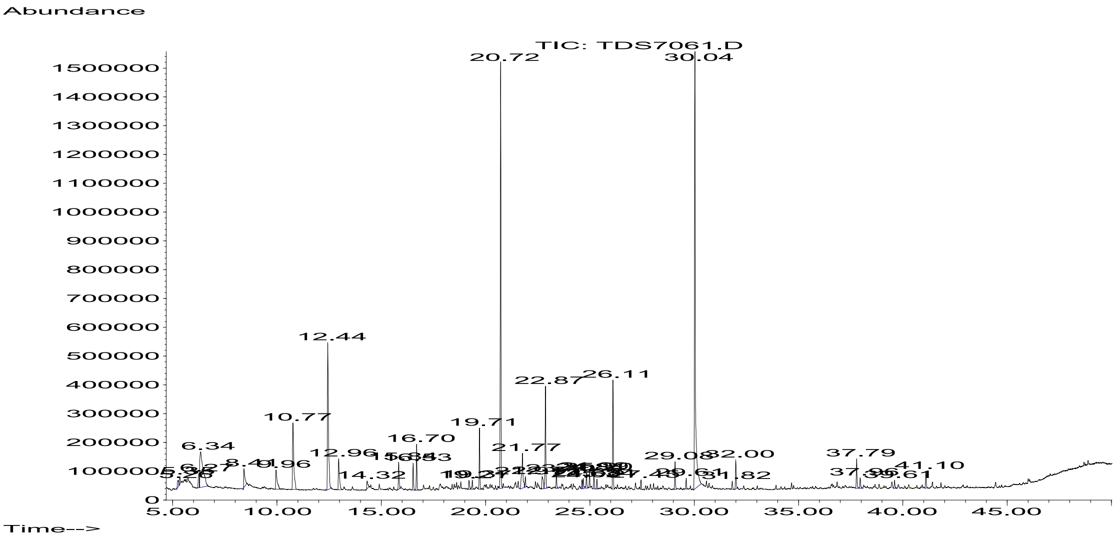


Figure 3653-1: GC/MS chromatogram on day 28 of emission testing on an acrylic sealant.

3333 Silicone sealant, manufacturer 2 (acidic cross linking)

Table 3333-1: Concentrations of organic compounds analysed from a silicone sealant 20-litre chamber, q = 10 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Acetic acid			n.a.	n.a.	n.d.	n.d.
Octamethylcyclotetrasiloxane	556-67-2	19.99	3100	2700	3000	18
Decamethylcyclopentasiloxane	541-02-6	25.88	20300	19000	12700	410
Dodecamethylcyclohexasiloxane	540-97-6	31.82	1790	2500	4150	5600
Cluster of alkanes 30 – 36.5 min		< 36.5	2800	3700	5000	3100
Cluster of alkanes 36.5 – 42.5		> 36.5	3600	5700	5200	4300
TVOC			28000	28000	25000	9100

* Generalised name, no exact specification possible

Table 3333-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample		Silicone sealant 3333			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	27.800 !!	<= 10	9.100 !!	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		4.300 !!	<= 0.1
[C]	R (dimensionless)	no requirement		0.38	<= 1
[D]	Σ VOC without LCI	no requirement		9.100 !!	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)		addit. inform.		addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key inkey in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	9,400	addit. inform.	18	addit. inform.

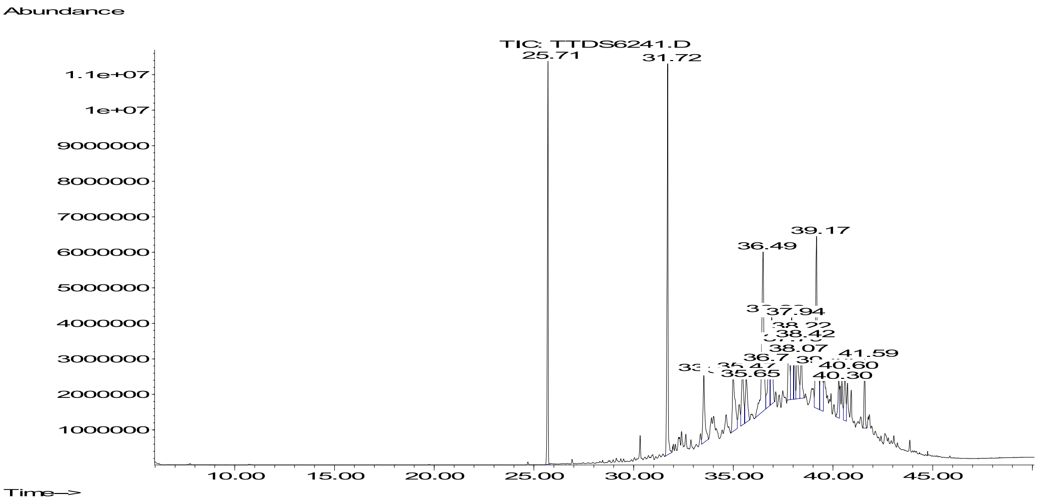


Figure 3333-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

3338 Silicone sealant, manufacturer 3 (neutrally cross linking)

Table 3338-1: Concentrations of organic compounds analysed from a silicone sealant; 20-litre chamber, q = 44 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m³]**	**Day 3 [µg/m³]**	**Day 10 [µg/m³]**	**Day 28 [µg/m³]**
Trimethylsilanol		6.41	2200	1300	510	24
Hexamethyldisiloxane	1189-93-1	8.81	4300	3700	6500	n.d.
2-methyl-1-butanol	137-32-6	9.84	190	94	2	n.d.
1-pentanol	71-41-0	10.74	500	400	150	130
2-amino-1-butanal	96-20-8	11.22	930	8	n.d.	n.d.
Octamethyltrisiloxane	107-51-7	15.57	910	620	1420	4
Octamethylcyclotetrasiloxane	556-67-2	19.67	30	31	40	9
Decamethyltetrasiloxane	141-62-8	21.67	100	82	130	2
Decamethylcyclopentasiloxane	541-02-6	25.61	2200	1600	2000	150
Dodecamethylpentasiloxane		26.77	500	330	440	37
Tridecane	629-50-5	30.2	13	n.d.	10	5
Dodecamethylcyclohexasiloxane	540-97-6	31.64	2800	2100	2000	800
Tetradecane	629-59-4	33.36	5	2	3	1
Tetradecamethylcycloheptasiloxane	107-50-6	36.8	390	310	270	190
TVOC			14678	10267	13205	1162

Table 3338-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample		Silicone sealant 3338			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m³]		Day 28 [mg/m³]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	10.286 !!	<= 10	1.169 !!	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0.185 !!	<= 0.1
[C]	R (dimensionless)	no requirement		0.05	<= 1
[D]	Σ VOC without LCI	no requirement		1.020 !!	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)		addit. inform.		addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	0.433	addit. inform.	0.148	addit. inform.

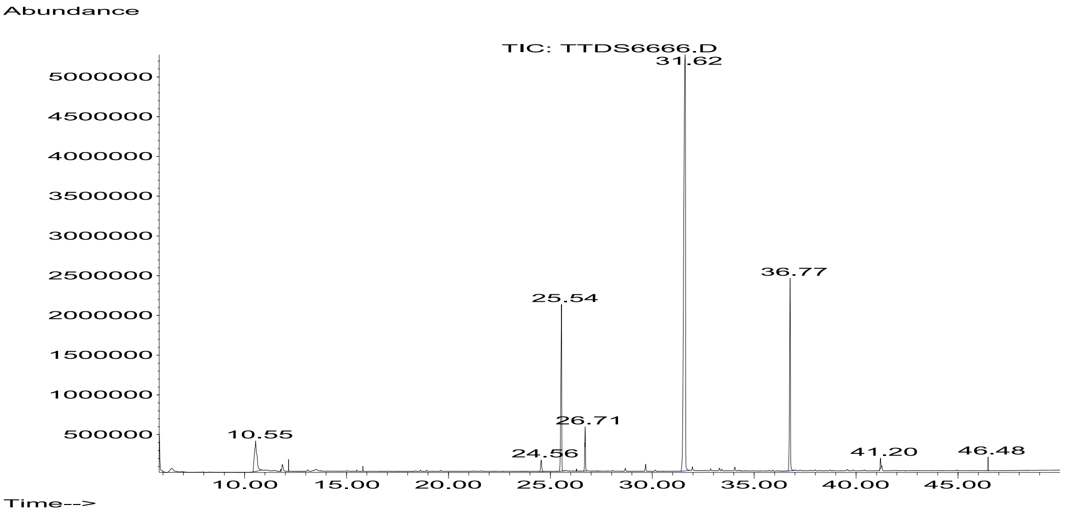


Figure 3338-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

Table 3338-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	12.1	3.3	-1.6	1.3
3	11	10.6	2.9	-1.6	1.2
10	9	11.5	4.5	-3.1	0.6
28	10	14.1	3.2	no data	no data

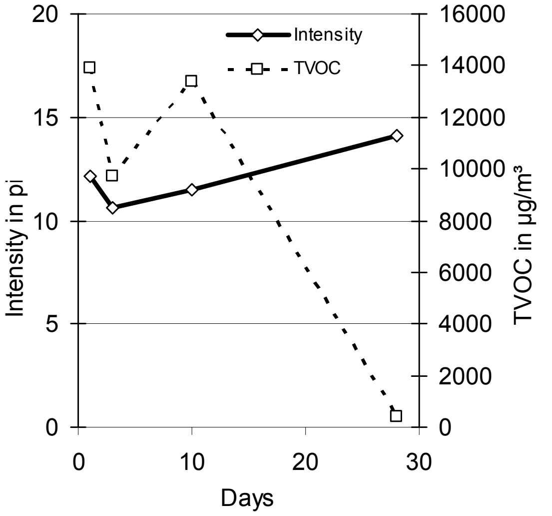


Figure 3338-2: Intensity and TVOC

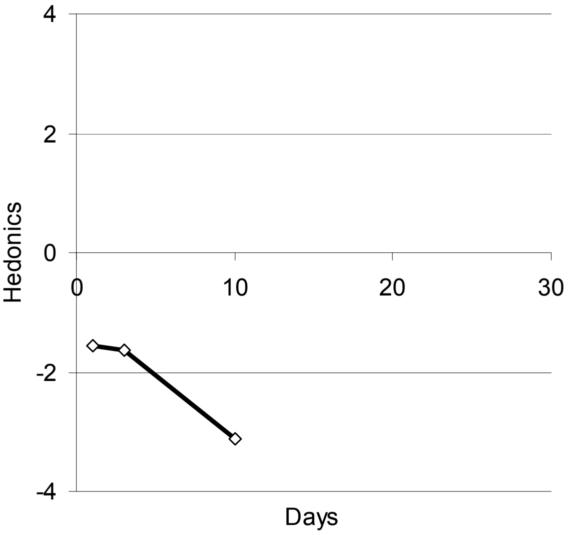


Figure 3338-3: Hedonics

3353 Silicone sealant, manufacturer 7 (acidic cross linking)

Table 3353-1: Concentrations of organic compounds analysed from a silicone sealant; 20-litre chamber, q = 83 m^{3}m^{-2}h^{-1}

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m^3]**	**Day 3 [µg/m^3]**	**Day 10 [µg/m^3]**	**Day 28 [µg/m^3]**
Acetic acid	64-19-7	6.04	8500	300	43	13
Hexamethylcyclotrisiloxane	541-05-09	11.06	380	39	13	9
Benzaldehyde	100-52-7	14.48	12	13	5	5
Phenol	108-95-2	15.42	7	6	3	2
Octamethylcyclotetrasiloxane	556-67-2	16.98	480	130	3	2
Acetophenone	98-86-2	17.92	9	11	4	4
Nonanal	124-19-6	19.46	6	5	3	1
Decamethylcyclopentasiloxane	541-02-6	22.1	460	330	21	1
Unknown VOC*		24.67	17	7	2	n.d.
Dodecamethylcyclohexasiloxane	540-97-6	27.77	190	180	150	43
Tetradecane	629-59-4	29.4	20	20	21	7
Pentadecane	629-62-9	32.13	43	45	46	30
Hexadecane	544-76-3	34.64	41	42	45	30
Cluster of alkanes RT 29-34.64		-34.64	8100	5300	3900	1800
Cluster of alkanes RT 34.64-40 (SVOC)		-40	1500	1300	1400	970
TVOC			18300	1100	4250	1950

* Generalised name, no exact specification possible

Table 3353-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample		Silicone sealant 3353				
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3]		Day 28 [mg/m^3]		
		measured val.	requirement	measured val.		requirement
[A]	TVOC (C_6 - C_{16})	6.384	<= 10	1.961	!!	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0.970	!!	<= 0.1
[C]	R (dimensionless)	no requirement		0.08		<= 1
[D]	Σ VOC without LCI	no requirement		1.872	!!	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0		<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.		addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	0.565	addit. inform.	0.085	addit. inform.

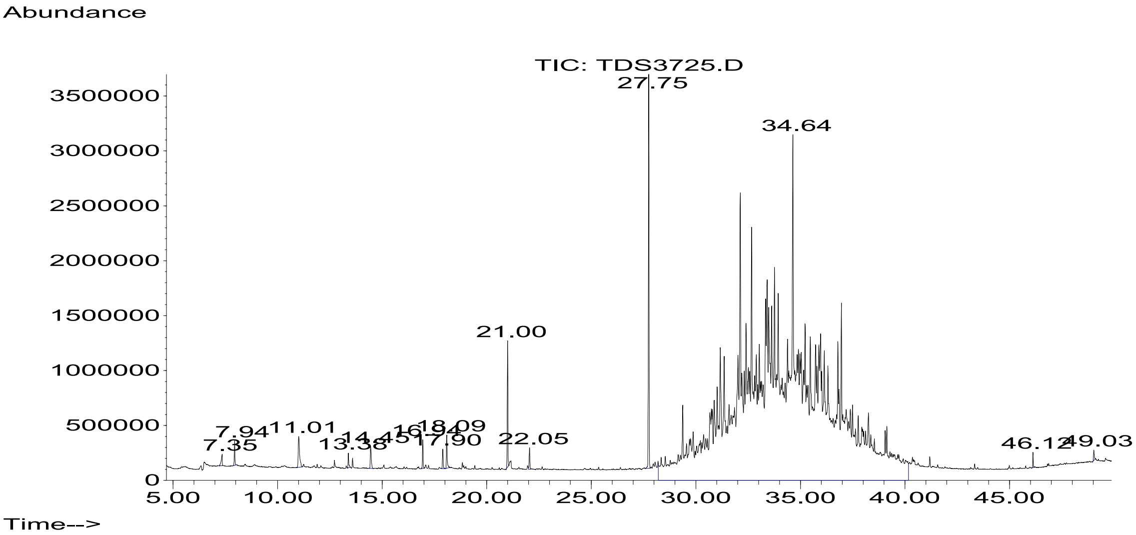


Figure 3353-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

3477 Silicone sealant 1, manufacturer 16 (acidic cross linking)

Table 3477-1: Concentrations of organic compounds analysed from a silicone sealant; 20-litre chamber, q = 44 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	6.04	4800	260	51	n.d.
Benzene	71-43-2	6.34	19	32	8	n.d.
Hexanal	66-25-1	9.6	1	3	n.d.	n.d.
Hexamethylcyclotrisiloxane	541-05-09	11.06	550	74	13	n.d.
Benzaldehyde	100-52-7	14.48	8	20	4	n.d.
Phenol	108-95-2	15.42	3	10	2	2
n-decane	124-18-5	16.81	280	24	n.d.	n.d.
Octamethylcyclotetrasiloxane	55-67-2	16.98	290	110	3	2
2-ethyl-1-hexanol	104-76-7	17.25	10	4	n.d.	n.d.
2,6-dimethyl-nonane	17302-28-2	17.63	110	14	n.d.	n.d.
Butylcyclohexane	1678-93-9	17.81	140	10	n.d.	n.d.
Acetophenone	98-86-2	17.92	7	16	3	n.d.
Naphthalene, dehydro-,trans-	493-02-7	18.5	230	18	n.d.	n.d.
1-octanol	111-87-5	18.53	30	7	n.d.	n.d.
Nonanal	124-19-6	19.46	19	5	3	n.d.
C7-C16 hydrocarbons		20	740	340	4	n.d.
Trans-2-methyl decalone*	1000152-47-3	20.33	160	34	1	n.d.
Decamethylcyclopentasiloxane	541-02-6	22.1	650	740	204	2
Decanal	112-31-2	22.69	7	9	3	n.d.
1-dodecene	112-41-4	22.83	22	14	n.d.	n.d.
n-dodecane	112-40-3	23.2	420	390	66	n.d.
Undecane, 2,6-dimethyl-	17301-23-4	23.75	86	52	15	n.d.
Heptylcyclohexane	5617-41-4	24.45	32	24	5	n.d.
Unknown VOC*		24.68	58	30	13	1
Dodecamethylpentasiloxane	141-63-9	25.1	1	0	n.d.	n.d.
n-tridecane	629-50-5	26.41	13	16	7	1
Cluster of alkanes		18 - 26	9790	4592	595	n.d.
Dodecamethylcyclohexasiloxane	540-97-6	27.79	790	680	557	309
n-tetradecane		29.4	2	4	3	1
n-pentadecane		32.13	0	0	0	1
Tetramethylcycloheptasiloxane	107-50-6	32.67	110	100	126	93
n-hexadecane	544-76-3	34.64	3	5	4	3
TVOC			19000	7600	1690	420

* Generalised name, no exact specification possible

Table 3477-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample		Silicone sealant 3356			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3]		Day 28 [mg/m^3]	
		measured val.	requirement	measured val.	requirement
[A]	TVOC (C_6 - C_{16})	7.625	<= 10	0.409	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		0.00	<= 1
[D]	Σ VOC without LCI	no requirement		0.404 !!	<= 0.1
[E]	Σ carcinogens	0.026 !!	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.		addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H]	Σ VOC with LCI	1.100	addit. inform.	0	addit. inform.

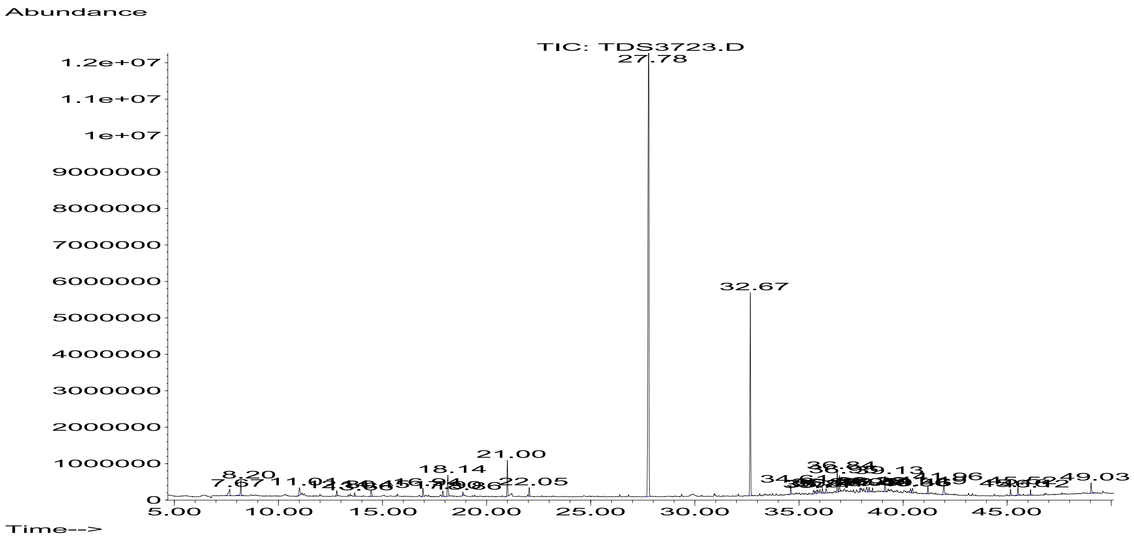


Figure 3477-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

3478 Silicone sealant, manufacturer 17 (neutrally cross linking)

Table 3478-1: Concentrations of organic compounds analysed from a silicone sealant; 20-litre chamber, q = 83 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
1-Propanol	71-23-8	5.59	90	52	2	n.d.
Dimethoxydimethylsiloxane	001112-39-6	6.86	227	n.d.	n.d.	n.d.
Acetic acid	64-19-7	7.08	n.d.	n.d.	n.d.	n.d.
Trimethoxyvinylsiloxane	2768-02-7	10.58	n.d.	n.d.	n.d.	n.d.
Diethoxydimethylsiloxane	78-62-6	10.75	49	2	n.d.	n.d.
Hexamethylcyclotrisiloxane	541-05-9	11.81	97	26	23	20
Unknown VOC- (siloxane)*		13.02	8	n.d.	n.d.	n.d.
Unknown VOC- siloxane*		15.39	24	n.d.	n.d.	n.d.
Unknown VOC- siloxane*		17.5	3	n.d.	n.d.	n.d.
Octamethylcyclotetrasiloxane	556-67-2	17.83	200	170	49	4
Phenol	108-95-2	16.2	1	n.d.	n.d.	n.d.
Ethylhexanol	104-76-7	18.12	38	18	n.d.	n.d.
Unknown VOC- siloxane*		19.74	22	0	n.d.	n.d.
Decamethylcyclopentasiloxane	541-02-6	23.13	230	210	95	14
Silicic acid (H_4SiO_4) tetrapropylester**	682-01-9	26.9	16	n.d.	n.d.	n.d.
Dodecamethylcyclohexasiloxane	540-97-6	28.74	110	110	69	48
Tetradecamethylcycloheptasiloxane	107-50-6	33.56	33	25	28	26
TVOC			1200	620	270	110

* Generalised name, no exact specification possible
** Suggestion of the mass sprectra library

Table 3478-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample	Silicone sealant 3478			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.565	<= 10	0.112	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.108 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.052	addit. inform.		addit. inform.
[G] TVOC (C_6 – C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.190	addit. inform.	0	addit. inform.

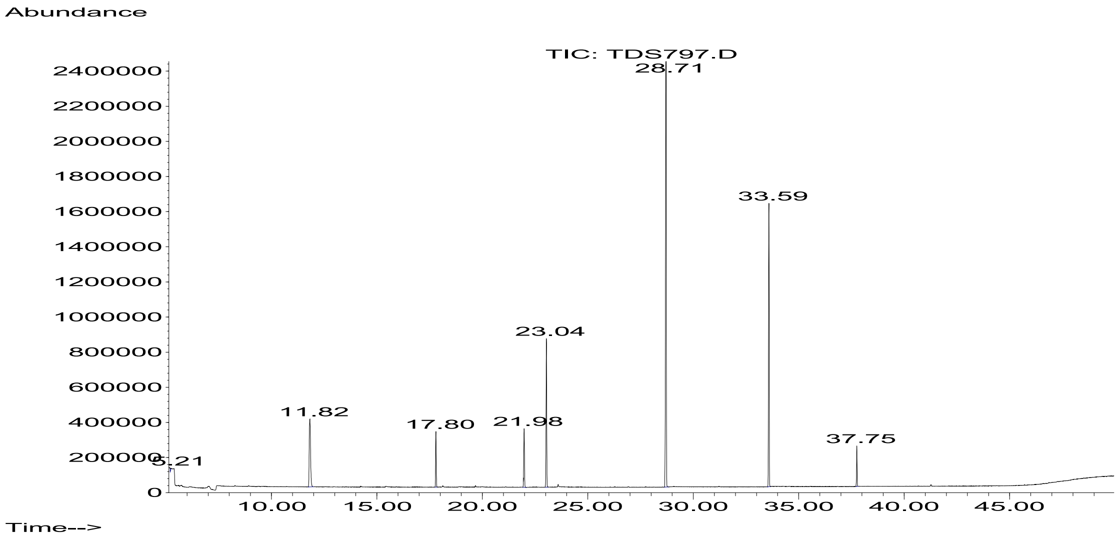


Figure 3478-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

Table 3478-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	14.8	3.0	-2.1	1.4
3	8	12.0	3.9	-2.4	1.0
10	8	9.0	5.9	-1.3	1.7
28	9	13.1	3.4	-2.7	1.5

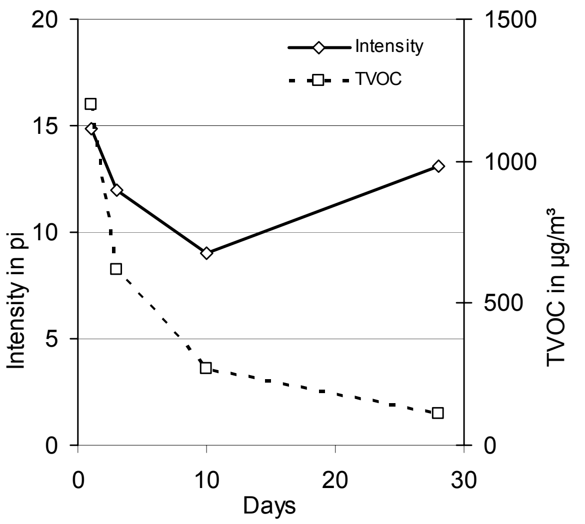


Figure 3478-2: Intensity and TVOC

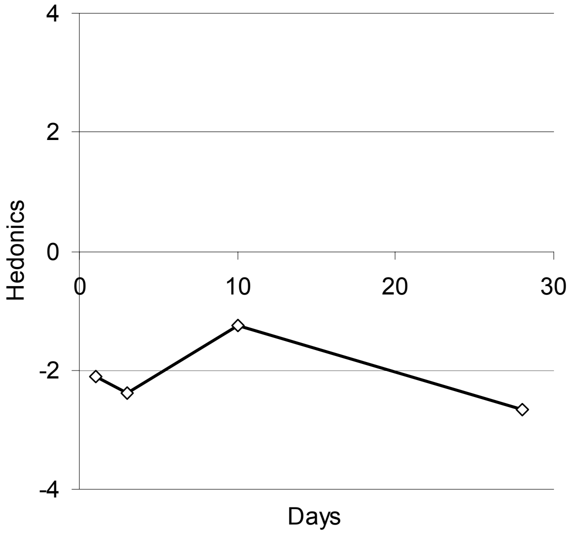


Figure 3478-3: Hedonics

3707 Silicone sealant 2, manufacturer 16 (acidic cross linking)

Table 3707-1: Concentrations of organic compounds analysed from a silicone sealant; 20-litre chamber, q = 44 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 8 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	6.96	16000	4100	80	n.d.
Hexamethylcyclotrisiloxane	541-05-09	10.78	610	200	25	n.d.
Decane	124-18-5	16.54	700	110	2	n.d.
Octamethylcyclotetrasiloxane	556-67-2	16.72	390	130	17	n.d.
Butylcyclohexane	1678-93-9	17.51	190	48	n.d.	n.d.
Trans-decahydronaphthalene	493-02-7	18.18	200	40	n.d.	n.d.
5-methyldecane	13151-35-4	18.47	90	32	n.d.	n.d.
4-methyldecane	2847-72-5	18.58	120	41	2	n.d.
2-methyldecane	6975-98-0	18.7	130	48	2	n.d.
3-methyldecane	13151-34-3	18.9	140	50	3	n.d.
Undecane	1120-21-4	19.77	1200	620	49	n.d.
Trans-2-methyldecalin	1000152-47-3	20.08	130	46	3	n.d.
2-methyldecahydronaphthalene	2958-76-1	20.48	130	61	6	n.d.
3.7-dimethyldecane	17312-54-8	20.6	102	60	9	n.d.
Hexylcyclopentane	4457-00-5	20.8	50	28	3	n.d.
6-methylundecane	17302-33-9	21.42	56	44	9	n.d.
5-methylundecane	1632-70-8	21.45	72	36	8	n.d.
4-methylundecane	2980-69-0	21.57	80	52	11	n.d.
2-methylundecane	7045-71-8	21.71	90	64	16	n.d.
Decamethylcyclopentasiloxane	541-02-6	21.83	560	450	190	3
3-methylundecane	1002-43-3	21.92	76	56	14	n.d.
1-dodecane	112-40-3	22.93	490	350	113	n.d.
2.6-dimethylundecane	17301-23-4	23.42	72	50	20	n.d.
Hexylcyclohexane	4292-75-5	24.12	20	12	4	n.d.
Unknown VOC*	mz 121/233/177/79	24.37	140	100	46	5
Tridecane	629-50-5	26.1	9	16	9	n.d.
Dodecamethylcyclohexasiloxane	540-97-6	27.5	600	940	600	260
Tetradecane	629-59-4	29.09	1	6	2	n.d.
Pentadecane		31.82	2	3	3	2
Tetradecamethylcycloheptasiloxane		32.4	130	130	120	90
Hexadecane	544-76-3	34.35	5	8	9	8
Cluster of alkanes		11.5-26.5	17000	7900	1200	3
TVOC			40000	15800	2540	370

* Generalised name, no exact specification possible

Table 3707-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a silicone sealant.

Sample		Silicone sealant 3707			
AgBB Overview of results Version: 8-f-2004		Day 3 [mg/m^3] measured val.	requirement	Day 28 [mg/m^3] measured val.	requirement
[A]	TVOC (C_6 - C_{16})	7.919	<= 10	0.369	<= 1
[B]	Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C]	R (dimensionless)	no requirement		0.00	<= 1
[D]	Σ VOC without LCI	no requirement		0.359 !!	<= 0.1
[E]	Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F]	VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G]	TVOC (C_6 – C_{16}) given as toluene equivalent	10.303	key in the value manually!	0.493	key in the value manually!
[H]	Σ VOC with LCI	5.233	addit. inform.	8	addit. inform.

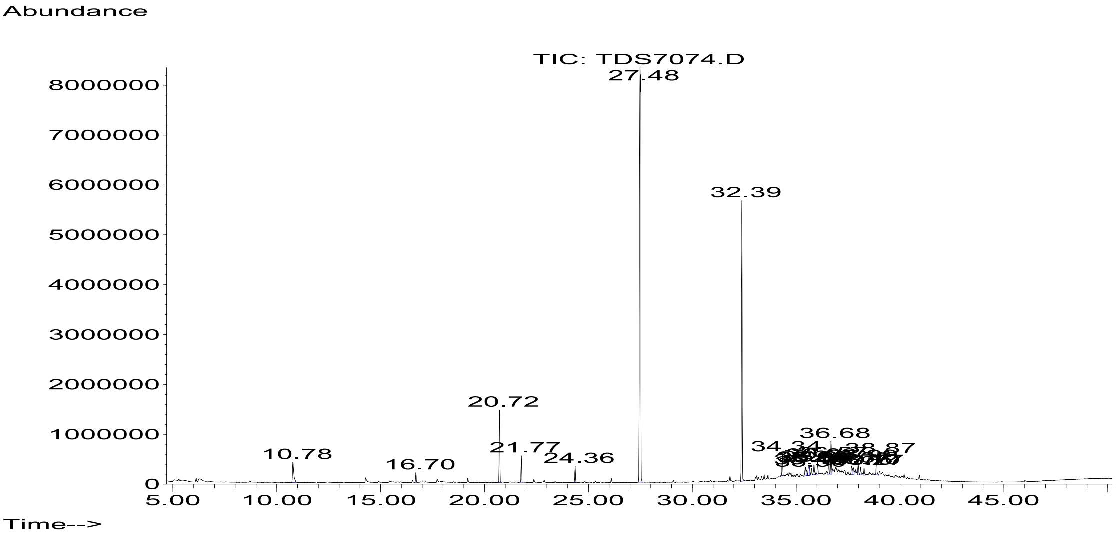


Figure 3707-1: GC/MS chromatogram on day 28 of emission testing on a silicone sealant.

Synthetic resin premixed plaster

3342 SR plaster, manufacturer 4

Table 3342-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, q = 0.53 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m³]**	**Day 3 [µg/m³]**	**Day 10 [µg/m³]**	**Day 28 [µg/m³]**
Butanol	71-36-3	7.91	1300	460	65	24
Ethylbenzene	100-41-4	13.99	26	20	2	1
p-xylene	106-42-3	14.32	32	26	4	2
Propanoic acid -2-methylpropyl ester	540-42-1	15.00	100	95	4	1
Propanoic acid butyl ester	590-01-2	15.54	22	16	n.d.	n.d.
1-methylethylbenzene	98-82-8	16.36	39	37	2	1
Benzaldehyde	100-52-7	17.03	120	48	1	0
Propylbenzene	103-65-1	15.54	33	37	n.d.	n.d.
Benzonitrile	100-47-0	17.68	38	19	3	1
Butanoic acid hexyl ester	2639-63-6	18.75	21	16	3	1
1-methylpropylbenzene	135-98-8	18.44	14	19	2	1
Acetophenone	98-86-2	20.86	45	16	3	1
2-methyl-(2H)-isothiazolone (MIT)	2682-20-4	24.04	35	80	140	87
Formaldehyde DNPH	50-00-0	3.8	21	13	2	2
Acetaldehyde DNPH	75-07-0	6.1	7	4	1	4
TVOC *			1900	880	230	110

* Without DNPH values

Table 3342-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	synthetic resin plaster 3342			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.878	<= 10	0.113	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.01	<= 1
[D] Σ VOC without LCI	no requirement		0.087	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.018	addit. inform.	0.006	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.585	addit. inform.	0.024	addit. inform.

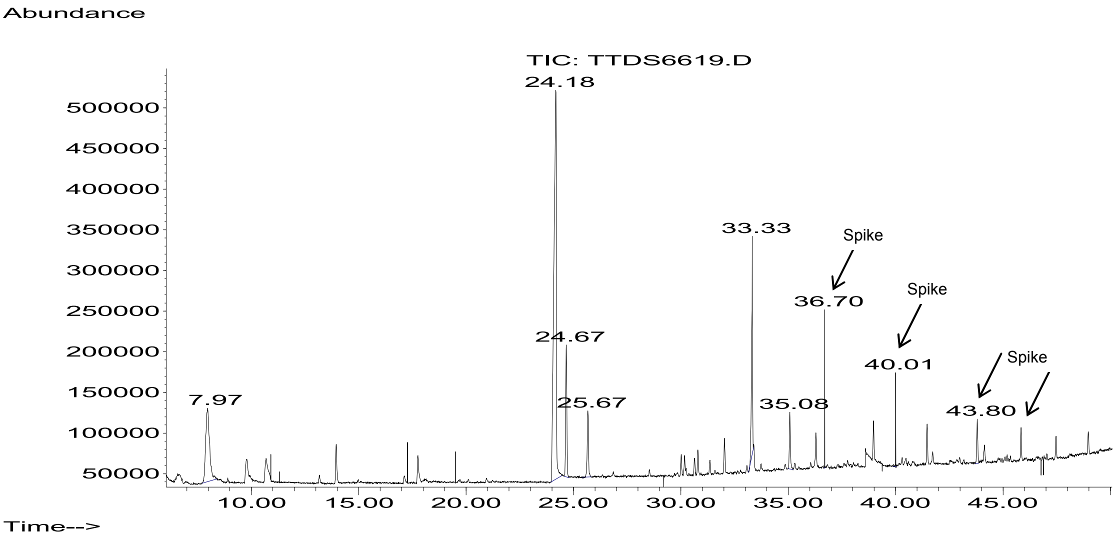


Figure 3342-1: GC/MS chromatogram on day 28 of emission testing on a synthetic resin premixed plaster.

Table 3342-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	n.m.*	19.0	n.m.	n.m.	n.m.
3	n.m.	10.0	n.m.	n.m.	n.m.
10	9	6.7	3.8	-1.2	0.9
28	11	14.8	2.3	n.m.	n.m.

* n.m.: not measured

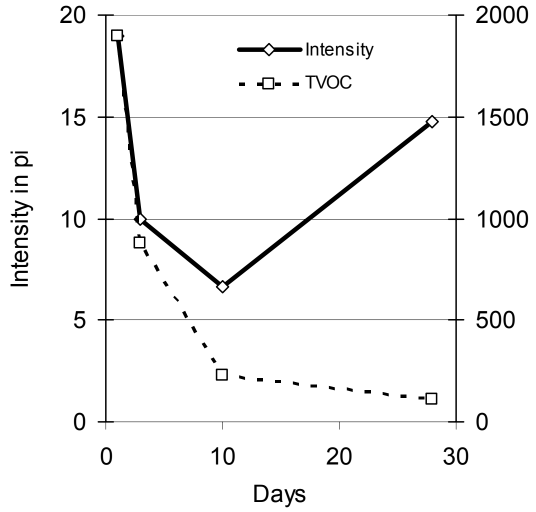


Figure 3342-2: Intensity and TVOC

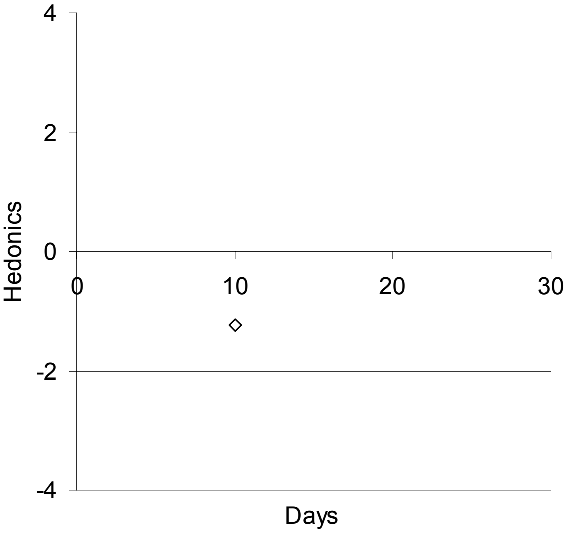


Figure 3342-3: Hedonics

3345 SR plaster 1, manufacturer 5

Table 3345-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, $q = 0.53\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Propylene glycol	57-55-6	10.35	n.d.	n.d.	275	29
Di-tert.-butylperoxide	110-05-4	10.56	81	18	n.d.	n.d.
Ethylbenzene	100-41-4	14.05	300	40	n.d.	n.d.
p-xylene	106-42-3	14.38	21	7	n.d.	n.d.
Styrene	100-42-5	14.99	61	10	n.d.	n.d.
1.3-dimethylbenzene	108-38-3	15.18	3600	370	220	n.d.
1-methylethylbenzene	98-82-8	16.39	440	121	3	n.d.
1-butoxy-2-propanol	57018-52-7	16.90	1350	231	9	n.d.
Benzaldehyde	100-52-7	17.07	60	18	12	18
n-propylbenzene	103-65-1	17.46	204	56	n.d.	n.d.
Octamethylcyclotetrasiloxane	556-67-2	19.67	280	310	58	17
2-ethyl-1-hexanol	104-76-7	20.14	850	460	120	23
Acetic acid-2-ethylhexylester	103-09-3	24.45	350	39	60	5
Glycol*		28.34	270000	210000	120000	34000
n-tridecane	629-50-5	30.36	64	26	1290	17
n-tetradecane	629-59-4	33.46	200	280	200	86
2-cyclohexyloctane	2883-05-8	34.85	340	450	350	180
n-pentadecane	629-62-9	36.11	200	240	230	160
n-hexadecane	544-76-3	38.99	170	190	210	190
n-heptadecane	629-78-7	41.43	80	84	100	110
Eicosan	112-95-8	45.77	0	33	48	77
Formaldehyde DNPH	50-00-0	3.8	1400	320	170	160
TVOC**			280000	210000	120000	35000

* Generalised name, no exact specification possible
** Without DNPH values

Table 3345-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	synthetic resin plaster 3345			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	214.018	<= 10	34.492 !!	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0.189 !!	<= 0.1
[C] R (dimensionless)	no requirement		0.34	<= 1
[D] Σ VOC without LCI	no requirement		33.947 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.320	addit. inform.	0.160	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	2.368	addit. inform.	0.545	addit. inform.

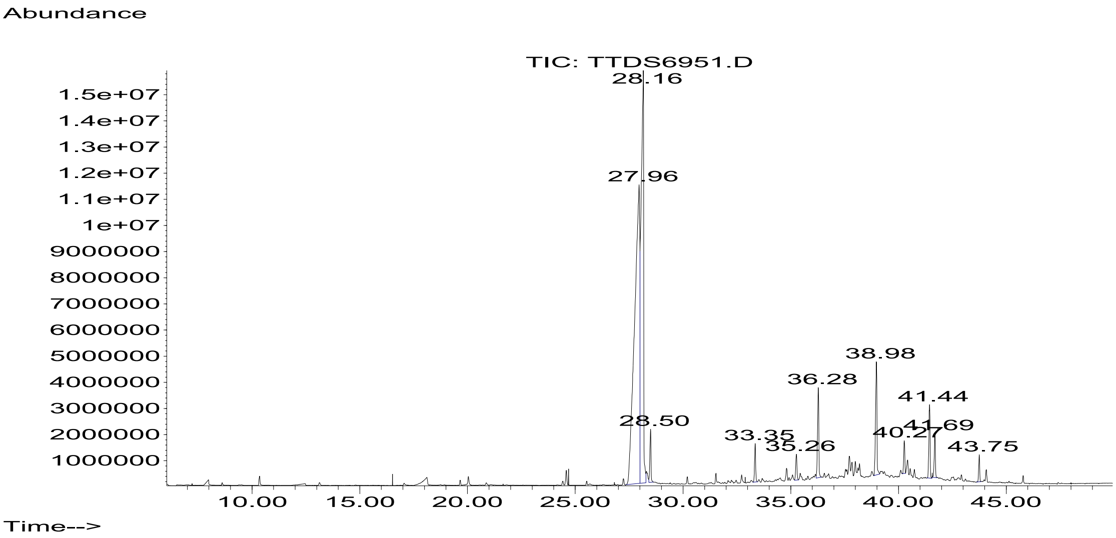


Figure 3345-1: GC/MS chromatogram on day 28 of emission testing on a synthetic resin premixed plaster.

Table 3345-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	27.9	6.0	-4.0	0.0
3	9	32.7	7.6	-4.0	0.0
10	13	11.1	8.9	-3.6	1.0
28	8	20.9	3.3	-4.0	0.0

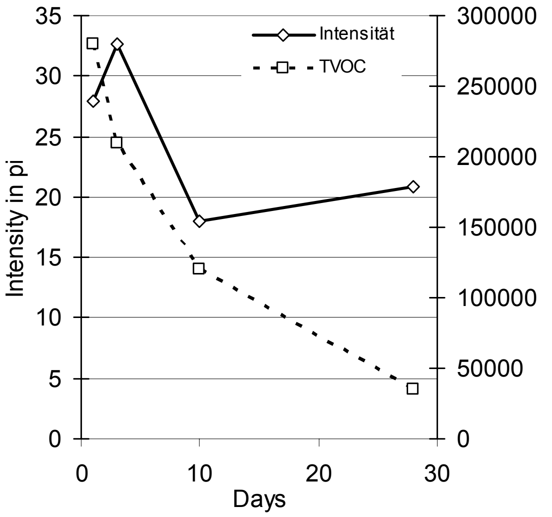


Figure 3345-2: Intensity and TVOC

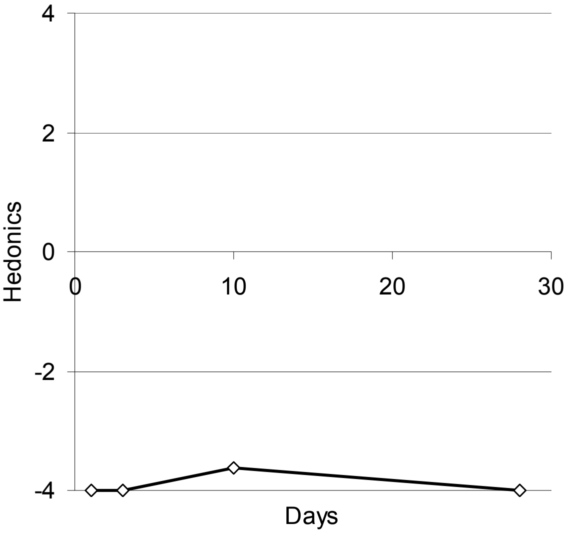


Figure 3345-3: Hedonic

3357 SR plaster, manufacturer 8

Table 3357-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, q = 0.53 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
1-butanol	71-36-3	7.16	36	68	13	2
Hexamethylcyclotrisiloxane	541-05-9	11.81	140	250	4	7
Benzaldehyde	100-52-7	15.37	8	9	1	n.d.
Octamethylcyclotetrasiloxane	556-67-2	17.83	28	37	1	1
Phenol	108-95-2	16.2	16	3	1	n.d.
2-ethyl-1-hexanol	104-76-7	18.12	7	2	2	n.d.
Acetophenone	98-86-2	19.74	8	7	1	n.d.
Nonanal	124-19-6	20.39	4	2	1	n.d.
Decamethylcyclopentasiloxane	541-02-6	23.13	12	10	n.d.	n.d.
Siloxane		28.74	14	9	n.d.	n.d.
Propanoic acid ......ester*		29.08	1	1	n.d.	n.d.
Teatradecane	629-59-4	30.33	7	2	n.d.	n.d.
1-dodecene	112-41-4	31.92	1	n.d.	1	n.d.
Tetrabutylammonium t-butylphosphite ???*		32.75	290	17	22	17
Tetradecamethylcycloheptasiloxane	107-50-6	33.56	7	5	n.d.	n.d.
TVOC			590	420	46	27

* Generalised name, no exact specification possible
** Suggestion of the mass sprectra library

Table 3357-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	Synthetic resin plaster 3357			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.412	<= 10	0.024	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.024	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.005	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.121	addit. inform.	0	addit. inform.

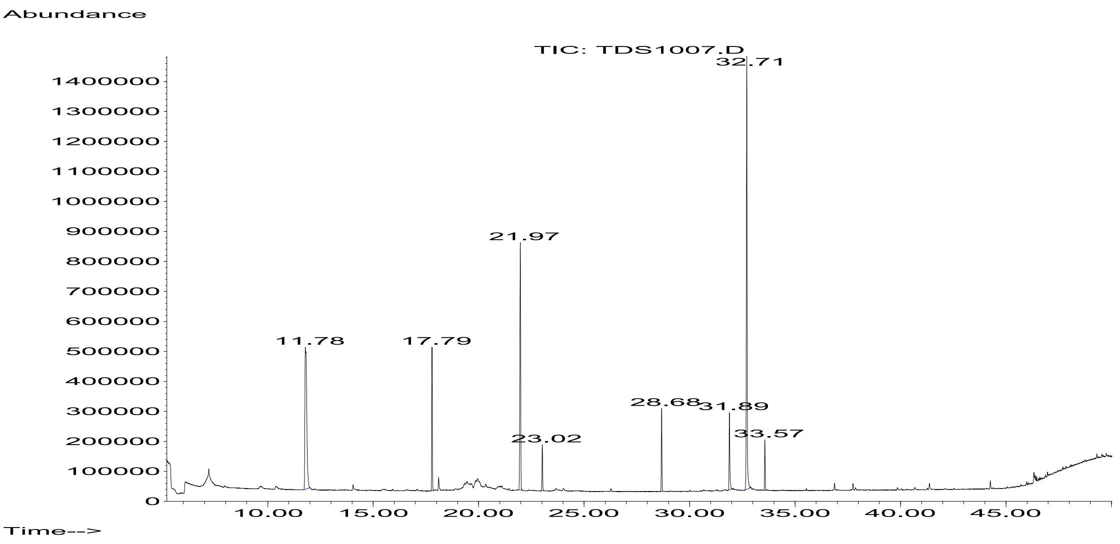
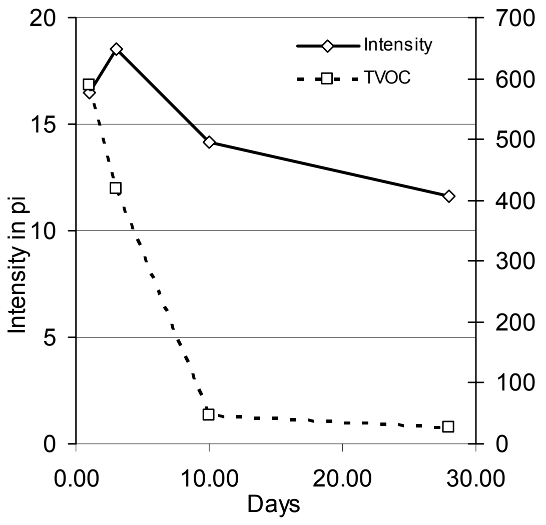


Figure 3357-1: GC/MS chromatogram on day 28 of emission testing on a synthetic resin premixed plaster.

Table 3357-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	11	16.5	5.3	-3.0	1.0
3	10	18.5	5.1	-3.4	0.8
10	11	14.2	3.5	-3.1	0.8
28	10	11.6	3.7	-2.4	1.0



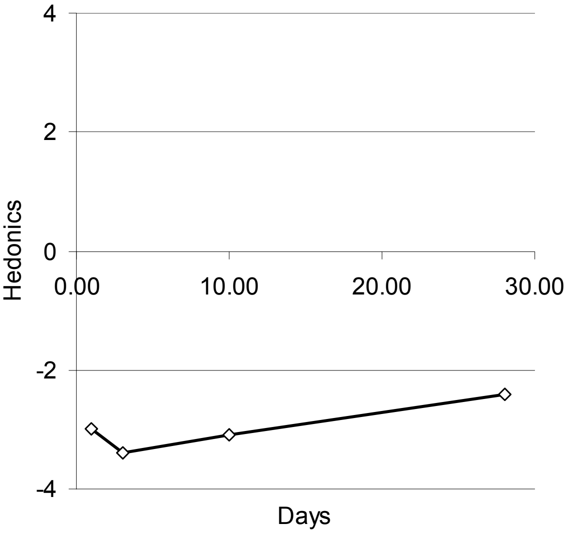


Figure 3357-2: Intensity and TVOC

Figure 3357-3: Hedonics

3487 SR plaster 2, manufacturer 5

Table 3487-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, q = 0.53 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Benzene	71-43-2	6.57	9	13	20	n.d.
1-butanol	71-36-3	6.56	6800	150	n.d.	n.d.
Toluene	108-88-3	8.56	220	110	5	n.d.
Propylene glycol	57-55-6	8.65	n.d.	n.d.	1100	120
Ethylbenzene	100-41-4	11.47	270	270	5	n.d.
p-xylene	106-42-3	11.77	770	560	9	n.d.
o-xylene	95-47-6	14.22	42.5	170	9	n.d.
n-decane	124-18-5	16.76	2200	3600	2300	66
n-propylbenzene	103-65-1	14.66	680	660	110	1
Naphthalene	91-20-3	21.6	33	21	16	1
Cluster of alkanes		8.50- 22.0	33000	31000	32000	2000
Unknown VOC*		23.34				162
Unknown VOC*		23.37	120	81	54	22
Propanoic acid -2-methyl-, 2.2-dimethyl-1-(2-hydroxy-1-methylethyl)propylester**	074367-33-2*	26.9-28.9	16000	14000	14000	2900
1-dodecanol	000112-53-8	30.6	20	19	26	7
TXIB	6846-50-0	33.79	150	110	92	29
Formaldehyde DNPH	50-00-0	3.8	48	57	16	15
Propanal DNPH	123-38-6	12.7	21	10	5	8
TVOC***			60000	51000	49000	5400

* Generalised name, no exact specification possible
** Suggestion of the mass sprectra library
*** Without DNPH values

Table 3487-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	synthetic resin plaster 3487			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3] measured val.	requirement	Day 28 [mg/m^3] measured val.	requirement
[A] TVOC (C_6 - C_{16})	52.686 !!	<= 10	5.345 !!	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.48	<= 1
[D] Σ VOC without LCI	no requirement		3.137 !!	<= 0.1
[E] Σ carcinogens	0.011 !!	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.057	addit. inform.	0.008	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	36.932	addit. inform.	2.208	addit. inform.

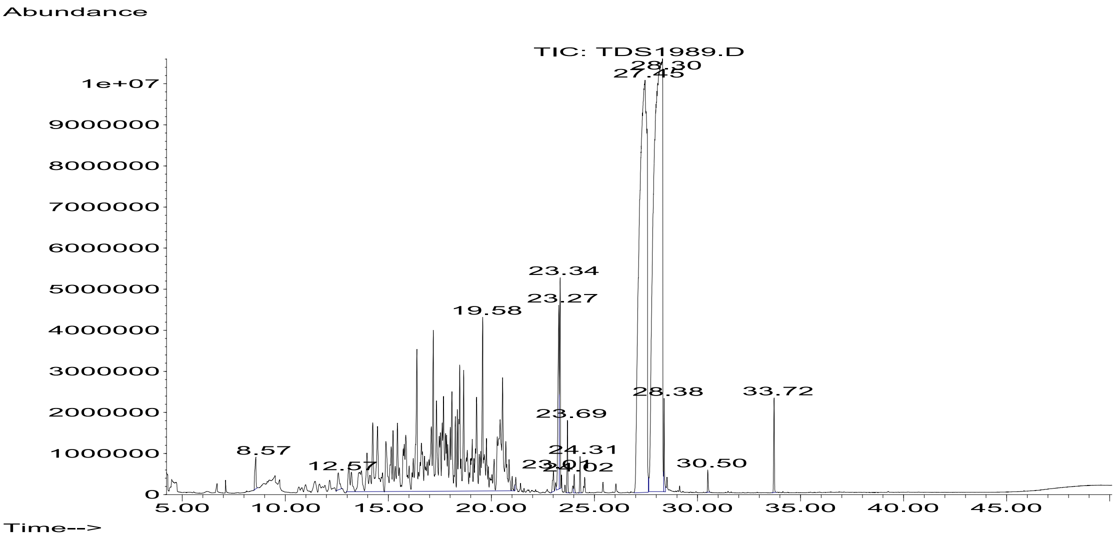


Figure 3487-1: GC/MS chromatogram on day 28 of emission testing on a synthetic resin premixed plaster.

3614 SR plaster, manufacturer 22

Table 3614-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, q = 0.53 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	7.21	n.d.	80	150	18
3(2H)-isothiazolone, 2-methyl-	2682-20-4	20.55	n.d.	260	590	210
Dipropylene glycol-m-n-butyl ether*	35884-42-5	23.88	260	320	68	15
Dipropylene glycol-m-n-butyl ether*	35884-42-6	24.03	240	310	78	20
Dodecanoic acid, methyl ester*	111-82-0	32.23	10	7	12	5
Formaldehyde DNPH	50-00-0	3.8	5	4	n.d.	n.d.
Acetaldehyde DNPH	75-07-0	6.1	15	8	n.d.	n.d.
TVOC **			510	980	900	270
TVOC given as toluene equivalent			680	900	450	250

* Suggestion of the mass sprectra library
** Without DNPH values

Table 3614-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	synthetic resin plaster 3614			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.982	<= 10	0.268	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.07	<= 1
[D] Σ VOC without LCI	no requirement		0.215 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.012	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.898	key in the value manually!	0.250	key in the value manually!
[H] Σ VOC with LCI	0.713	addit. inform.	0.053	addit. inform.

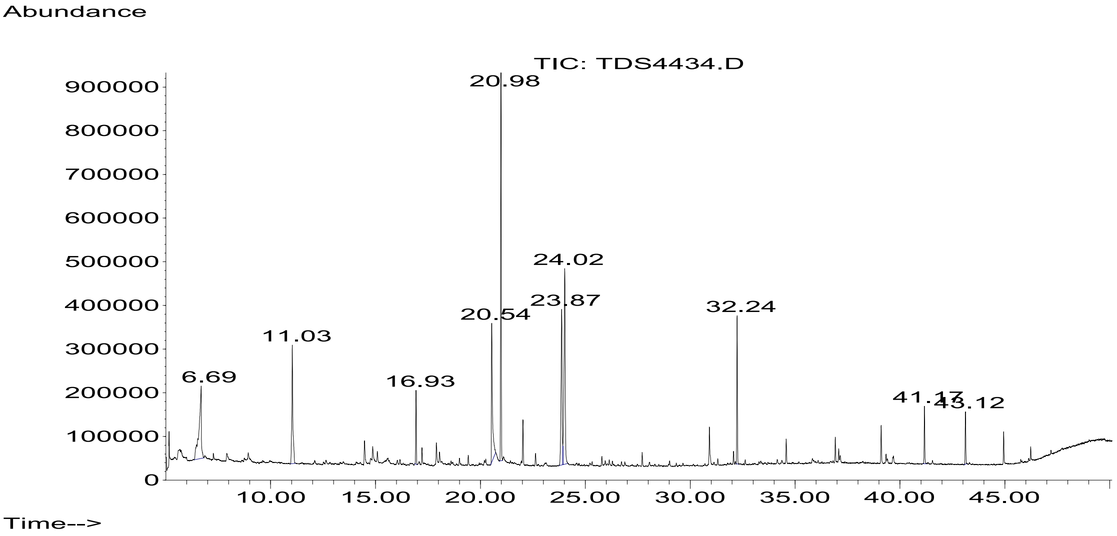


Figure 3614-1: GC/MS chromatogram on day 28 of emission testing on a synthetic resin premixed plaster.

Table 3614-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	7	11.9	1.9	-1.3	1.6
3	9	12.9	2.3	-2.6	1.1
10	7	11.3	2.0	-1.1	0.5
28	9	11.9	1.0	-1.7	0.6

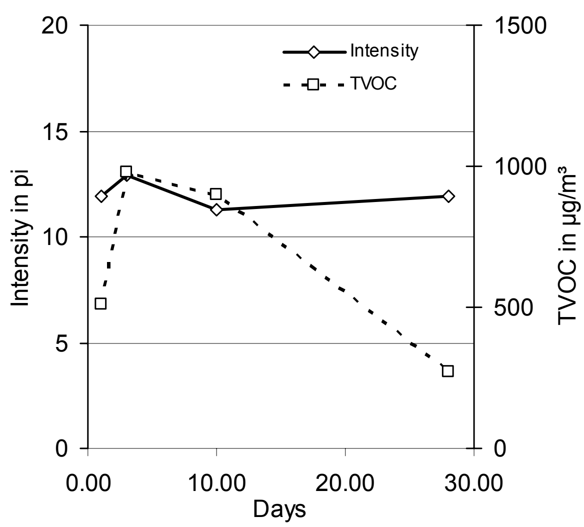


Figure 3614-2: Intensity and TVOC

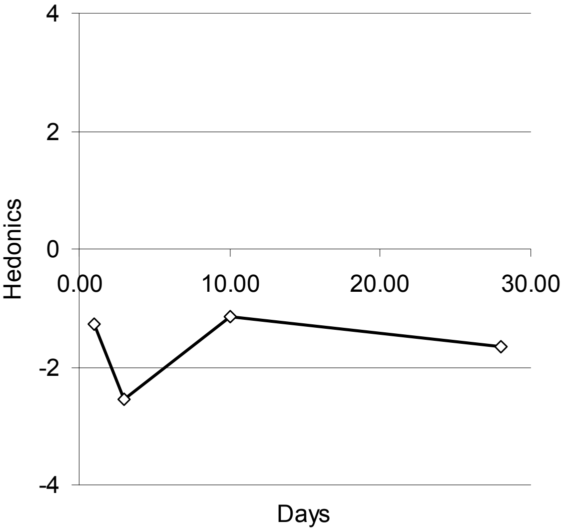


Figure 3614-3: Hedonics

3623 SR plaster 3, manufacturer 5

Table 3623-1: Concentrations of organic compounds analysed from a synthetic resin premixed plaster; 20-litre chamber, q = 0.53 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m^3]**	**Day 3 [µg/m^3]**	**Day 10 [µg/m^3]**	**Day 28 [µg/m^3]**
Acetic acid	64-19-7	6.87	34	510	210	61
Ethanediol	107-21-1	8.93	0	960	720	140
1.2-propanediol	57-55-6	9.55	54	1800	830	130
Toluene	108-88-3	8.87	3	4	4	n.d.
Acetamide	60-35-5	9.92	n.d.	6	5	n.d.
Acetamide, N,N-dimethyl-	127-19-5	11.65	0	12	2	n.d.
Ethylbenzene	100-41-4	11.74	13	34	1	n.d.
m,p-xylene	108-38-3 106-42-3	12.01	7	11	3	n.d.
o-xylene	95-47-6	12.74	3	7	1	n.d.
Cumene	98-82-8	13.84	4	10	n.d.	n.d.
Benzaldehyde	100-52-7	14.45	94	37	9	n.d.
Propylbenzene	103-65-1	14.82	5	13	0	n.d.
Phenol	108-38-3	15.7	7	5	3	n.d.
Butanoic acid butyl ester	109-21-7	16.06	4	5	n.d.	n.d.
2-(2-ethoxyethoxy)ethanol,	111-90-0	16.29	n.d.	35	15	1
2-ethyl-1-hexanol,	104-76-7	17.21	170	520	240	38
Dipropylene glycol mix*	25265-71-8	17.34	110	1300	1800	710
3(2H)-isothiazolone, 2-methyl- (MIT)	2682-20-4	20.94	n.d.	95	200	75
Acetic acid, 2-ethylhexyl ester	103-09-3	21.11	140	260	110	23
2-(2-butoxyethoxy)-ethanol,	112-34-5	22.03	190	460	350	76
Decamethylcyclopentasiloxane	541-02-6	22.08	2	6	3	1
Unknown VOC**		23.2	26	22	17	6
2-propenoic acid, 6-methylheptyl ester*	54774-91-3	23.6	26	34	22	5
Propanoic acid, 2,2-dimethyl-, 2-ethylhexyl ester*	016387-18-1	24	45	77	39	5
1-dodecanol	112-53-8	30.96	14	16	34	12
Formaldehyde DNPH	50-00-0	3.8	80	47	60	21
Acetaldehyde DNPH	75-07-0	6.1	93	66	10	5
TVOC ***			950	6300	4600	1300

* Suggestion of the mass sprectra library
** Generalised name, no exact specification possible
*** Without DNPH values

Table 3623-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a synthetic resin premixed plaster.

Sample	Synthetic resin plaster 3623			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	6.305	<= 10	1.284 !!	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		2.46 !!	<= 1
[D] Σ VOC without LCI	no requirement		0.103 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.113	addit. inform.	0.026	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	3.847	key in the value manually!	0.891	key in the value manually!
[H] Σ VOC with LCI	5.993	addit. inform.	1.177	addit. inform.

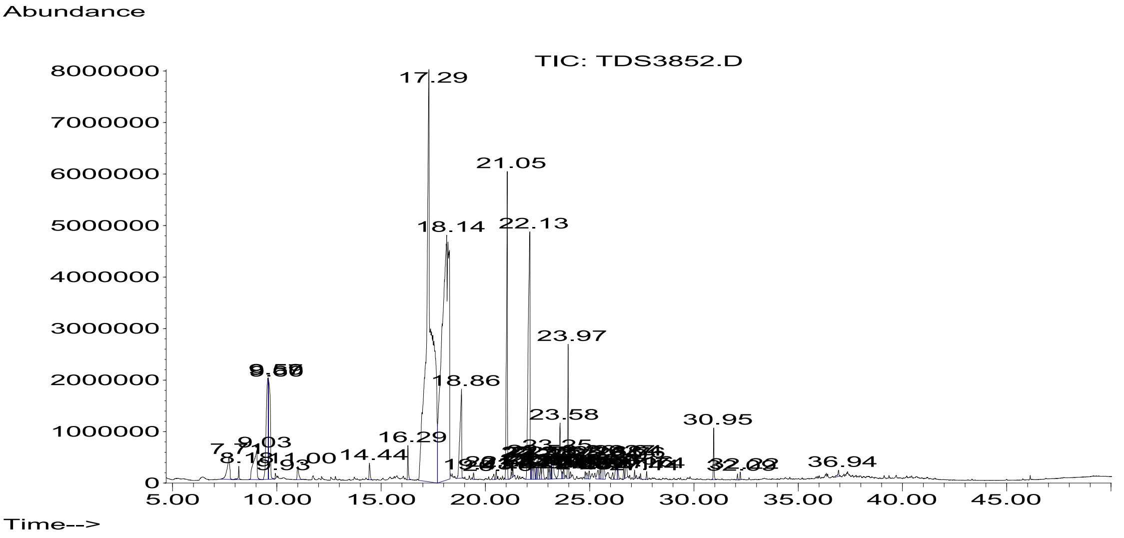


Figure 3623-1: GC/MS chromatogram on the day 10 of emission testing on a synthetic resin premixed plaster.

Table 3623-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	8	21.3	2.7	-3.4	0.6
3	9	19.7	2.9	-2.6	1.3
10	9	15.3	2.1	-2.9	0.6
28	8	14.1	2.1	-1.2	1.2

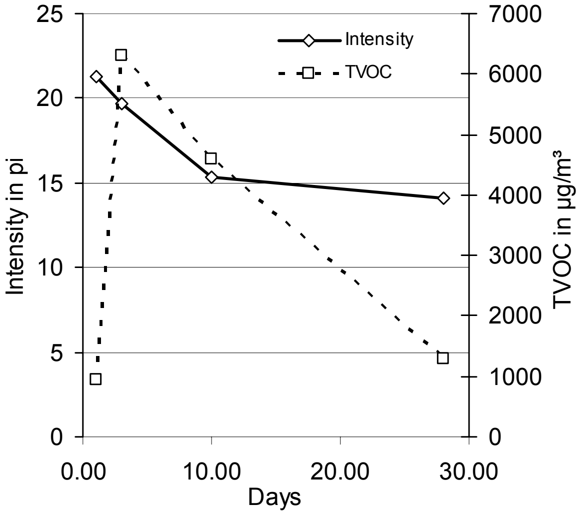


Figure 3623-2: Intensity and TVOC

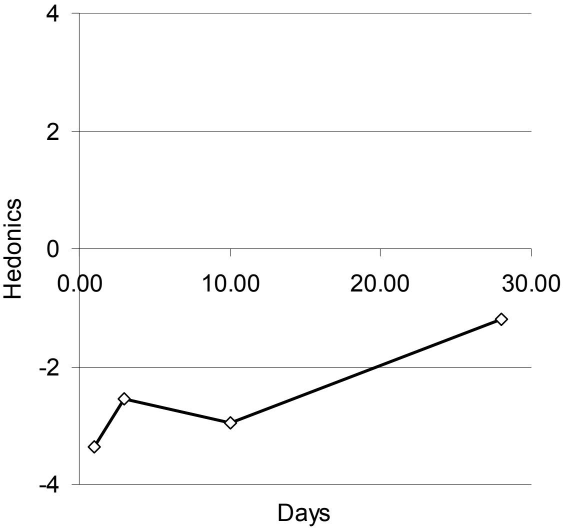


Figure 3623-3: Hedonics

Wood and wood-based products

3382 OSB board 1, manufacturer 9

Table 3382-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Pentanal	110-62-3	8.50	80	59	27	40
Pentanol	71-41-0	10.66	33	48	42	28
Hexanal	66-25-1	11.48	590	330	180	120
Heptanal	111-71-7	15.13	24	16	8	5
Pentanoic acid	109-52-4	15.54	31	27	23	11
α-pinene	80-56-8	17.12	340	97	35	22
Hexanoic acid	142-62-1	18.44	350	170	89	60
β-pinene	127-91-3	18.61	2	1	12	0
Octanal	124-13-0	18.88	23	0	10	8
Δ_3-carene	498-15-7	19.83	220	89	30	22
alpha-terpinene	99-86-5	20.06	360	140	48	35
Limonene	138-86-3	20.42	23	1	3	0
alpha-terpineol	98-55-5	25.95	2	1	0	0
Terpene*	-	23.98	530	300	180	82
Terpene*	-	26.28	24	13	120	5
Terpene*	-	24.75	83	96	63	39
Aromatic compound*	-	20.05	12	33	10	4
Longifolene	475-20-7	33.88	5	3	2	2
Formaldehyde DNPH	50-00-0	3.8	52	48	41	33
Acetaldehyde DNPH	75-07-0	6.1	100	87	57	23
Acetone DNPH	67-64-1	9.9	56	59	57	15
Pentanal DNPH	110-62-3	29.6	61	48	49	31
Hexanal DNPH	66-25-1	31.9	520	350	220	100
Heptanal DNPH	111-71-7	33.5	30	22	14	22
Octanal DNPH	124-13-0	35.1	19	15	12	10
Nonanal DNPH	124-19-6	36.6	12	10	8	8
TVOC **			2700	1400	870	480

* Generalised name, no exact specification possible
** Without DNPH values

Table 3382-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3382			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.355	<= 10	0.445	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.41	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.194	addit. inform.	0.071	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	1.355	addit. inform.	0.445	addit. inform.

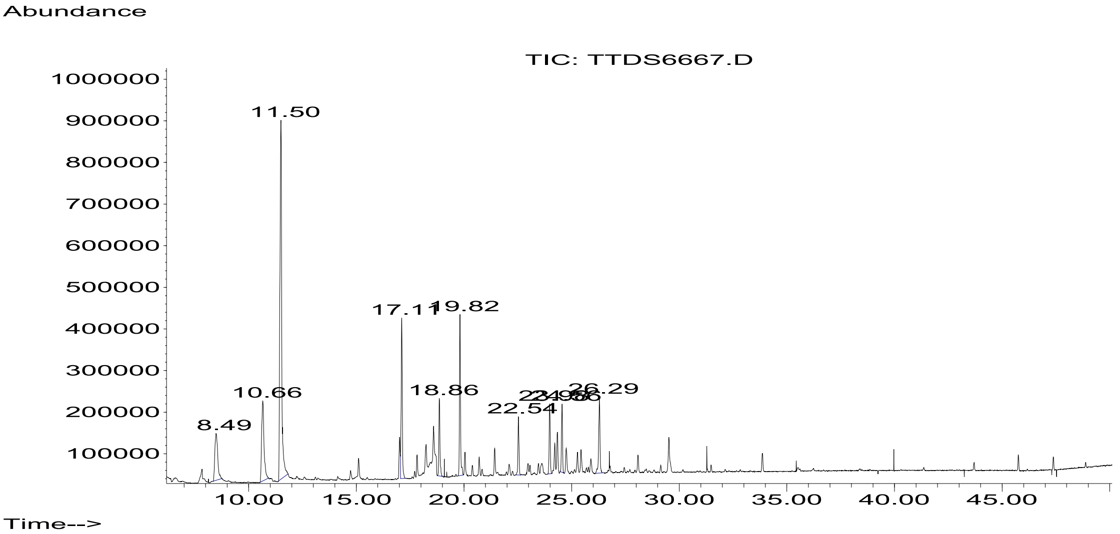


Figure 3382-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3382-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	17.1	1.9	-1.4	2.1
3	11	18.1	3.0	-1.6	1.2
10	9	16.8	6.1	-2.9	1.9
28	10	17.5	2.5	-3.3	1.1

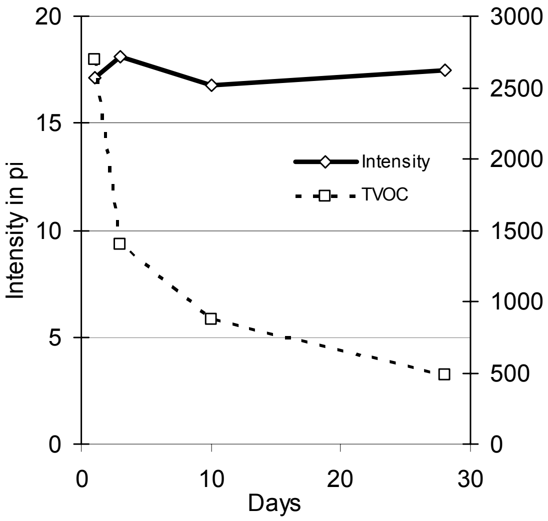


Figure 3382-2: Intensity and TVOC

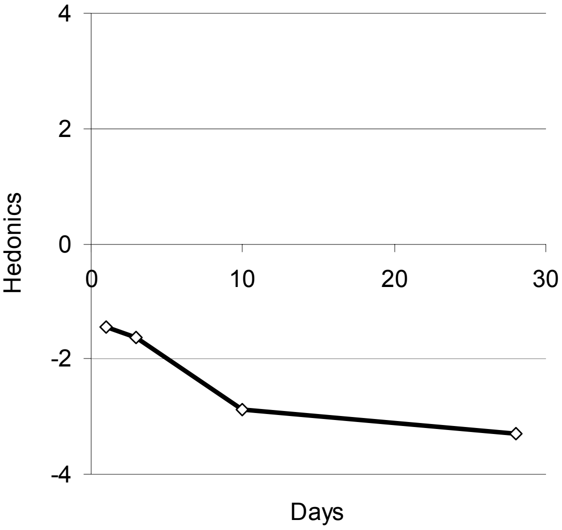


Figure 3382-3: Hedonics

3383 OSB board, manufacturer 10

Table 3383-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [$\mu g/m^3$]	Day 3 [$\mu g/m^3$]	Day 10 [$\mu g/m^3$]	Day 28 [$\mu g/m^3$]
Pentanal	110-62-3	8.50	32	26	13	22
Pentanol	71-41-0	10.66	30	21	17	17
Hexanal	66-25-1	11.48	105	64	37	33
Heptanal	111-71-7	15.13	14	10	6	4
Pentanoic acid	109-52-4	15.54	0	64	31	0
α-pinene	80-56-8	17.12	114	51	28	22
Hexanoic acid	142-62-1	18.44	475	125	50	36
β-pinene	127-91-3	18.61	25	12	5	3
Octanal	124-13-0	18.88	15	10	6	5
Δ_3-carene	498-15-7	19.83	68	40	19	17
Terpene*	-	26.33	32	15	9	7
Terpene*	-	29.56	15	6	4	3
Longifolene	475-20-7	33.88	3	2	1	1
Hexadecane	544-76-3	38.89	1	0	0	3
Formaldehyde DNPH	50-00-0	3.8	30	24	20	19
Acetaldehyde DNPH	75-07-0	6.1	63	46	31	20
Acetone DNPH	67-64-1	9.9	28	27	27	47
Pentanal DNPH	110-62-3	29.6	23	12	12	22
Hexanal DNPH	111-71-7	31.9	100	57	32	35
TVOC **			930	450	230	170

* Generalised name, no exact specification possible
** Without DNPH values

Table 3383-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3383			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3] measured val.	requirement	Day 28 [mg/m^3] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.443	<= 10	0.170	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.17	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.113	addit. inform.	0.092	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.443	addit. inform.	0.170	addit. inform.

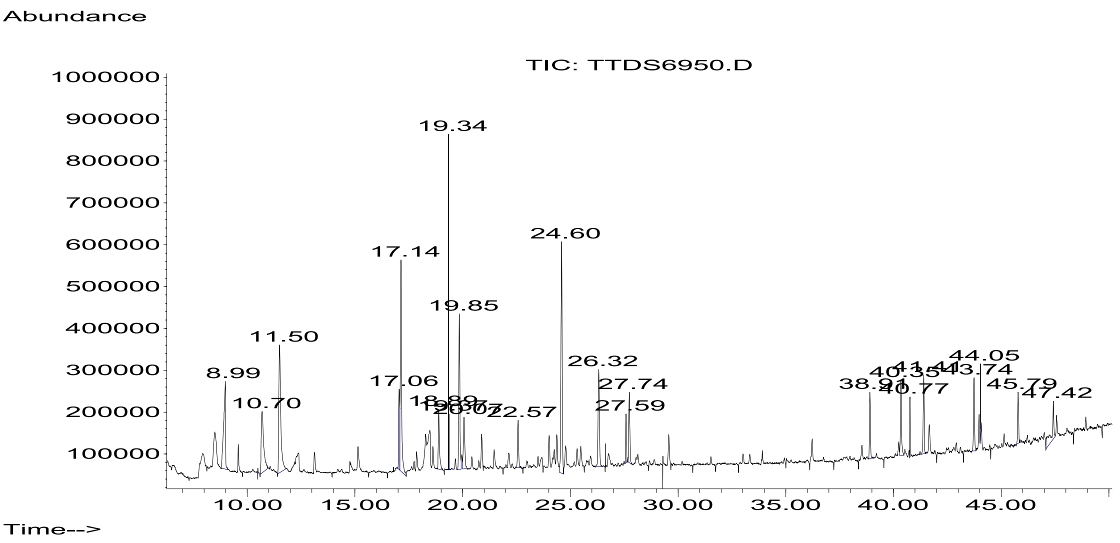


Figure 3383-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3383-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	21.3	4.0	-3.1	1.0
3	9	18.4	1.6	-3.0	1.6
10	13	10.8	8.8	-3.1	1.4
28	8	18.1	4.7	-3.3	0.8

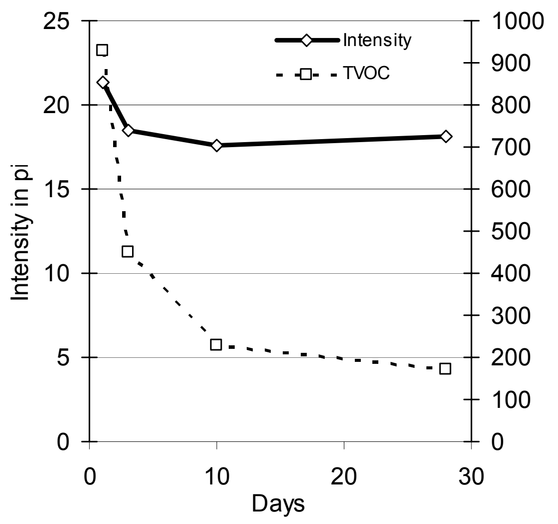


Figure 3383-2: Intensity and TVOC

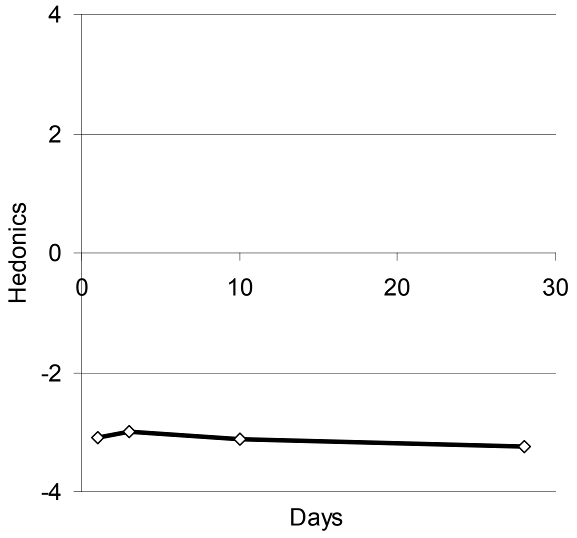


Figure 3383-3: Hedonics

3488 OSB board 2, manufacturer 9

Table 3488-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 $[\mu g/m^3]$	Day 3 $[\mu g/m^3]$	Day 10 $[\mu g/m^3]$	Day 28 $[\mu g/m^3]$	Day 81 $[\mu g/m^3]$
Pentanal	110-62-3	7.66	180	110	110	55	27
1-pentanol	71-41-0	9.64	55	46	44	21	14
Hexanal	66-25-1	10.37	750	510	290	130	67
2-heptanone	110-43-0	13.28	22	12	6	3	2
Pentanoic acid	109-52-4	13.49	59	14	11	n.d.	5
Heptanal	111-71-7	13.62	55	40	24	11	7
α-pinene	80-56-8	15.42	175	81	47	29	24
1-heptanol	111-70-6	16.12	15	12	7	3	2
Benzene, 1-methyl-3-(1-methylethyl)-	535-77-3	16.47	17	10	4	2	1
β-pinene	127-91-3	16.77	41	17	7	3	3
Octanal	124-13-0	17.04	49	40	32	21	n.d.
Hexanoic acid	142-60-1	17.45	510	340	180	68	60
Δ_3-carene	498-15-7	17.89	180	110	64	42	33
Benzene, 1-methyl-4-(1-methylethyl)-[o-Cumol]	99-87-6	18.1	15	13	4	2	1
D-limonene	5989-27-5	18.41	11	6	2	n.d.	1
2-octenal	2548-87-0	18.72	28	20	16	10	4
1-octanol	111-87-5	19.42	12	9	7	4	3
Heptanoic acid	111-14-8	19.72	16	12	4	n.d.	2
Nonanal	124-19-6	20.33	44	34	29	19	14
Terpene*		20.59	3	2	1	n.d.	n.d.
Terpene*		21.49	10	8	5	n.d.	n.d.
Octanoic acid	124-07-2	22.67	16	14	6	n.d.	4
Bicyclo[3.1.1]hept-3-en-2-one, 4.6.6-trimethyl-, (1S)-	1196-01-6	23.61	18	12	9	n.d.	4
Terpene*		26.66	13	8	4	n.d.	3
Longifolene	475-20-7	30.66	2	2	1	1	1
Formaldehyde DNPH	50-00-0	3.8	36	63	103	88	
Acetaldehyde DNPH	75-07-0	6.1	28	40	32	11	
Acetone DNPH	67-64-1	9.9	25	48	73	24	
TVOC **			2290	1480	920	430	280
TVOC Toluene equivalent**			1310	830	680	380	130

* Generalised name, no exact specification possible
** Without DNPH values

Table 3488-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3488			
AgBB Overview of results Version: 8-f-2004	Day 3 $[mg/m^3]$		Day 28 $[mg/m^3]$	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.461	<= 10	0.423	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.98	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.152	addit. inform.		addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	1.461	addit. inform.	0.423	addit. inform.

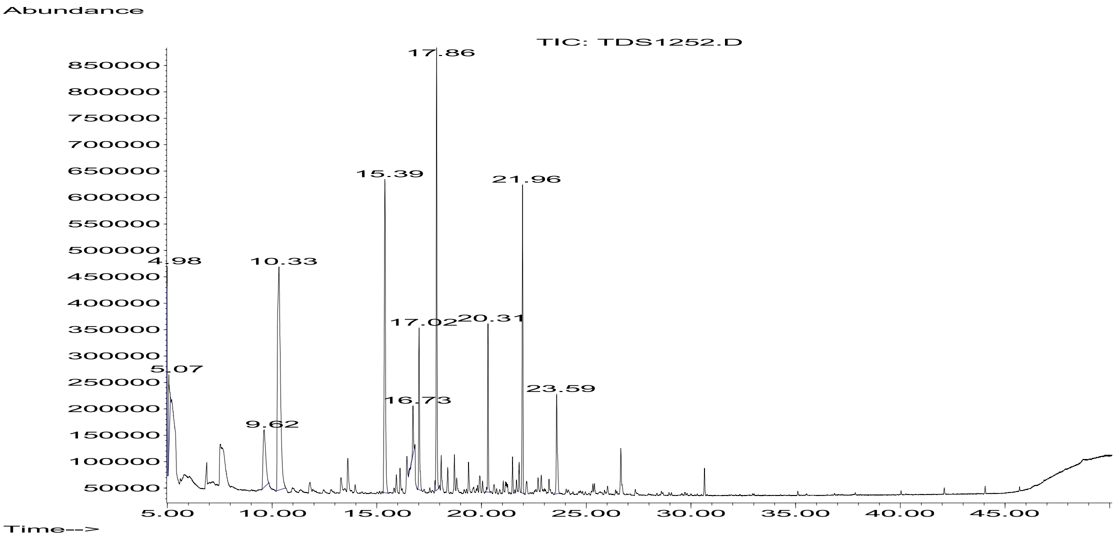


Figure 3488-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3488-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	18.7	3.3	-2.5	1.8
3	8	19.0	3.4	-2.6	2.0
10	8	17.0	2.2	-2.9	0.6
28	10	16.0	1.9	-2.4	1.3

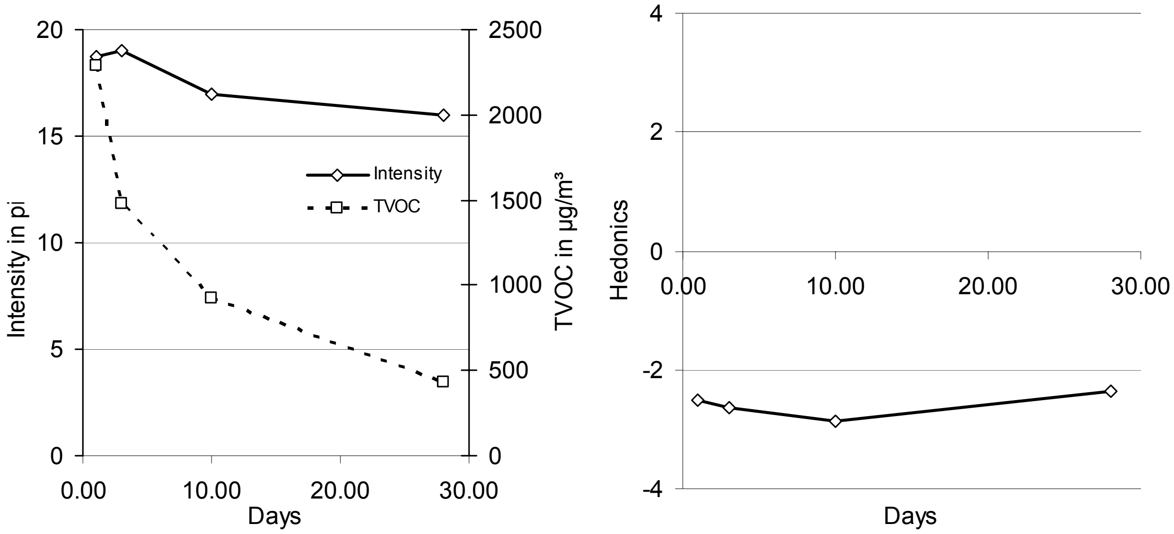


Figure 3488-2: Intensity and TVOC

Figure 3488-3: Hedonics

3543 OSB board 1, manufacturer 13

Table 3543-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	6.57	39	200	67	69
Pentanal	110-62-3	6.57	160	28	79	49
1-pentanol	71-41-0	8.53	98	62	42	29
Hexanal	66-25-1	9.31	400	350	190	100
2-heptanon	110-43-0	12.06	36	24	10	5
n-pentanoic acid	109-52-4	12.34	50	34	16	12
Heptanal	111-71-7	12.43	29	27	21	13
α-pinene	80-56-8	14.22	670	430	190	64
Camphene	79-92-5	14.52	37	21	12	8
1-methyl-4-(1-methylethyl)-benzene*	99-87-6	15.13	107	69	25	7
ß-pinene	127-91-3	15.43	97	57	14	4
n-hexanoic acid	142-62-1	15.63	180	160	96	68
Octanal	124-13-0	15.75	24	22	27	15
Δ_3-carene	498-15-7	16.54	125	92	50	26
1-isopropyl-3-methylbenzene	535-77-3	16.68	130	100	48	13
Limonene	138-86-3	17.09	37	25	8	2
n-heptanoic acid **Please check!**	111-14-8	18.52	20	n.d.	n.d.	n.d.
2-octenal	2363-89-5	17.42	24	21	13	8
Champhor	76-22-2	18.59	10	11	9	3
Nonanal	124-19-6	19.03	20	20	19	14
Terpene**		19.7	13	13	9	4
Terpene**		20.13	25	25	19	5
Terpene**		20.3	11	11	8	5
n-octanoic acid	124-07-2	21.35	28	n.d.	n.d.	n.d.
Terpene**		22.11	35	31	24	15
2.5-cyclohexadiene-1.4-dione, 2-(1.1-dimethylethyl)*	3602-55-9	25.24	17	14	9	5
Longifolene	475-20-7	29.16	8	8	7	4
Formaldehyde DNPH	50-00-0	3.8	36	36	33	34
Acetaldehyde DNPH	75-07-0	6.1	180	180	140	89
Acetone DNPH	67-64-1	9.9	1060	110	110	3
Pentanal DNPH	110-62-3	29.6	87	34	19	2
Hexanal DNPH	111-71-7	31.9	560	300	150	2
Octanal DNPH	124-13-0	35.1	25	13	14	n.d.
TVOC ***			2400	1900	1000	550

* Suggestion of the mass sprectra library
** Generalised name, no exact specification possible
*** Without DNPH values

Table 3543-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3543			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.862	<= 10	0.548	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		1.04 !!	<= 1
[D] Σ VOC without LCI	no requirement		0.028	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.326	addit. inform.	0.126	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	1.715	addit. inform.	0.506	addit. inform.

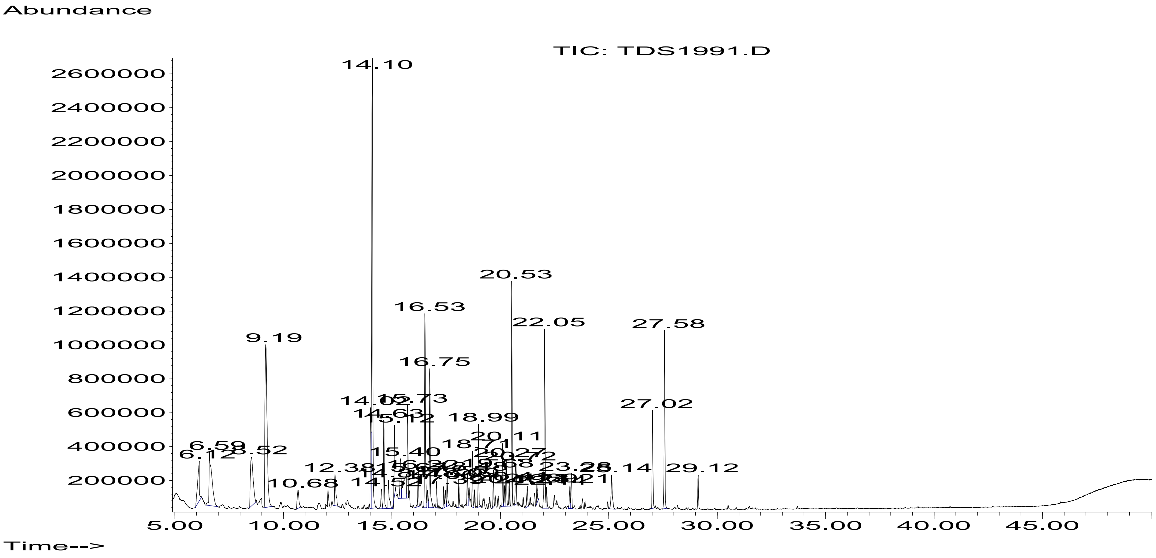


Figure 3543-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3543-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	4	27.5	1.8	-1.9	1.7
3	4	26.5	6.1	-1.3	2.2
10	0				
28	5	16.1	1.2	-1.6	1.4

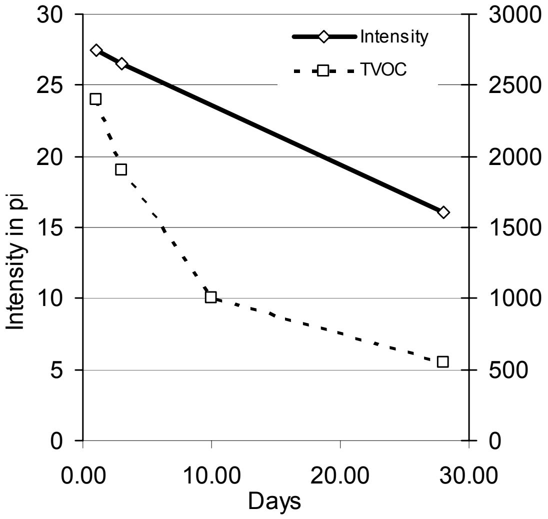


Figure 3543-2: Intensity and TVOC

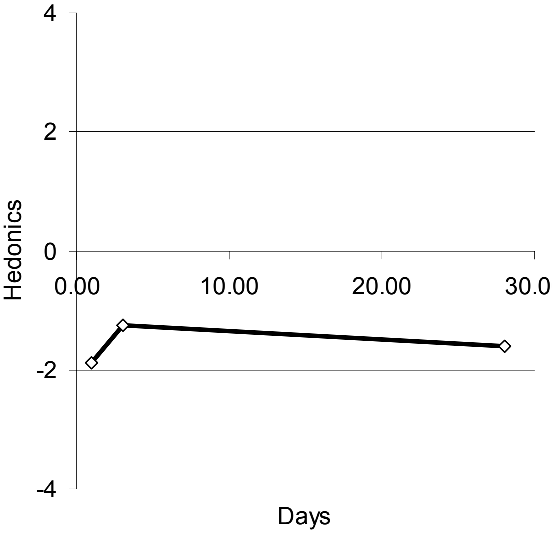


Figure 3543-3: Hedonics

3559 OSB board 2, manufacturer 13

Table 3559-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Acetic acid	64-19-7	6.57	71	30	23	35
Pentanal	110-62-3	6.57	40	40	28	39
Pentanol	71-41-0	8.53	19	10	14	23
Hexanal	66-25-1	9.21	170	90	40	50
2-heptanone	110-43-0	12.06	26	12	4	4
Heptanal	111-71-7	12.38	38	23	7	6
α-pinene	80-56-8	14.22	250	87	27	22
Camphene	79-92-5	14.52	10	0	0	1
Terpene*		14.64	11	7	2	4
1-heptanol	110-70-6	14.84	18	13	9	7
Benzene, 1-methyl-4-(1-methylethyl)-	535-77-3	15.13	53	17	5	2
ß-pinene	127-91-3	15.43	70	10	5	3
Hexanoic acid	142-62-1	15.58	130	48	39	39
Octanal	124-13-0	15.74	52	41	13	9
Δ_3-carene	498-15-7	16.55	160	62	15	12
Cumene -m	527-84-4	16.64	13	5	1	n.d.
Cumene -o	527-84-5	16.79	120	50	14	6
Limonene	5989-27-5	17.09	21	11	2	5
2-octenal	2548-87-0	17.39	18	25	7	7
1-octanol	111-87-5	18.1	10	5	3	4
Heptanoic acid	111-14-8	18.45	20	10	8	7
Terpene*		18.48	8	5	1	2
Terpene*		18.56	11	8	1	3
Benzene, 1-methyl-4-(1-methylethenyl)-	1195-32-0	18.72	8	2	3	3
Nonanal	124-19-6	18.99	46	32	14	12
Terpene*		19.7	11	8	2	3
Terpene*		19.8	8	7	1	2
Terpene*		20.12	18	12	2	2
Champhor	76-22-2	20.19	10	10	1	2
Terpene*		20.29	10	10	2	5
Terpene*		20.44	20	10	3	5
Terpene*		20.74	20	20	3	5
Ethanone, 1-(4-methylphenyl)-	122-00-9	20.84	3	4	2	1
Borneol	507-70-0	21.07	10	5	1	2
Unknown VOC*		21.27	20	10	10	6
Octanoic acid	124-07-2	21.38	40	20	20	13
Unknown VOC*		21.4	20	10	10	6
Terpene*	564-94-3	21.7	10	10	2	3
2-decanon	693-54-9	21.75	2	13	2	1
4-carene	29050-33-7	21.81	4	3	1	1
Terpene*	1196-01-6	22.12	70	50	10	24
3-isopropyl benzaldehyde	34246-57-6	22.5	10	4	2	2
2-cyclohexene-1-ol, 2-methyl-5-(1-methylethenyl)-, cis-**	1197-06-4	22.62	10	10	3	2
2-cyclohexene-1-one, 2-methyl-5-(1-methylethenyl)-, (S)-**	2244-16-8	23.19	10	5	3	2
Bornyl acetate**	76-49-3	24.95	4	2	1	1
Unknown VOC		25.15		20	10	8
Longifolene	475-20-8	29.16	10	10	4	4
Formaldehyde DNPH	50-00-0	3.8	14	9	8	7
Acetaldehyde DNPH	75-07-0	6.1	4	110	49	21
Acetone DNPH	67-64-1	9.9	4	200	160	110
Pentanal DNPH	110-62-3	29.6	n.d.	27	2	15
Hexanal DNPH	66-25-1	31.9	n.d.	70	60	55
Heptanal DNPH	111-71-7	33.5	n.d.	73	59	41
Octenal DNPH	2548-87-0	34.4	1	81	n.d.	18
Octanal DNPH	124-13-0	35.1	n.d.	33	16	12
Nonenal DNPH	2463-53-8	35.9	n.d.	n.d.	36	18
TVOC ***			1710	900	380	400

* Generalised name, no exact specification possible
** Suggestion of the mass sprectra library
*** Without DNPH values

Table 3559-2: Comprehensive evaluation according to AgBB scheme on a DIBt reporting mask from an OSB board.

Sample	OSB board 3559			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.901	<= 10	0.394	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.73	<= 1
[D] Σ VOC without LCI	no requirement		0.030	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.323	addit. inform.	0.138	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.804	addit. inform.	0.325	addit. inform.

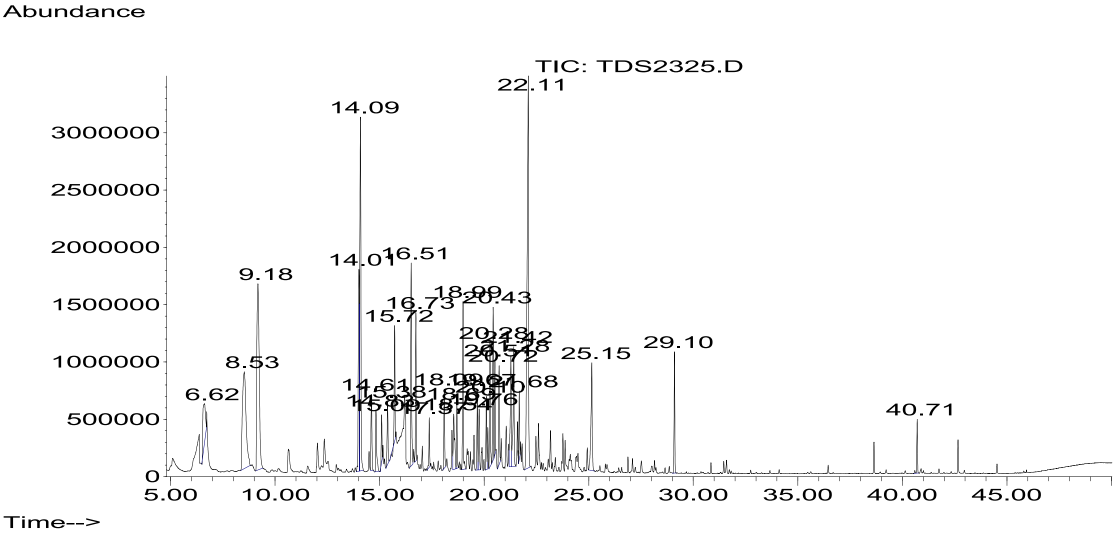


Figure 3559-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3559-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	5	18.3	0.9	-2.4	1.0
3	6	17.8	2.0	-1.8	2.2
10	5	14.2	3.0	-1.0	1.1
28	7	13.2	2.9	-0.6	1.4

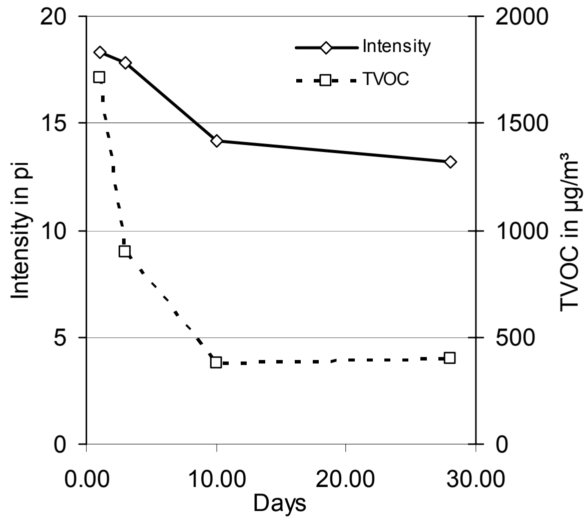


Figure 3559-2: Intensity and TVOC

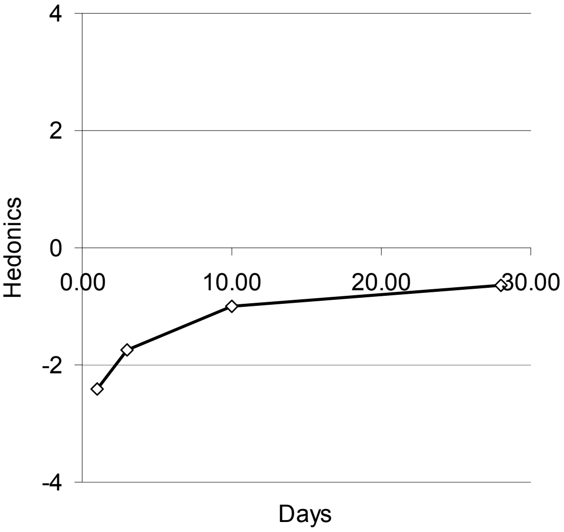


Figure 3559-3: Hedonics

3628 OSB board 3, manufacturer 9

Table 3628-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 2 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 8 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	7.01	49	60	n.d.	n.d.
Pentanal	110-62-3	6.87	180	76	54	23
1-pentanol	71-41-0	8.85	51	31	20	9
Hexanal	66-25-1	9.62	990	490	300	120
2-heptanone	110-43-0	12.49	6	3	2	1
Pentanoic acid	109-52-4	12.62	34	24	n.d.	5
α-pinene	80-56-8	14.58	780	220	70	30
1-methyl-2-(1-methylethyl)-benzene	527-84-4	15.56	40	10	10	1
ß-pinene	127-91-3	15.88	230	56	15	5
Octanal	124-13-0	16.16	24	13	15	8
Hexanoic acid	142-62-1	16.41	200	120	47	38
Δ_3-carene	498-15-7	16.97	420	160	69	38
1-methyl-3-(1-methylethyl)-benzene	535-77-3	17.09	4	1	1	n.d.
1-methyl-4-(1-methylethyl)-benzene	99-87-6	17.21	42	17	7	1
D-limonene	5989-27-5	17.51	52	19	6	n.d.
2-octenal	2548-87-0	17.84	59	36	18	7
Heptanoic acid	111-14-8	18.68	17	8	n.d.	n.d.
Octanoic acid	124-07-2	21.62	35	39	10	6
2-decenal	3913-81-3	24.4	11	7	2	1
Nonanoic acid	112-05-0	24.71	21	46	n.d.	n.d.
2-undecenal	2463-77-6	27.6	8	5	2	1
Longifolene	475-20-7	29.66	5	2	2	1
Formaldehyde DNPH	50-00-0	3.8	72	67	64	54
Acetaldehyde DNPH	75-07-0	6.1	69	47	29	13
Acetone DNPH	67-64-1	9.9	230	200	150	70
Propanal DNPH	123-38-6	12.7	32	29	23	10
Butanal DNPH	123-72-8	24.4	10	11	8	4
Pentanal DNPH	110-62-3	29.6	90	56	43	20
Hexanal DNPH	66-25-1	31.9	560	540	320	130
Heptenal DNPH	2463-63-0	32.9	13	8	7	4
Heptanal DNPH	111-71-7	33.5	41	29	22	19
Octenal DNPH	2548-87-0	34.4	130	80	61	36
Octanal DNPH	124-13-0	35.1	3	22	20	24
Nonanal DNPH	124-19-6	36.6	23	10	18	18
TVOC *			3300	1400	650	300

* Without DNPH values

Table 3628-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3628			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.448	<= 10	0.287	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.65	<= 1
[D] Σ VOC without LCI	no requirement		0.068	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.314	addit. inform.	0.137	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	1.353	key in the value manually!	0.279	key in the value manually!
[H] Σ VOC with LCI	0.968	addit. inform.	0.219	addit. inform.

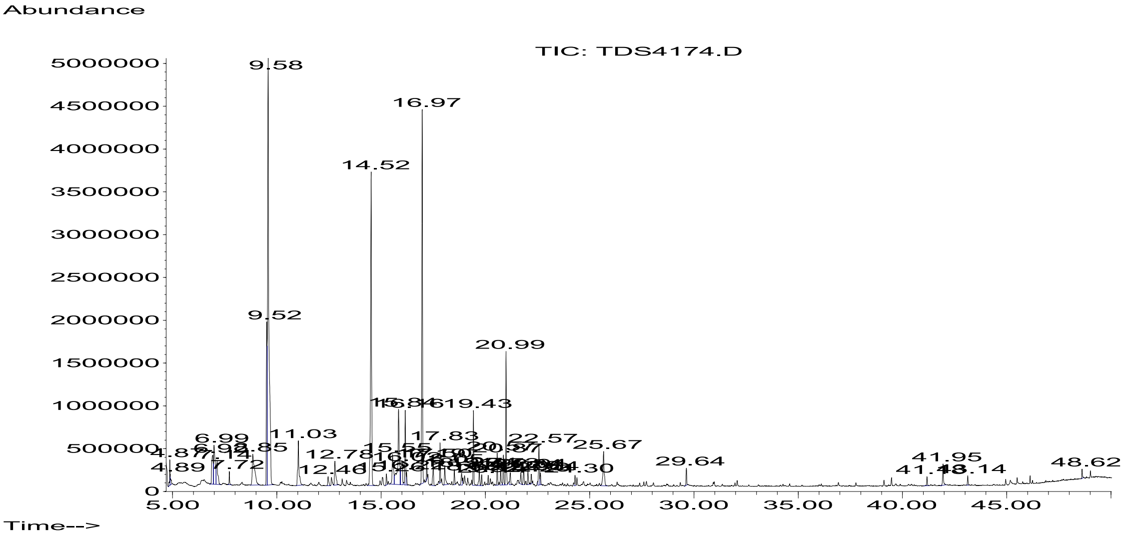


Figure 3628-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

Table 3628-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	8	12.3	3.2	-0.8	1.3
3	8	12.4	2.2	-0.9	1.3
10	7	13.7	2.9	-0.9	1.5
28	7	11.9	2.4	0.6	1.9

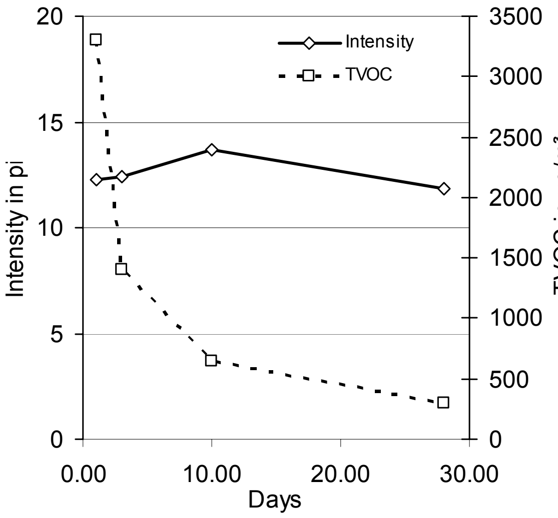


Figure 3628-2: Intensity and TVOC

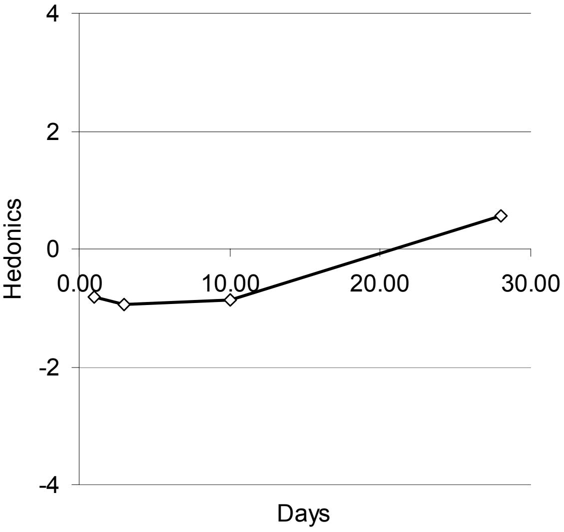


Figure 3628-3: Hedonics

3689 OSB board, manufacturer 16

Table 3698-1: Concentrations of organic compounds analysed from an OSB board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]	Day 81 [µg/m^3]
Acetic acid	64-19-7	7.01	81	70	40	38	26
Pentanal	110-62-3	6.87	110	75	52	43	45
1-pentanol	71-41-0	8.85	42	31	21	19	21
Hexanal	66-25-1	9.62	560	460	330	170	50
2-hexenal	505-57-7	11.04	4	3	2	1	1
2-heptanone	110-43-0	12.49	4	2	2	1	1
Benzaldehyde	100-52-7	14.38	20	20	15	9	17
α-pinene	80-56-8	14.58	150	110	80	51	32
ß-pinene	127-91-3	15.88	20	11	9	5	4
Octanal	124-13-0	16.16	25	20	21	15	10
Hexanoic acid	142-62-1	16.41	100	90	69	69	53
Δ_3-carene	498-15-7	16.97	320	260	202	200	160
1,2,3-trimethylbenzene	526-73-8	16.98	6	5	4	3	n.d.
1-methyl-4-(1-methylethyl)-benzene	99-87-6	17.21	8	5	3	2	n.d.
2-ethyl-1-hexanol aluminium adhesive tape???	104-76-7	17.25	22	14	8	3	2
D-limonene	5989-27-5	17.51	5	4	3	2	1
2-octenal	2548-87-0	17.76	19	17	13	9	3
1-octanol	111-87-5	18.45	4	4	4	2	n.d.
Nonanal	124-19-6	19.35	21	20	20	16	14
Octanoic acid	124-07-2	21.62	12	15	15	11	6
Decanal	112-31-2	22.56	2	3	2	2	2
2-decenal	3913-81-3	24.4	6	6	6	4	2
Nonanoic acid	112-05-0	24.71	n.d.	6	7	4	n.d.
2-undecenal	2463-77-6	27.6	3	3	3	2	1
Longifolene	475-20-7	29.66	4	3	3	2	1
Formaldehyde DNPH	50-00-0	3.8	15	12	11	9	6
Acetaldehyde DNPH	75-07-0	6.1	47	32	25	19	15
Acetone DNPH	67-64-1	9.9	310	190	118	85	60
Propanal DNPH	123-38-6	12.7	18	11	16	12	14
Pentanal DNPH	110-62-3	29.6	71	49	7	23	1
Hexenal DNPH	505-57-7		22	1	4	3	10
Hexanal DNPH	66-25-1	31.9	360	260	24	14	1
Heptenal DNPH	2463-63-0	32.9	14	10	4	3	54
Heptanal DNPH	111-71-7	33.5	29	23	18	20	2
Octenal DNPH	2548-87-0	34.4	20	17	7	1	10
Octanal DNPH	124-13-0	35.1	20	17	17	1	5
Nonanal DNPH	124-19-6	36.6	17	15	8	7	5
TVOC *			1540	1252	930	680	450

* Without DNPH values

Table 3689-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an OSB board.

Sample	OSB board 3689			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.249	<= 10	0.677	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		1.26	<= 1
[D] Σ VOC without LCI	no requirement		0.013	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.334	addit. inform.	0.112	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	1.205	addit. inform.	0.651	addit. inform.

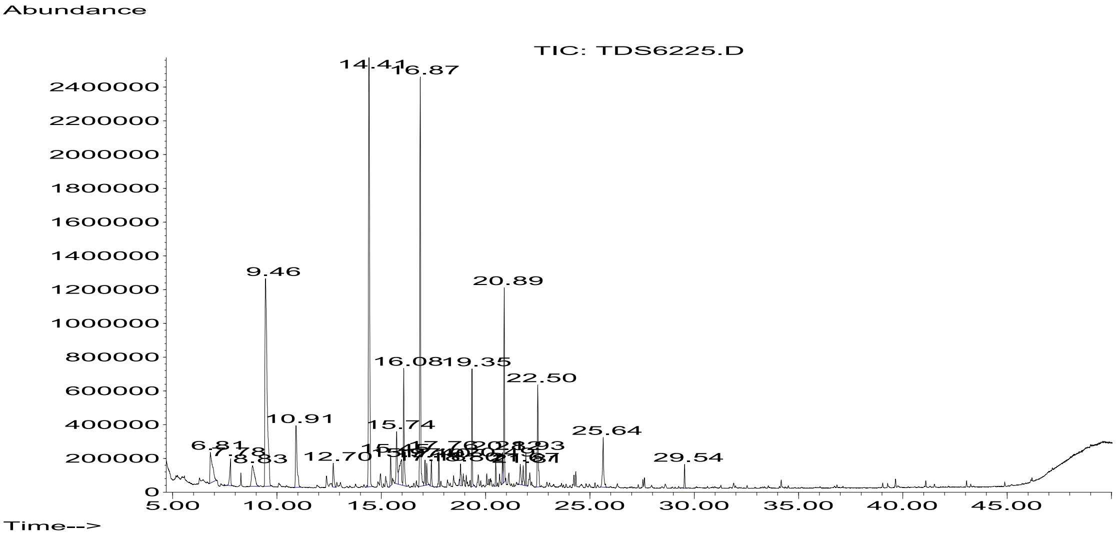


Figure 3689-1: GC/MS chromatogram on day 28 of emission testing on an OSB board.

3384 Spruce board, manufacturer 2

Table 3384-1: Concentrations of organic compounds analysed from a spruce board (glued) 20-litre chamber, q = 1 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid	64-19-7	7.9	230	160	180	110
Pentanol	71-41-0	10.66	11	11	11	10
Hexanal	66-25-1	11.48	11	12	12	12
α-pinene	80-56-8	17.12	54	68	76	51
Hexanoic acid	142-62-1	18.44	7	5	8	6
Δ_3-carene	498-15-7	19.83	28	27	33	25
Limonene	138-86-3	20.42	4	4	5	4
Hexanal DNPH	66-25-1	31.9	10	10	10	8
TVOC *			350	290	320	220

* Without DNPH values

Table 3384-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a spruce board (verleimt).

Sample	Spruce board 3384			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.367	<= 10	0.207	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.13	<= 1
[D] Σ VOC without LCI	no requirement		0.022	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.001	addit. inform.	0.001	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.278	addit. inform.	0.185	addit. inform.

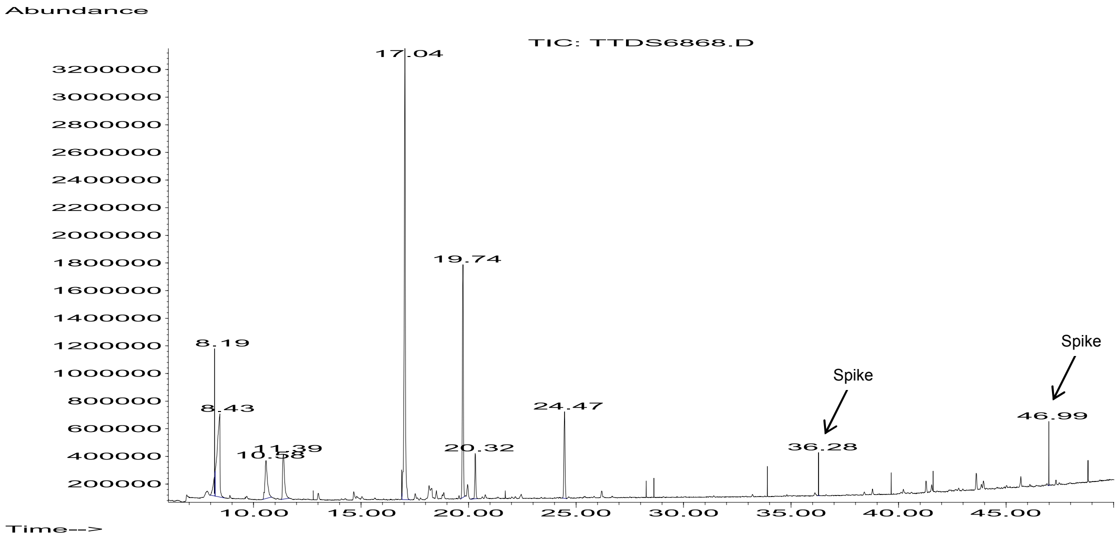


Figure 3384-1: GC/MS chromatogram on day 28 of emission testing on a spruce board (glued).

Table 3384-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	13.0	3.1	-2.0	2.0
3	10	14.4	3.2		
10	9	13.1	1.3	-1.7	2.0
28	11	12.5	2.5	-2.6	0.8

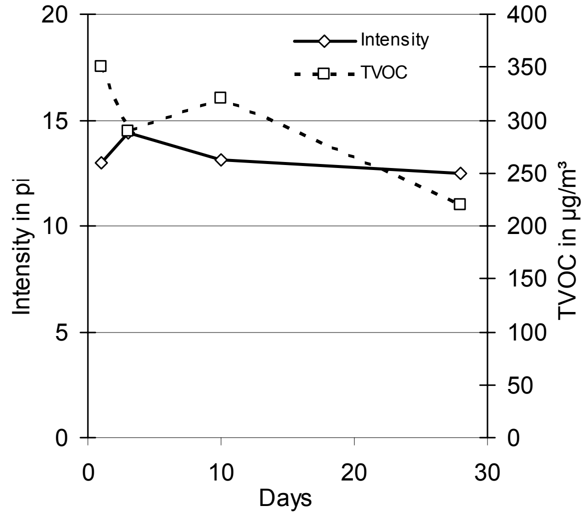


Figure 3384-2: Intensity and TVOC

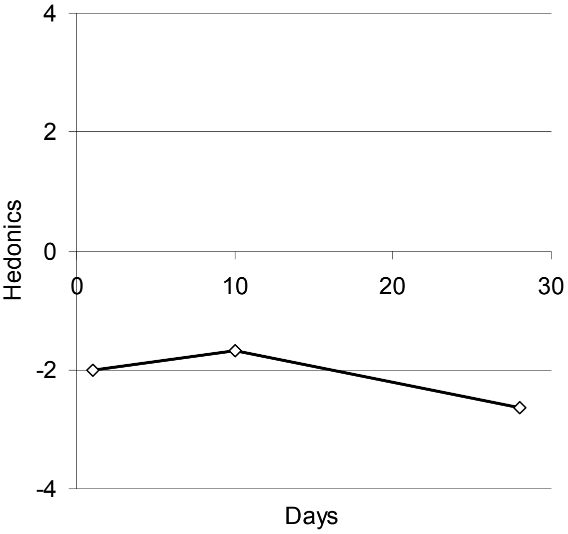


Figure 3384-3: Hedonics

3479 Cork parquet, manufacturer 13

Table 3479-1: Concentrations of organic compounds analysed from cork parquet; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Acetic acid	64-19-7	7.08	110	49	26	n.d.
Phenol	108-95-2	16.36	7	4	3	5
Benzoic acid, methyl ester*	93-58-3	19.91	8	4	1	1
BHT	128-37-0	32.9	2	1	2	1
Benzophenone	119-61-9	35.4	160	130	190	110
TVOC *			280	190	220	120

* Suggestion of mass spectra library

Table 3479-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from cork parquet.

Sample	Corc parquet 3479			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.192	<= 10	0.119	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.104 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.054	addit. inform.	0	addit. inform.

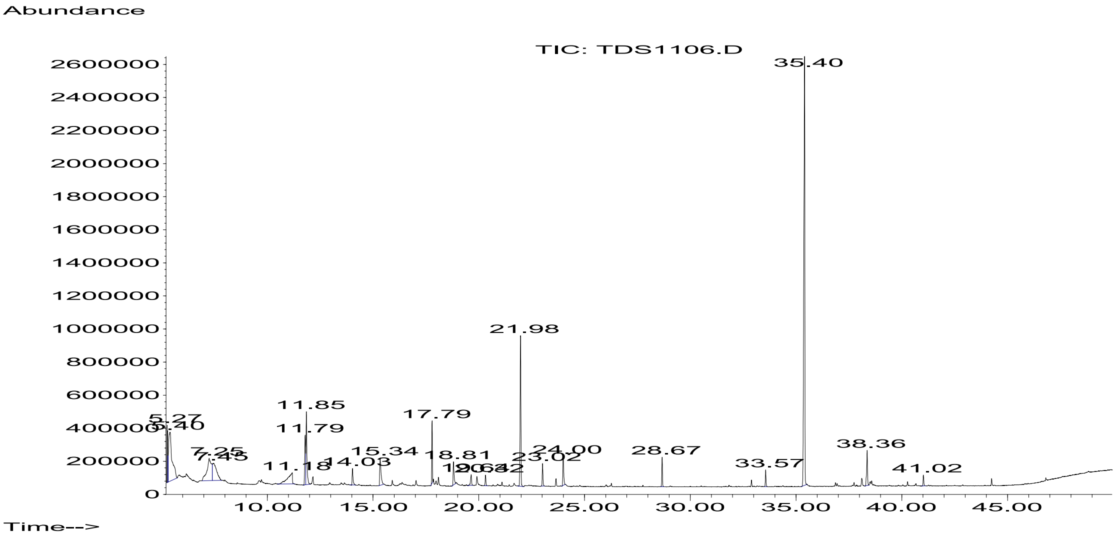


Figure 3479-1: GC/MS chromatogram on day 28 of emission testing on a cork parquet.

Table 3479-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	16.1	2.3	-2.2	1.6
3	9	17.2	3.0	-2.8	1.8
10	10	16.0	3.3	-2.9	0.9
28	8	16.5	4.4	-2.8	1.5

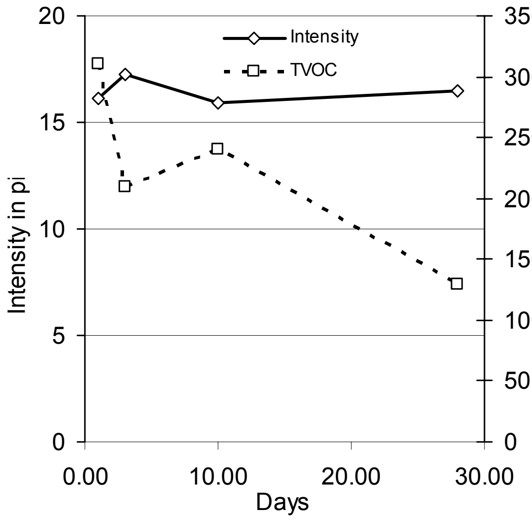


Figure 3479-2: Intensity and TVOC

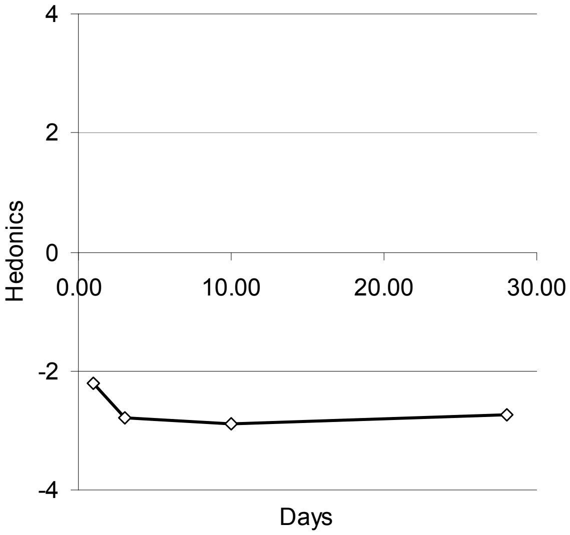


Figure 3479-3: Hedonics

3560 Chipboard, manufacturer 18

Table 3560-1: Concentrations of organic compounds analysed from a chipboard; 20-litre chamber, $q = 1\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m^3]	Day 3 [µg/m^3]	Day 10 [µg/m^3]	Day 28 [µg/m^3]
Acetic acid, methyl ester	79-20-9	4.58	490	290	n.d.	n.d.
Acetic acid	64-19-7	6.57	1090	1050	850	750
Pentanol	71-41-0	8.53	2	2	3	n.d.
Hexanal	66-25-1	9.21	40	30	30	10
Furfural	98-01-1	10.1	6	5	2	n.d.
Heptanal	111-71-7	12.38	5	4	3	2
α-pinene	80-56-8	14.22	10	0	0	2
ß-pinene	127-91-3	15.43	3	1	1	n.d.
Octanal	124-13-0	15.74	10	0	3	3
Δ_3-carene	498-15-7	16.55	7	2	2	n.d.
o-cumene	527-84-5	16.79	3	1	1	n.d.
2-ethyl-1-hexanol	104-76-7	16.78	20	13	6	2
2-octenal	2548-87-0	17.39	3	2	2	n.d.
Nonanal	124-19-6	18.99	3	3	1	1
Terpene		19.49	3	2	1	n.d.
Terpene		19.66	3	2	1	n.d.
2-propenoic acid-2-ethylhexylester	124-07-2	23.13	220	160	86	11
Unknown VOC*		23.43	0	0	2	n.d.
Longifolene		29.16	10	10	4	3
Naphthalene, hexahydro-dimethyl-methylethyl**		30.86	0	0	1	n.d.
Naphthalene, hexahydro-dimethyl-methylethyl**	31983-22-9	31.47	3	3	1	n.d.
Formaldehyde DNPH	50-00-0	3.8	11	13	12	8
Acetaldehyde DNPH	75-07-0	6.1	39	30	20	11
Acetone DNPH	67-64-1	9.9	37	20	10	5
Hexanal DNPH	66-25-1	31.9	25	23	21	10
TVOC **			1900	1600	1000	780

* Generalised name, no exact specification possible
** Suggestion of the mass sprectra library
*** Without DNPH values

Table 3560-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a chipboard.

Sample	OSB board 3560			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.606	<= 10	0.786	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		1.52 !!	<= 1
[D] Σ VOC without LCI	no requirement		0.003	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.063	addit. inform.	0.024	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	1.559	addit. inform.	0.771	addit. inform.

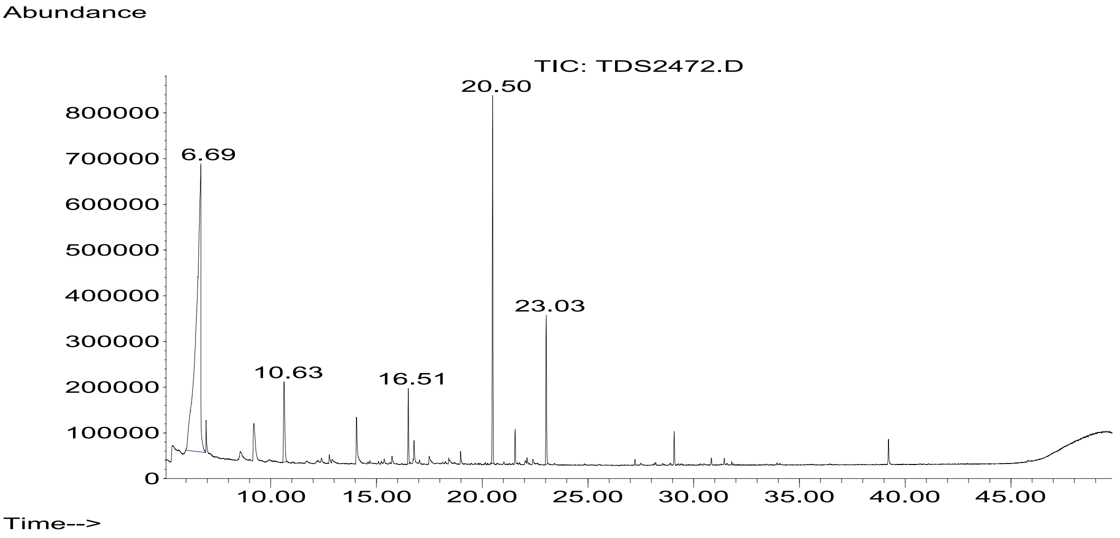


Figure 3560-1: GC/MS chromatogram on day 28 of emission testing on a chipboard.

Table 3560-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	4	17.5	2.2	-3.5	0.4
3	5	16.3	1.8	-2.9	0.6
10	0				
28	6	13.7	2.5	-2.9	0.5

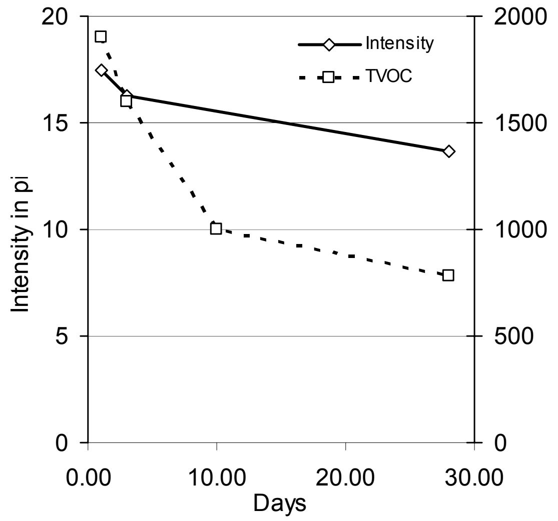


Figure 3560-2: Intensity and TVOC

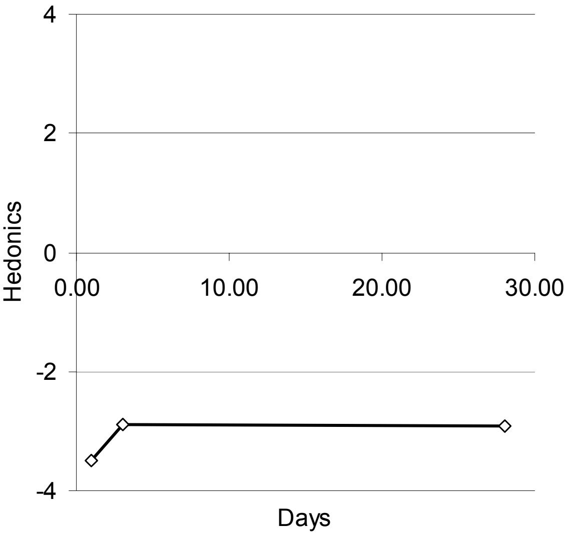


Figure 3560-3: Hedonics

3561 Cork parquet, manufacturer 19

Table 3561-1: Concentrations of organic compounds analysed from cork parquet; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m^3]**	**Day 3 [µg/m^3]**	**Day 10 [µg/m^3]**	**Day 28 [µg/m^3]**
Acetic acid	64-19-7	6.87	80	40	7	n.d.
Hexanal	66-25-1	9.23	0	3	2	2
Furfural	98-01-1	10.23	9	4	2	2
Ethylhexanol	104-76-7	16.8	8	0	0	0
Benzoic acid methyl ester	93-58-3	18.56	16	6	2	1
Nonanal	124-19-6	18.98	2	2	1	n.d.
Diethylene glycol monobutyl ether	112-34-5	21.44	22	16	6	n.d.
Terpene*		21.73	0	0	0	1
Ethylhexyl acrylate**		23.11	96	55	17	8
Butyl diglycol acetate	124-17-4	26.88	100	51	26	12
Terpene*		29.41	2	2	1	1
BHT	128-37-0	31.41	0	0	1	1
Dodecanoic acid methyl ester	111-82-0	31.75	2	2	n.d.	n.d.
Benzophenone	119-61-9	33.89	80	96	51	40
Formaldehyde DNPH	50-00-0	3.8	2	2	2	n.d.
Acetaldehyde DNPH	75-07-0	6.9	4	5	6	n.d.
Acetone DNPH	67-64-1	9.9	2	2	2	n.d.
TVOC ***			430	280	120	72

* Generalised name, no exact specification possible
** Suggestion of mass spectra library
*** Without DNPH values

Table 3561-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from cork parquet.

Sample	Cork parquet 3561			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C$_6$ - C$_{16}$)	0.280	<= 10	0.072	<= 1
[B] Σ SVOC (C$_{16}$ - C$_{22}$)	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.03	<= 1
[D] Σ VOC without LCI	no requirement		0.040	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C$_6$)	0.011	addit. inform.	0	addit. inform.
[G] TVOC (C$_6$ - C$_{16}$) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.180	addit. inform.	0.020	addit. inform.

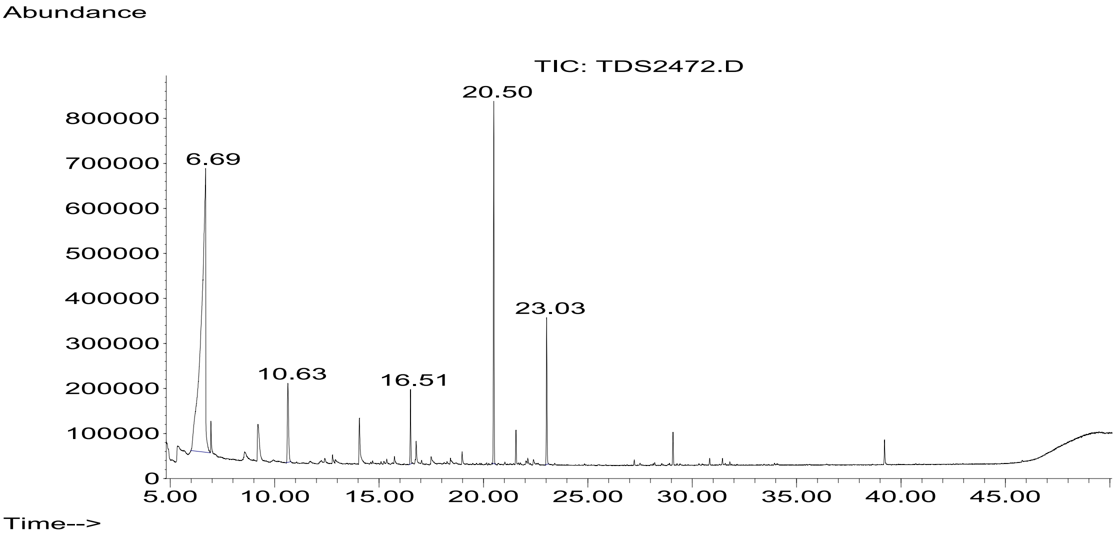


Figure 3561-1: GC/MS chromatogram on day 28 of emission testing on a cork parquet.

Table 3561-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	7	13.4	3.3	-3.2	0.8
3	5	13.6	4.2	-2.7	0.5
10	8	11.9	3.7	-2.9	0.7
28	6	11.0	1.6	-2.5	0.4

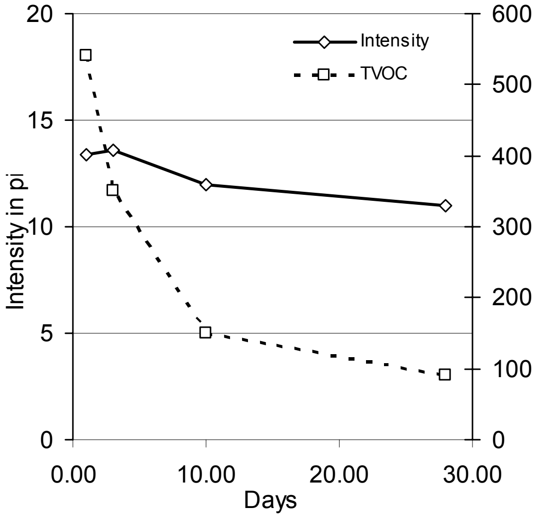


Figure 3561-3: Intensity and TVOC

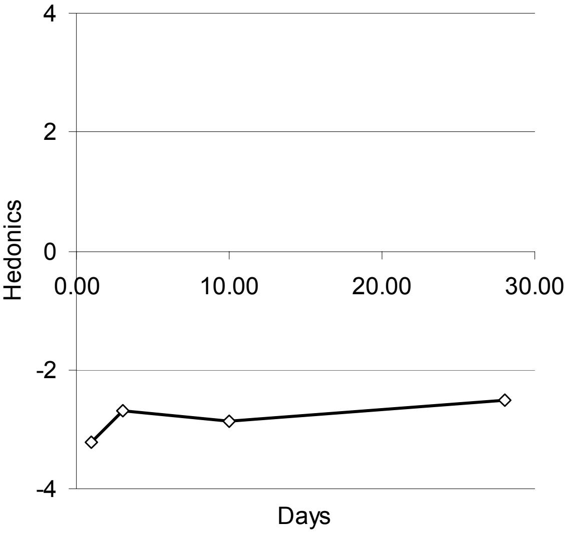


Figure 3561 Hedonics

3562 Laminate, manufacturer 2

Table 3562-1: Concentrations of organic compounds analysed from laminate; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1 [µg/m³]**	**Day 3 [µg/m³]**	**Day 10 [µg/m³]**	**Day 28 [µg/m³]**
Acetic acid	64-19-7	6.36	36	20	8	2
1,2 ethanediol	107-21-1	7.59	16	15	14	n.d.
Hexanal	66-25-1	9.58	2	2	2	3
Furfural	98-01-1	10.3	1	1	1	n.d.
Octanal	124-13-0	16.2	1	1	1	n.d.
Unknown VOC mass 109		16.85	2	1	n.d.	n.d.
Unknown VOC mass 123		27.05	2	2	n.d.	n.d.
Unknown VOC		27.22	3	3	2	n.d.
Unknown VOC		27.61	2	2	n.d.	n.d.
Unknown VOC		27.91	1	1	n.d.	n.d.
Unknown VOC		28.8	1	1	n.d.	n.d.
Unknown SVOC mass 247		39.68	7	6	3	2
Unknown SVOC mass 232		45.05	2	2	2	1
Formaldehyde DNPH	50-00-0	3.8	10	9	9	11
TVOC			74	56	32	9

** Without DNPH values

Table 3562-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from laminate.

Sample	Laminat 3562			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.050	<= 10	0.010	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0.003	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.003	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.011	addit. inform.	0.011	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.059	key in the value manually!	0.013	key in the value manually!
[H] Σ VOC with LCI	0.025	addit. inform.	0	addit. inform.

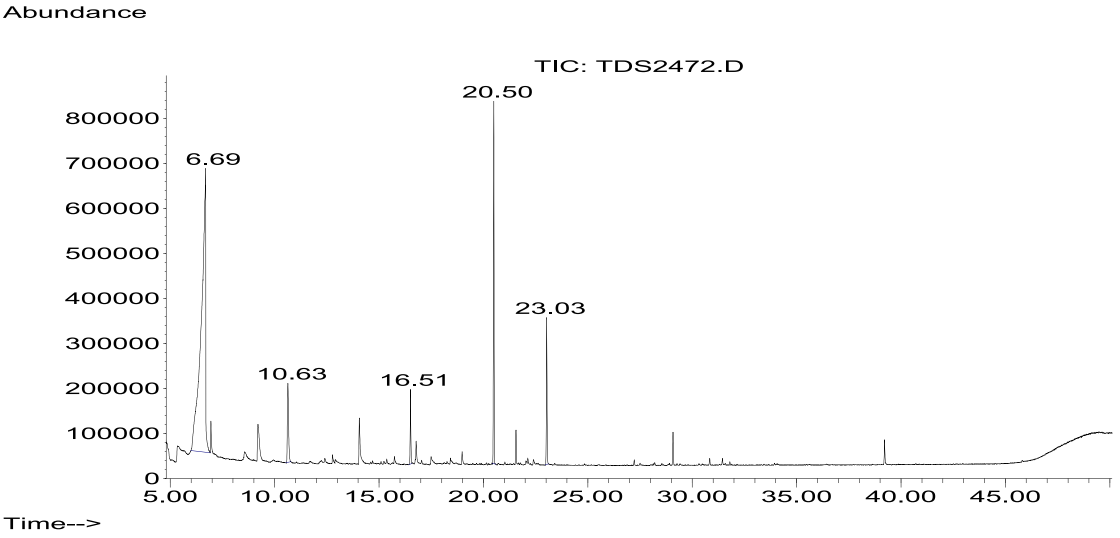


Figure 3562-1: GC/MS chromatogram on day 28 of emission testing on a laminate.

Table 3562-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	5	9.6	1.5	-2.0	0.7
3	6	9.3	3.7	-1.1	2.4
10	8	8.1	2.2	-1.9	0.9
28	7	10.3	2.1	-2.1	0.9

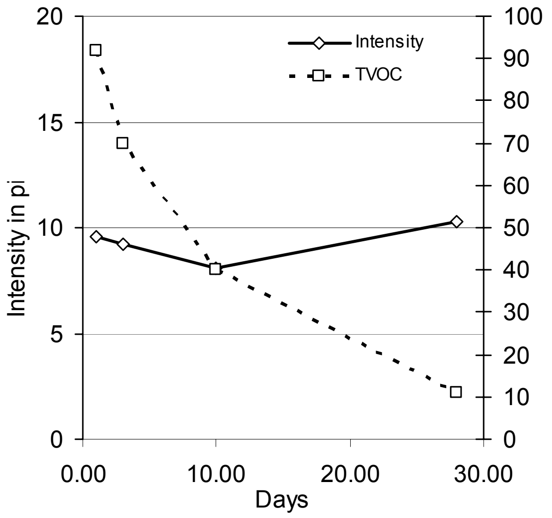


Figure 3562-2: Intensity and TVOC

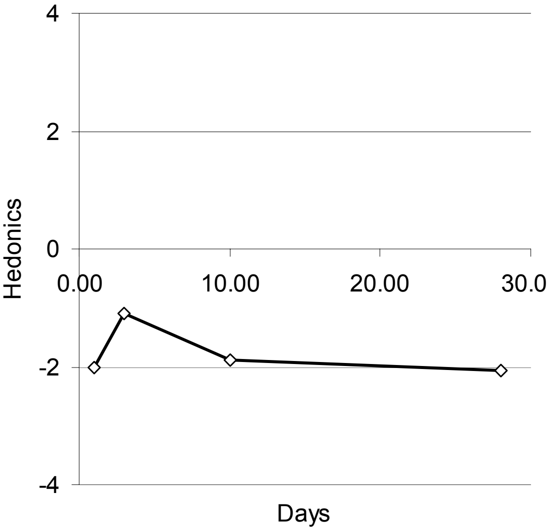


Figure 3562-3: Hedonics

3625 Beech wood board, manufacturer 15

Table 3625-1: Concentrations of organic compounds analysed from a beech wood board; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Acetic acid	64-19-7	6.87	430	120	n.d.	53
Hexanal	66-25-1	9.23	5	2	5	6
Furfural	98-01-1	10.23	2	1	7	1
Benzaldehyde	100-52-7	14.45	13	9	5	1
2-ethyl-1-hexanol	104-76-7	17.21	35	7	4	2
Acetophenone	98-86-2	17.91	4	3	3	n.d.
Formaldehyde DNPH	50-00-0	3.8	2	2	n.d.	2
Acetaldehyde DNPH	75-07-0	6.1	9	8	6	6
Acetone DNPH	67-64-1	9.9	14	8	11	6
Hexanal DNPH	66-25-1	31.9	3	6	3	3
TVOC*			490	140	24	62

* Without DNPH values

Table 3625-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a beech wood board.

Sample	Corc parquet 3561			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.143	<= 10	0.061	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.11	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.022	addit. inform.	0.015	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.151	key in the value manually!	0.144	key in the value manually!
[H] Σ VOC with LCI	0.138	addit. inform.	0.059	addit. inform.

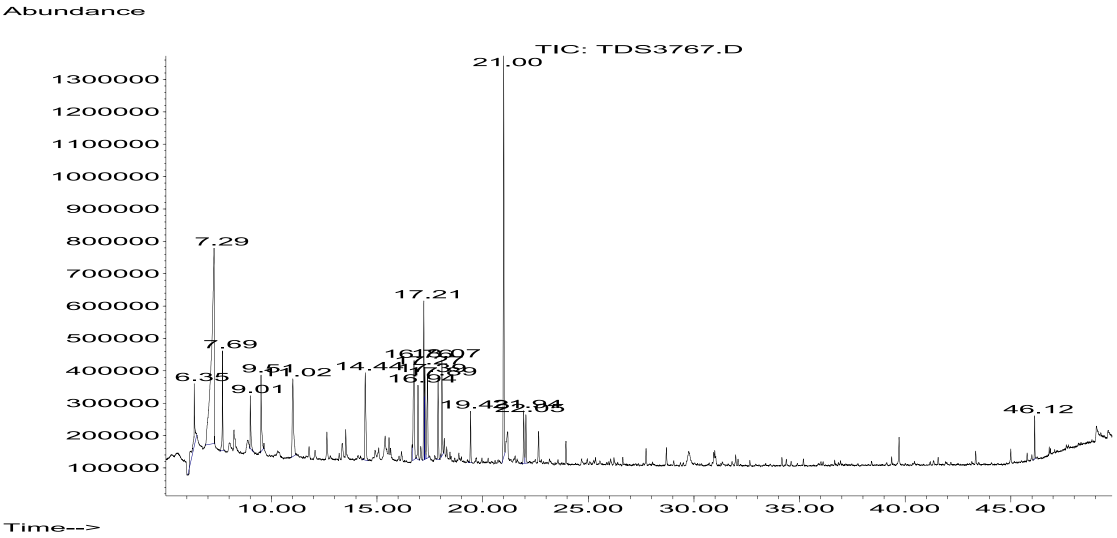


Figure 3625-1: GC/MS chromatogram on day 28 of emission testing on a beech wood board.

Table 3625-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	8	13.0	5.3	-1.7	0.8
3	9	14.9	3.0	-2.3	1.4
10	9	11.7	2.8	-1.7	0.9
28	8	11.8	2.1	-1.3	1.2

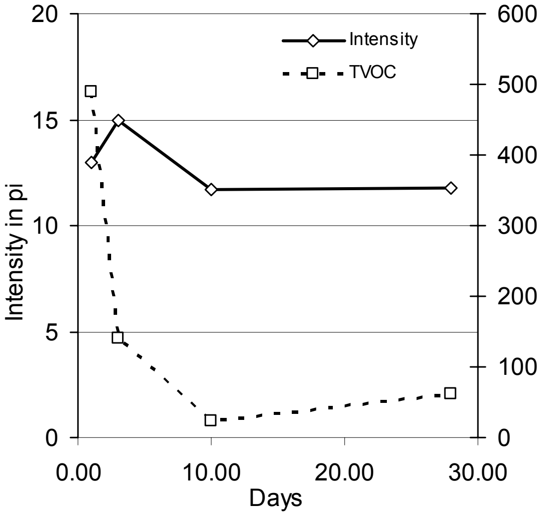


Figure 3625-2: Intensity and TVOC

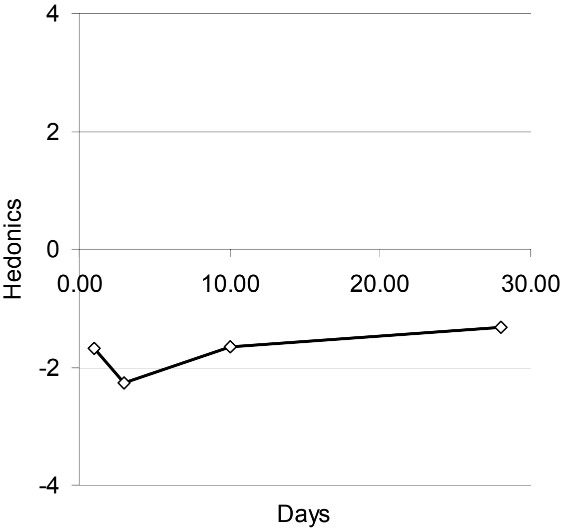


Figure 3625-3: Hedonics

Laquers

3385 Flooring varnish on glass plate, manufacturer 12

Table 3385-1: Concentrations of organic compounds analysed from a flooring varnish on glass plate; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1**	**Day 3**	**Day 10**	**Day 28**
Acetic acid	64-19-7	7.0	32	19	28	n.d.
Propanediol	57-55-6	10.28	41000	3290	n.d.	n.d.
Benzaldehyde	100-52-7	15.40	38	17	6	1
Benzyl alcohol	100-51-6	18.29	4200	1970	7	n.d.
Acetophenone	98-86-2	18.8	0	3	3	1
2-butoxyethylacetate	112-07-2	19.78	10	4	n.d.	n.d.
1,3-pentanediol, 2,2,4-trimethyl- *	000144-19-4	21.94	6	45	16	4
Acetic acid-2-ethylhexylester*	103-09-3	21.99	21	n.d.	n.d.	n.d.
2-(2-butoxyethoxy)-ethanol	000112-34-5	23.0	21	43	n.d.	n.d.
Ester of propanoic acid**	74367-33-2***	28.77	840	650	130	490
Ester of propanoic acid**		29.9	540	670	730	680
TXIB	6846-50-0	35.17	40	35	18	7
TVOC			47000	1400	880	1200

* Superpose ISTD
** Generalised name, no exact specification possible
*** Suggestion of mass spectra library

Table 3385-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from aflooring varnish on glass plate

Sample	Flooring varnish 3385			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	6.715	<= 10	1.181 !!	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		1.181 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	3.330	addit. inform.	0	addit. inform.

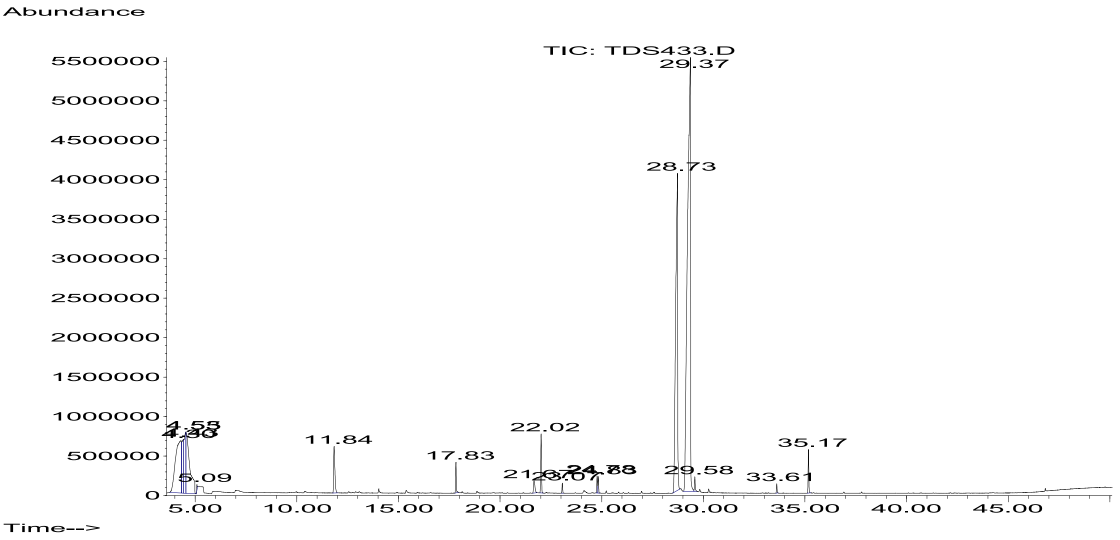


Figure 3385-1: GC/MS chromatogram on day 28 of emission testing on a flooring varnish on glass plate

Table 3385-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	13	12.4	4.9	-2.4	1.6
3	9	18.2	6.2	-3.7	0.5
10	13	14.8	5.2	-2.7	1.3
28	8	11.9	6.5	-2.7	1.2

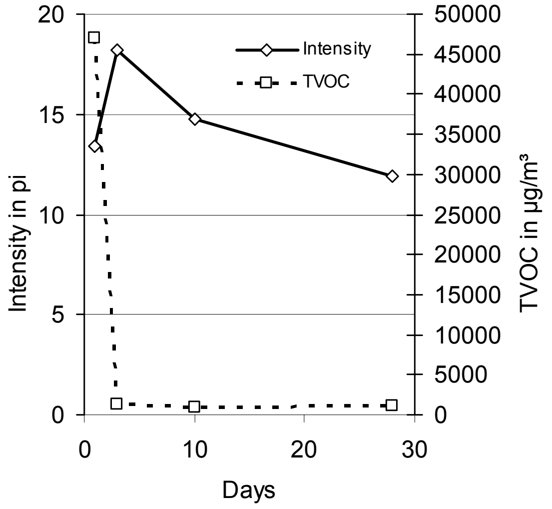


Figure 3385-2: Intensity and TVOC

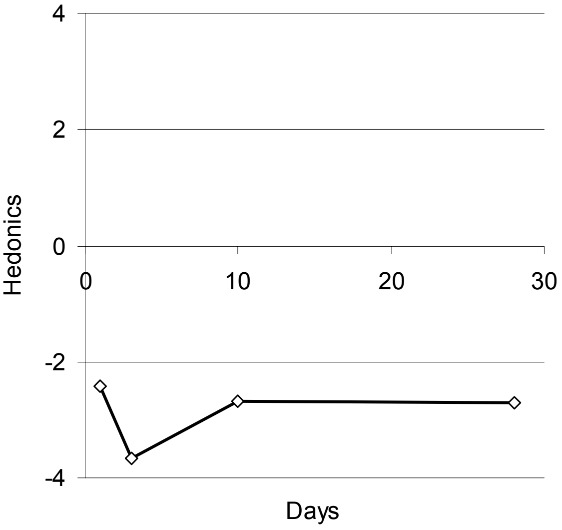


Figure 3385-3: Hedonics

3385A Flooring varnish on screed, manufacturer 12

Table 3385A-1: Concentrations of organic compounds analysed from a flooring varnish on screed plate; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.0	22	20	31	n.d.
Propanediol	57-55-6	10.28	3100	1300	730	350
Benzaldehyde	100-52-7	15.40	43	31	17	7
Benzyl alcohol	100-51-6	18.29	3300	2100	980	180
Acetophenone	98-86-2	18.8	12	12	4	n.d.
Acetic acid-2-ethylhexyl ester*	103-09-3	21.99	30	10	n.d.	n.d.
Propanoic acid ester**	74367-33-2***	28.77	480	270	160	85
Propanoic acid ester**		29.9	630	390	250	140
Cyclo-alkene**	719-22-2***	31.7	3	3	3	1
TVOC			7700	4100	2200	760

* Superposed ISTD

** Generalised name, no exact specification possible

*** Suggestion of mass spectra library

Table 3385A-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from aflooring varnish on screed plate

Sample	Flooring varnish 2003 – 3385A			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	4.108	<= 10	0.762	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		1.84 !!	<= 1
[D] Σ VOC without LCI	no requirement		0.222 !!	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	3.429	addit. inform.	0.540	addit. inform.

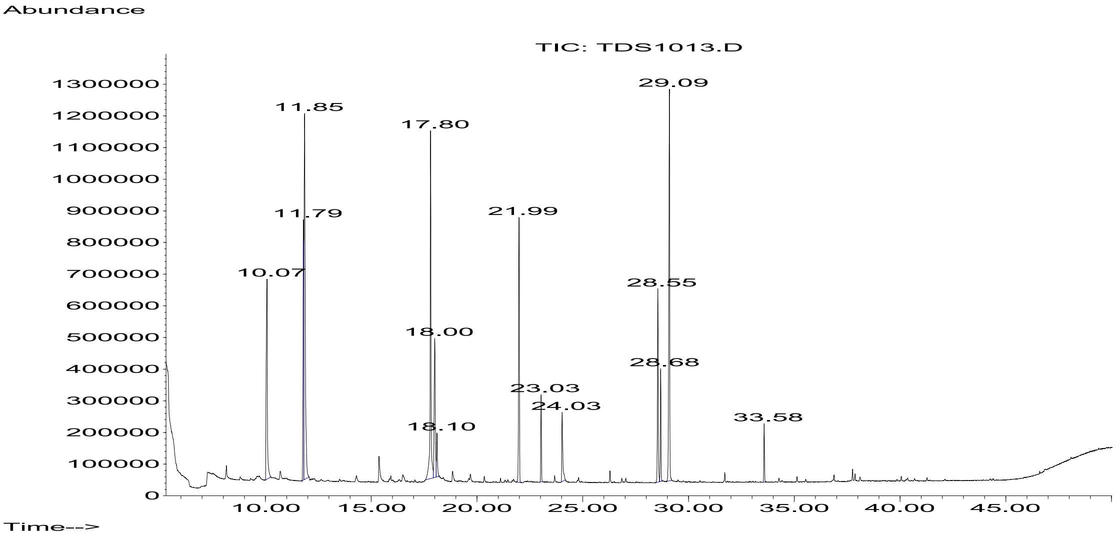


Figure 3385A-1: GC/MS chromatogram on day 28 of emission testing on a flooring varnish on screed plate

Table 3385A-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	11	16.9	4.1	-3.3	0.6
3	10	15.6	4.7	-3.0	1.0
10	11	12.9	4.7	-3.0	1.0
28	10	13.1	3.5	-2.8	0.9

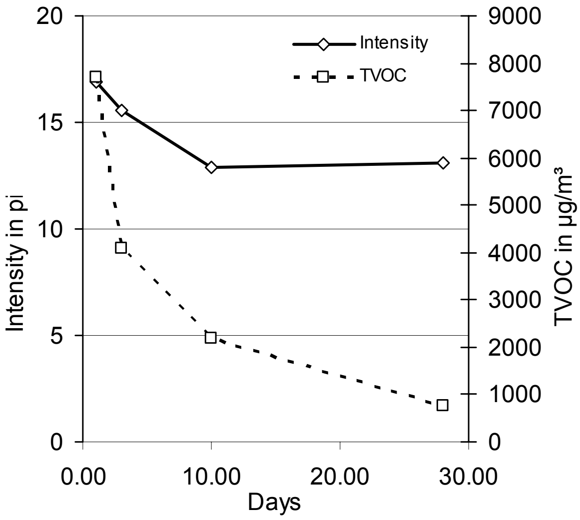


Figure 3385A-2: Intensity and TVOC

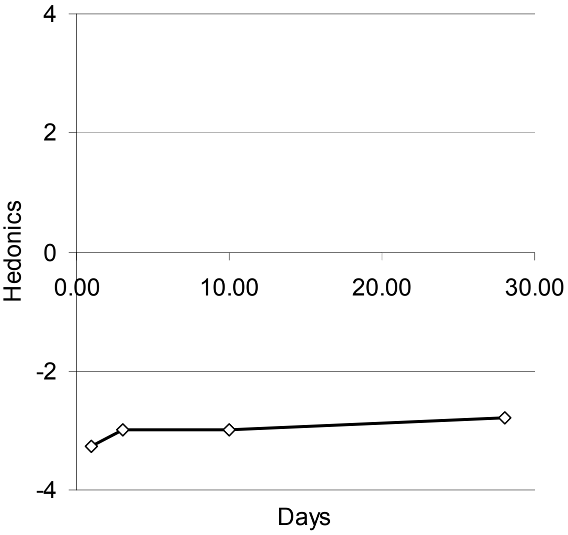


Figure 3385A-3: Hedonics

3388 Glaze, manufacturer 2

Table 3388-1: Concentrations of organic compounds analysed from a glaze on glass plate; 20-litre chamber, q = 3 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Propanediol	4254-14-2	9.24	4100	3	n.d.	n.d.
Dipropylene glycol (mixture of isomeres)	25265-71-8	18.22	4600	690	5	n.d.
Dipropylene glycol (mixture of isomeres)	110-98-5	18.79				
Dipropylene glycol (mixture of isomeres)	110-98-5	19.5				
Diethylene glycol-monobutyl ether	112-34-5	23.17	580	60	n.d.	n.d.
Tetradecane	15726-15-5	30.33	2	n.d.	n.d.	n.d.
Butanedioic acid-bis(2-methylpropyl)-ester*	100-52-7	31.74	760	490	100	13
Pentadecane	103-65-1	33.04	7	n.d.	n.d.	n.d.
Butanedioic acid-methyl-bis(1-methyl-propyl)-ester*	108-95-2	34.34	420	340	140	32
Hexanedioic acid-bis(2-methylpropyl)-ester*	109-21-7	36.82	150	130	92	43
TVOC			10600	1600	250	45

* Suggestion of mass spectra library

Table 3388-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a glaze on glass plate

Sample	Glaze 3388			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	1.584	<= 10	0.045	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0.043	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.045	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.748	addit. inform.	0	addit. inform.

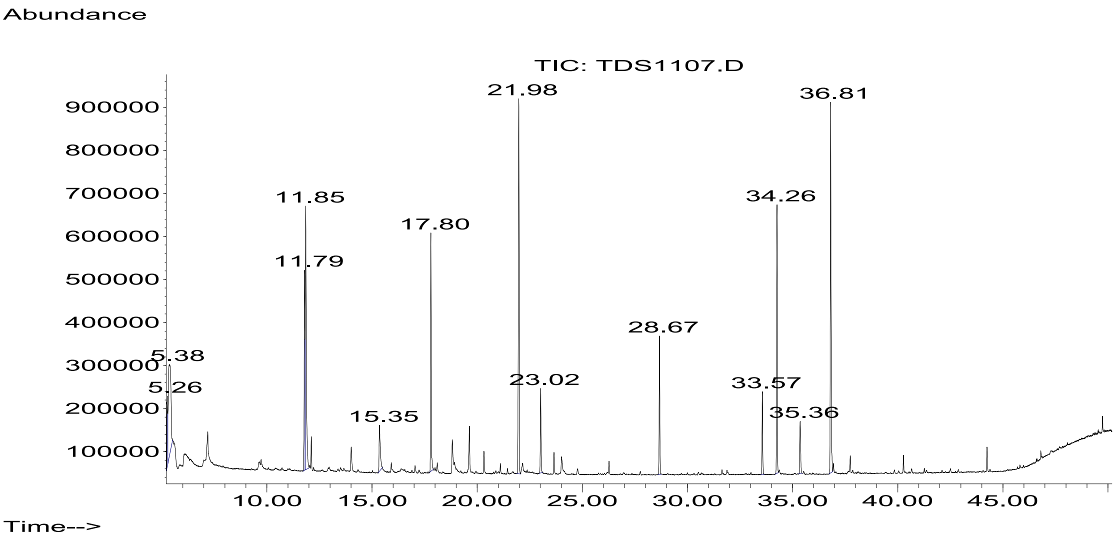


Figure 3388-1: GC/MS chromatogram on day 28 of emission testing on a glaze on glass plate

Table 3388-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	15.5	2.5	-3.2	0.7
3	9	11.8	3.1	-3.0	0.8
10	10	8.5	4.3	-2.1	1.2
28	8	11.8	3.0	-2.5	1.1

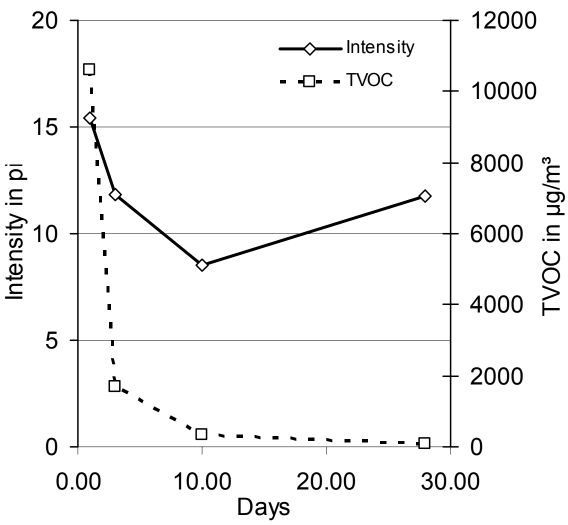


Figure 3388-2: Intensity and TVOC

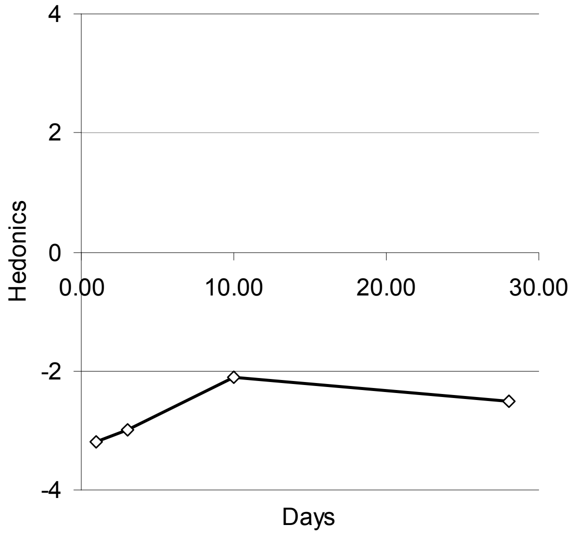


Figure 3388-3: Hedonics

3392 Laquer on spruce wood (3384), manufacturer 13

Table 3392-1: Concentrations of organic compounds analysed from a laquer on spruce wood (3384); 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
n-buthylether	142-96-1	15	76	6	n.d.	n.d.
Propanoic acid butyl ester	590-01-2	15.53	11	n.d.	n.d.	n.d.
Benzaldehyde	100-52-7	17.01	33	16	n.d.	n.d.
α-pinene	80-56-8	17.09	19	55	119	132
Dipropylene glycol monomethylether	34590-94-8	18.86	92	18	6	6
Dipropylene glycol	25265-71-8	18.93	100	19	7	5
1-(2-methoxypropoxy)-2-propanol	13429-07-7	19.45	240	46	13	11
ΔΔ$_3$-carene	498-15-7	19.79	57	17	47	53
Ethylhexanol	104-76-7	19.85	61	190	n.d.	n.d.
Pentanal DNPH	110-62-3	29.6	12	2	4	7
Heptanal DNPH	111-71-7	33.5	29	9	5	3
TVOC*			700	368	191	207

* Without DNPH values

Table 3392-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a laquer on spruce wood (3384)

Sample	Laquer 3392			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.367	<= 10	0.207	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.13	<= 1
[D] Σ VOC without LCI	no requirement		0.022	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001
This block provides additional information				
[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.278	addit. inform.	0.185	addit. inform.

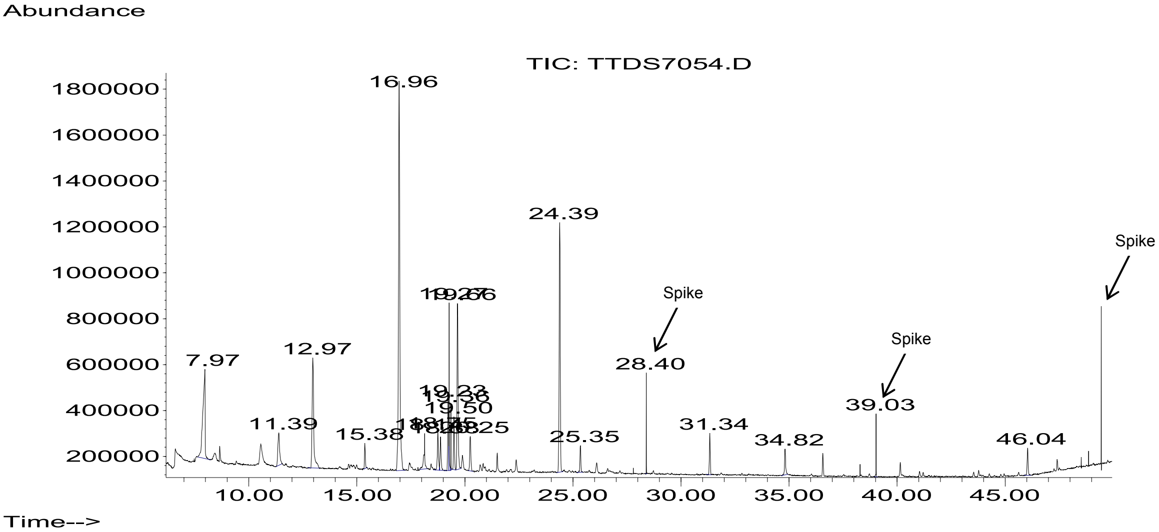


Figure 3392-1: GC/MS chromatogram on day 28 of emission testing on a laquer on spruce wood (3384)

Table 3392-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	15.4	3.7	-3.1	0.8
3	7	15.6	3.2	-3.0	1.1
10	9	12.9	2.9	-3.1	1.0
28	0	12.0	n.m.	-1.1	n.m.

n.m.: not measured

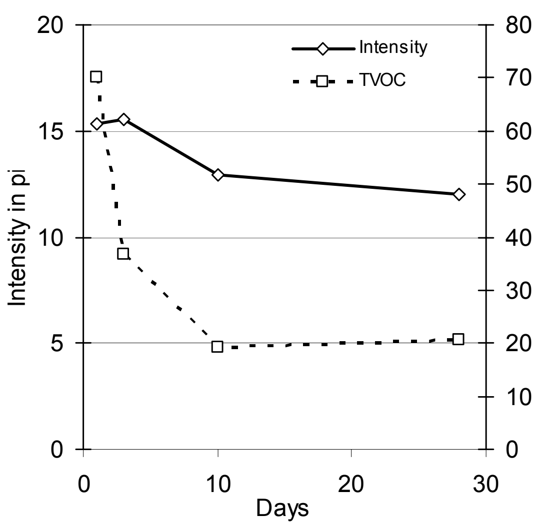


Figure 3392-2: Intensity and TVOC

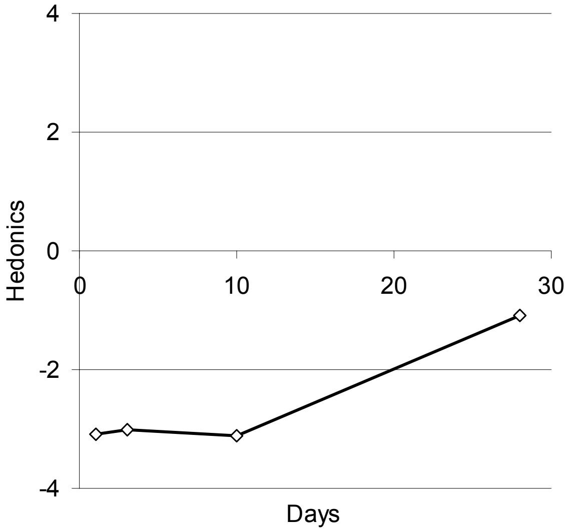


Figure 3392-3: Hedonics

3587 Flooring varnish, manufacturer 21

Table 3587-1: Concentrations of organic compounds analysed from a flooring varnish on glass plate; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	6.87	55	68	46	21
Heptane	142-82-5	7.46	18	18	10	10
1-pentanol	71-41-0	8.88	10	9	3	2
Octane	111-65-9	10.22	8	7	6	4
Hexanal	66-25-1	9.23	42	32	10	4
3-heptanone	106-35-4	12.36	8	0	n.d.	n.d.
2-heptanone	110-43-0	12.49	54	1	1	1
Pentanoic acid	109-52-4	12.57	41	28	20	22
Heptanal	111-71-7	12.78	10	10	4	2
Hexanoic acid	142-62-1	15.91	130	135	71	53
Octanal	124-13-0	16.18	5	3	2	1
Heptanoic acid	111-14-8	18.7	20	21	9	10
Undecane	1120-21-4	19.99	10	7	1	1
2-ethyl-hexanoic acid	149-57-5	20.31	86	67	19	9
Octanoic acid	124-07-2	21.68	34	41	22	19
Dodecane	112-40-3	23.19	21	16	4	3
Nonanoic acid	112-05-0	24.77	19	23	9	9
Formaldehyde DNPH	50-00-0	3.8	9	6	3	3
Acetaldehyde DNPH	75-07-0	6.1	31	15	6	n.d.
Acetone DNPH	67-64-1	9.9	33	30	13	7
Hexanal DNPH	66-25-1	31.9	98	30	10	2
Octenal DNPH	2548-87-0	34.4	62	13	8	1
TVOC*			570	490	240	170

* Without DNPH values

Table 3587-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a flooring varnish on glass plate

Sample	Flooring varnish 3587			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.484	<= 10	0.165	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.43	<= 1
[D] Σ VOC without LCI	no requirement		0.009	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.051	addit. inform.	0.009	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.485	key in the value manually!	0.170	key in the value manually!
[H] Σ VOC with LCI	0.459	addit. inform.	0.143	addit. inform.

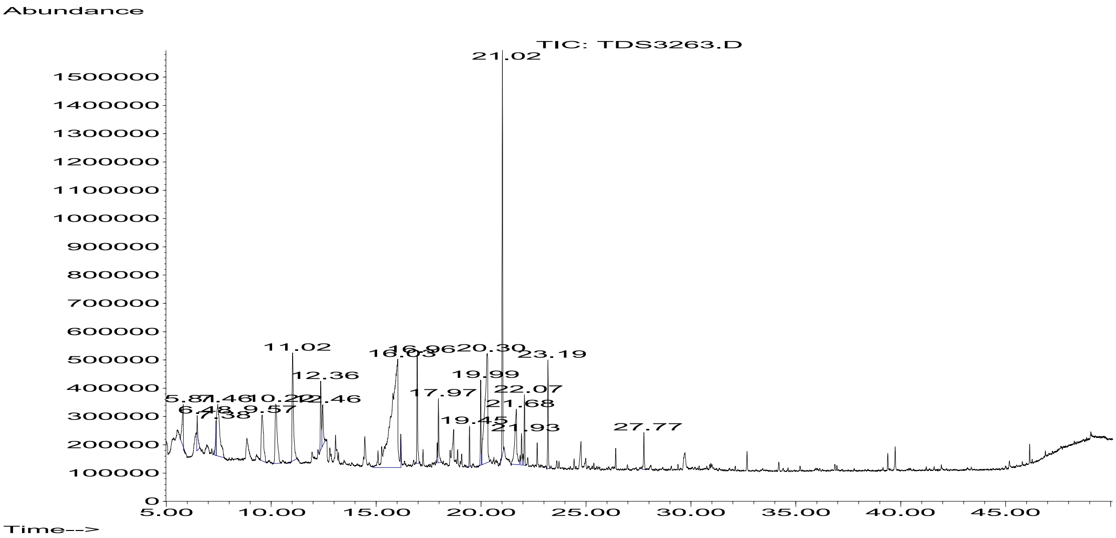


Figure 3587-1: GC/MS chromatogram on day 28 of emission testing on a flooring varnish on glass plate

Table 3587-3: Comprehensivedata of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	6	14.8	2.6	-2.9	0.8
3	9	14.6	2.7	-2.6	1.4
10	6	16.0	3.3	-2.8	0.3
28	5	11.8	2.8	-3.2	0.7

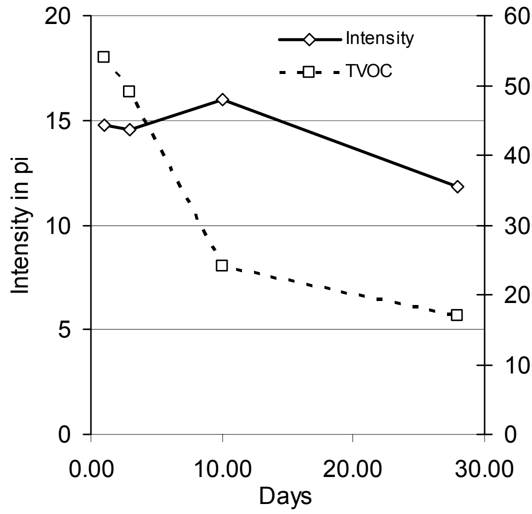


Figure 3587-2: Intensity and TVOC

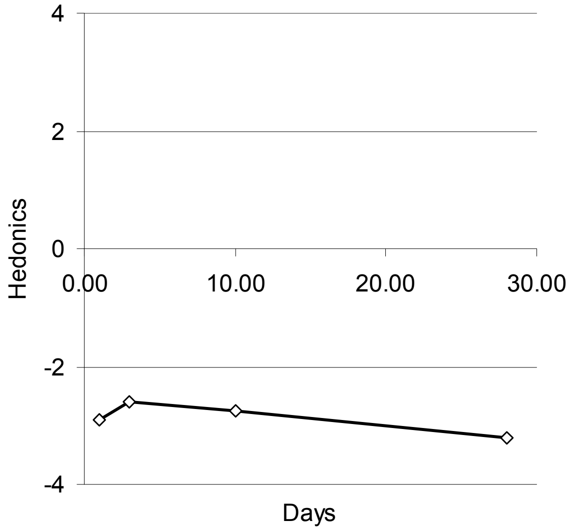


Figure 3587-3: Hedonics

3589 Laquer on beech wood board, manufacturer 21

Table 3589-1: Concentrations of organic compounds analysed from a laquer on beech wood 3625; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1 [µg/m³]	Day 3 [µg/m³]	Day 10 [µg/m³]	Day 28 [µg/m³]
Triethylamine	121-44-8	6.87	140	46	10	6
Acetic acid	64-19-7	8.74	79	13	23	18
1-butoxy-2-propanol	5131-66-8	14.37	140	25	6	1
Di-sec-butyl ether	6863-58-7	14.79	8	2	n.d.	n.d.
2-(2-ethoxyethoxy)-ethanol	111-90-0	16.29	3900	1200	340	120
1-methyl-2-pyrrolidinone	872-50-4	17.28	1100	860	420	140
Acetone DNPH	67-64-1	9.9		4	1	n.d.
TVOC*			5400	2100	800	290

* Without DNPH values

Table 3589-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a laquer on beech wood

Sample	Laquer3589			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	2.114	<= 10	0.291	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.22	<= 1
[D] Σ VOC without LCI	no requirement		0.128 !!	<= 0.1
[E] Σ carcinogens	3	<= 0.01	3 !!	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.004	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	2.538	key in the value manually!	0.421	key in the value manually!
[H] Σ VOC with LCI	0.870	addit. inform.	0.016	addit. inform.

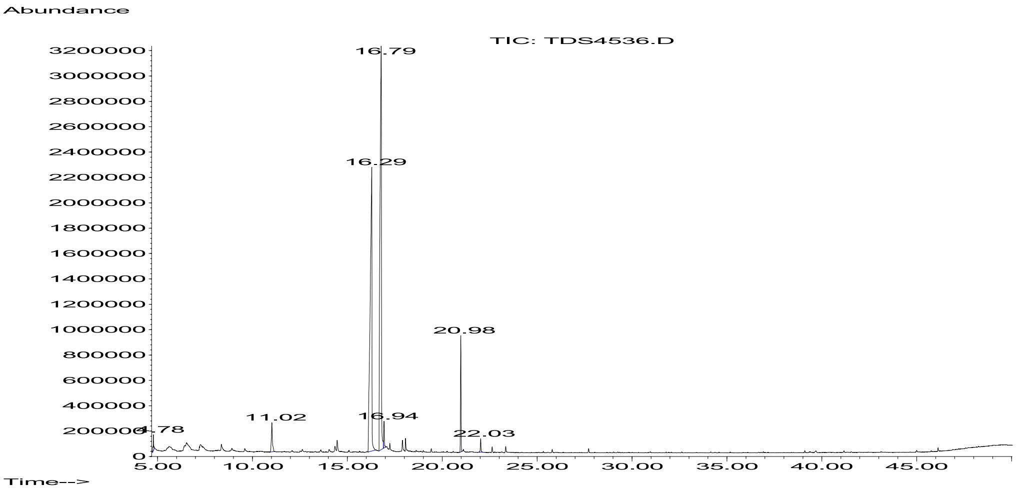


Figure 3589-1: GC/MS chromatogram on day 28 of emission testing on a laquer on beech wood

Table 3589-3: Comprehensivedata of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	13.3	1.6	-2.3	0.9
3	9	10.2	1.9	-1.8	1.1
10	8	11.3	2.2	-1.7	0.7
28	10	11.7	2.9	-1.7	1.0

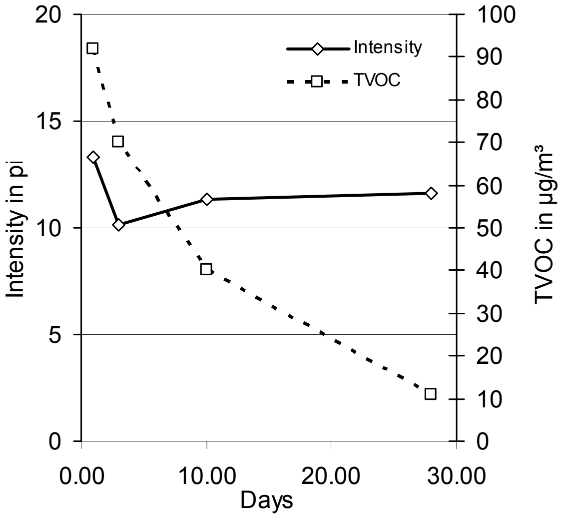


Figure 3589-2: Intensity and TVOC

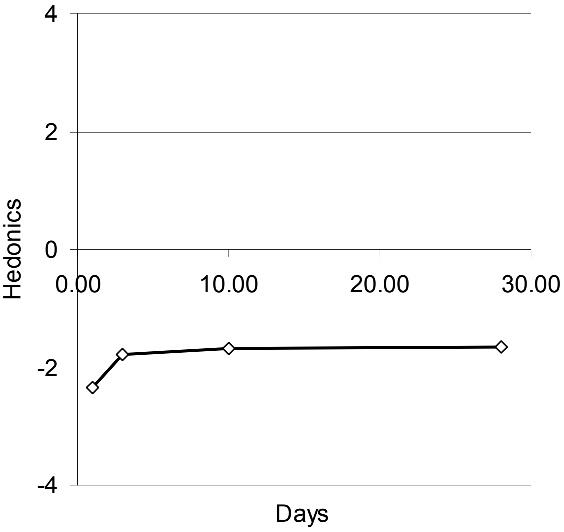


Figure 3589-3: Hedonics

3463 Dispersion wall paint (on glass fibre non-woven fabric), manufacturer 13

Table 3463-1: Concentrations of organic compounds analysed from a dispersion wall paint on glass fibre non-woven fabric (3444) with adhesive (3445) on glass plate; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.08	11	9	2	n.d.
n-butyl ether	107-21-1	13.53	6	n.d.	n.d.	n.d.
Propanoic acid butyl ester	4254-14-2	14.03	n.d.	n.d.	n.d.	n.d.
Methoxyphenyloxime*	142-96-1	14.10	2	n.d.	n.d.	n.d.
3-methyl-4-heptanone	590-01-2	14.71	2	n.d.	n.d.	n.d.
Phenol	108-95-2	16.47	1	23	n.d.	n.d.
Butanoic acid butyl ester	15726-15-5	16.94	2	n.d.	n.d.	n.d.
1-decanol	112-30-1	25.93	14	n.d.	1	n.d.
Hexanal	66-25-1	10.30	n.d.	1	n.d.	n.d.
Heptanal	111-71-7	13.64	n.d.	1	n.d.	n.d.
Benzyl alcohol	100-51-6	17.89	n.d.	7	n.d.	n.d.
2-ethyl-hexanoic acid	149-57-5	21.06	n.d.	n.d.	n.d.	n.d.
Butanedioic acid-bis(2-methylpropyl)-ester*	925-06-4	31.64	n.d.	7	n.d.	n.d.
Butanedioic acid methyl-bis(1-methylpropyl)-ester*	57983-31-0	34.26	n.d.	6	n.d.	n.d.
Adipic acid diisobutyl ester*	141-04-8	36.8	n.d.	4	3	n.d.
Formaldehyde DNPH	50-00-0	3.8	47	n.d.	5	5
TVOC**			28	48	4	0

* Suggestion of mass spectra library
** Without DNPH

Table 3463-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a dispersion wall paint on glass fibre non-woven fabric (3444) with adhesive (3445) on glass plate.

Sample	Dispersion wall paint 3463			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.110	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	5	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.106	addit. inform.	0	addit. inform.

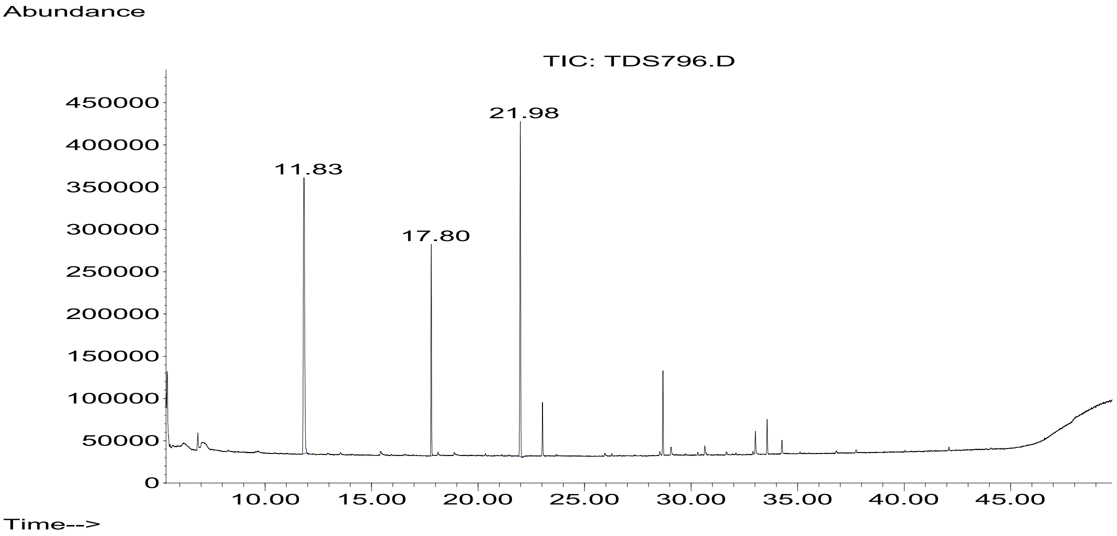


Figure 3463-1: GC/MS chromatogram on day 28 of emission testing on a dispersion wall paint on glass fibre non-woven fabric (3444) with adhesive (3445) on glass plate.

Table 3463-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	17.3	3.4	-3.7	0.7
3	8	17.6	4.3	-3.9	0.3
10	8	15.9	3.6	-2.3	2.5
28	9	5.5	2.8	-0.3	1.4

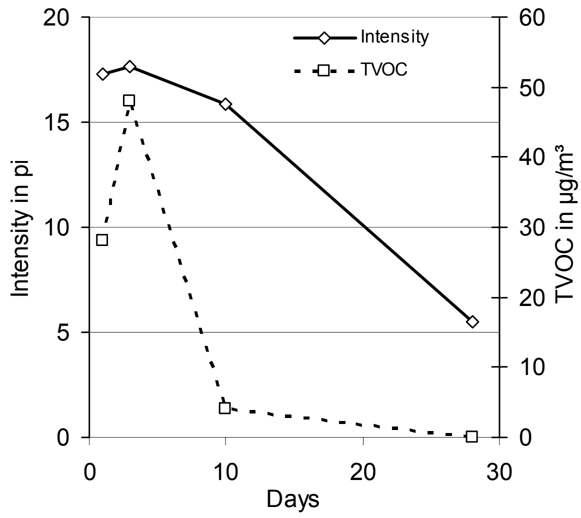


Figure 3463-2: Intensity and TVOC

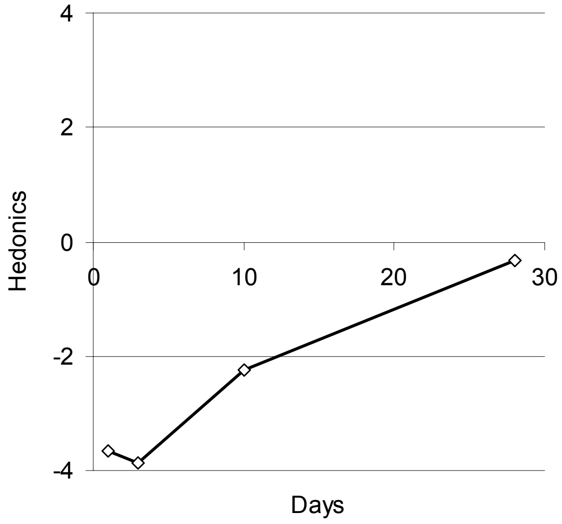


Figure 3463-3: Hedonics

3463A Dispersion wall paint (on glass plate), manufacturer 13

Table 3463A-1: Concentrations of organic compounds analysed from a dispersion wall paint on glass plate; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.08	11	10	0	n.d.
n-butyl ether	107-21-1	13.53	6	n.d.	n.d.	n.d.
Propanoic acid butyl ester	4254-14-2	14.03	n.d.	n.d.	n.d.	n.d.
Methoxyphenyloxime	142-96-1	14.1	2	n.d.	n.d.	n.d.
4-heptanone, 3-methyl-	590-01-2	14.71	2	n.d.	n.d.	n.d.
Phenol	108-95-2	16.47	1	n.d.	n.d.	n.d.
Butanoic acid butyl ester	15726-15-5	16.94	2	n.d.	n.d.	n.d.
1-decanol	112-30-1	25.93	14	n.d.	1	n.d.
Hexanal		10.3	n.d.	1	n.d.	n.d.
Heptanal	111-71-7	13.64	n.d.	1	n.d.	n.d.
Benzyl alcohol	100-51-6	17.89	n.d.	7	n.d.	n.d.
2-ethyl-hexanoic acid	149-57-5	21.06	n.d.	n.d.	n.d.	n.d.
Butanedioic acid-bis(2-methylpropyl)-ester	925-06-4	31.64	n.d.	7	n.d.	n.d.
Butanedioic acid-methyl-bis(1-methylpropyl)-ester	57983-31-0	34.26	n.d.	6	n.d.	n.d.
Hexanedioic acid-bis(2-methylpropyl)-ester	141-04-8	36.8	n.d.	4	3	n.d.
Formaldehyde DNPH	50-00-0	3.8	n.d.	1.5	n.d.	n.d.
TVOC**			39	35	6	0

* Suggestion of mass spectra library
** Without DNPH

Table 3463A-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from adispersion wall paint on glass plate.

Sample	Dispersion wall paint 3463A			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.035	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.0015	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.019	addit. inform.	0	addit. inform.

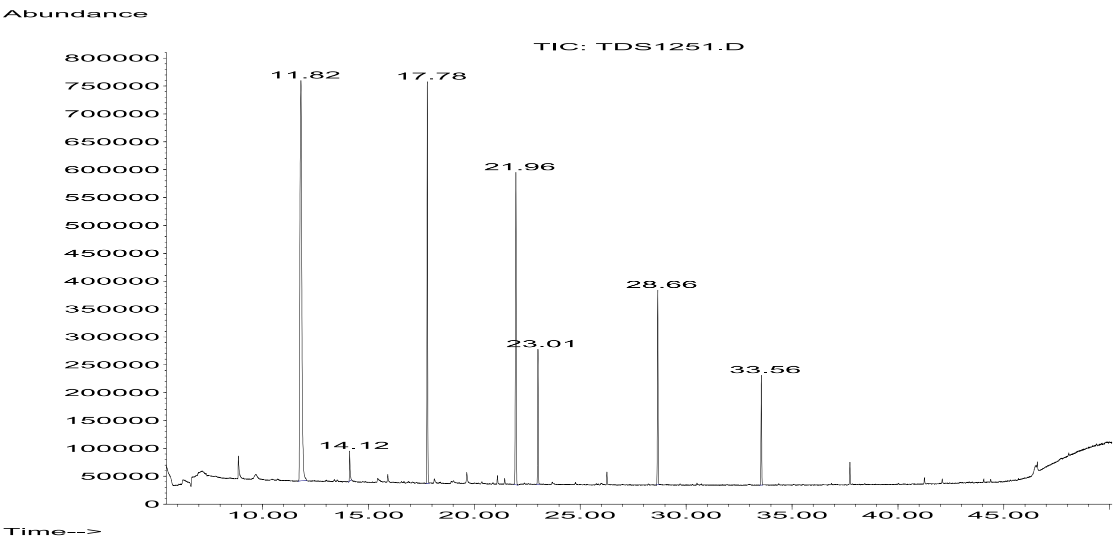


Figure 3463A-1: GC/MS chromatogram on day 28 of emission testing on a dispersion wall paint on glass plate.

Table 3463A-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	12.7	3.9	-3.1	1.6
3	8	15.5	3.9	-2.8	2.0
10	8	12.9	4.0	-2.4	1.7
28	10	10.7	3.2	-1.9	1.0

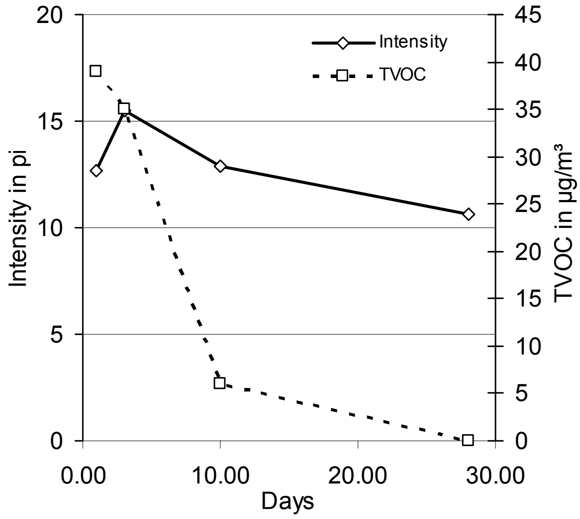


Figure 3463A-2: Intensity and TVOC

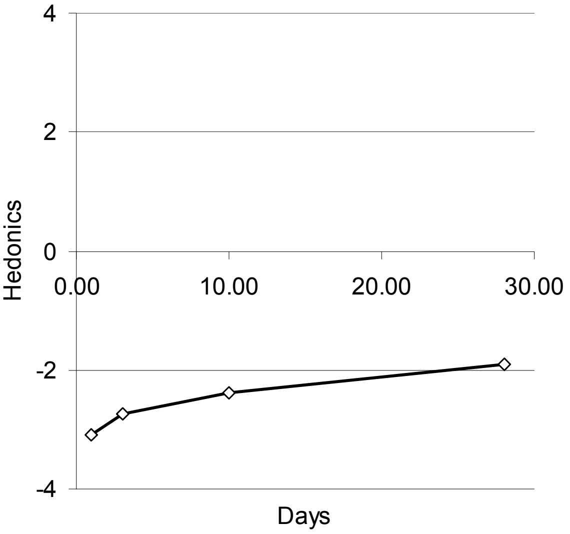


Figure 3463A-3: Hedonics

3558 Latex dispersion wall paint, manufacturer 2

Table 3558-1: Concentrations of organic compounds analysed from a latex dispersion wall paint on glass plate; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	6.57	n.d.	67	6	n.d.
Acetic acid butyl ester	123-86-4	9.8	n.d.	2	n.d.	n.d.
Ethylbenzene	100-41-4	11.37	n.d.	1	n.d.	n.d.
4-heptanone	123-19-3	11.57	n.d.	0	n.d.	n.d.
p-xylene	106-42-3	11.67	n.d.	1	n.d.	n.d.
Styrene	100-42-5	12.22	n.d.	14	n.d.	n.d.
n-buty ether	142-96-1	12.29	n.d.	4	n.d.	n.d.
Propanoic acid butyl ester	590-01-2	12.79	n.d.	4	n.d.	n.d.
4-heptanone, 3-methyl-	15726-15-5	13.45	n.d.	1	n.d.	n.d.
Hexanoic acid	142-62-1	15.4	n.d.	3	n.d.	n.d.
Butane acid butyl ester	109-21-7	15.64	n.d.	1	n.d.	n.d.
2-methyl-(2H)-isothiazolone (MIT)	2682-20-4	20.08	n.d.	120	43	n.d.
TVOC				220	48	

* Suggestion of mass spectra library

Table 3558-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a latex-dispersion wall paint on glass plate.

Sample	Latex-dispersion wall paint 3558			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.211	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.078	addit. inform.	0	addit. inform.

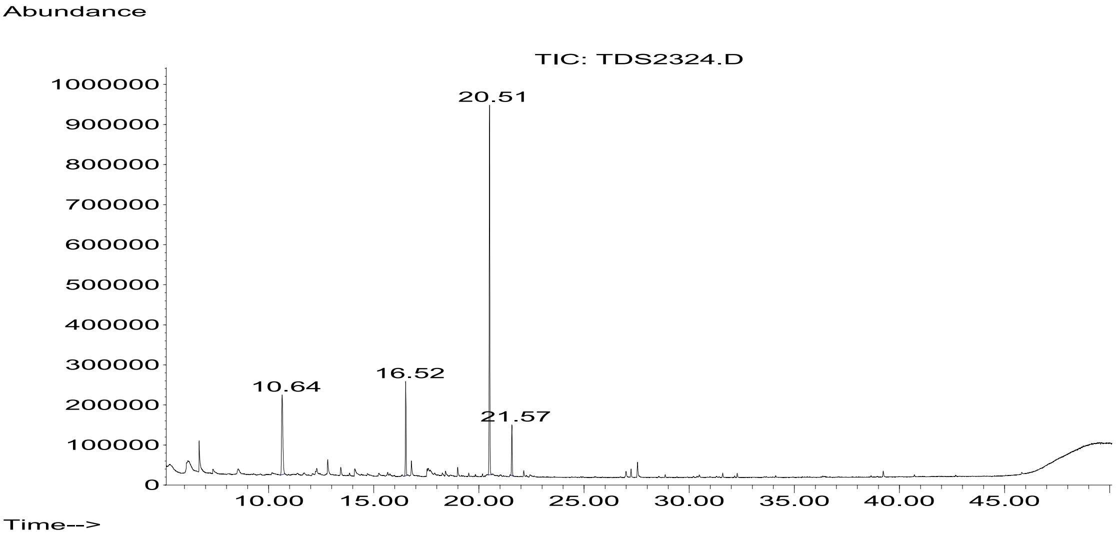


Figure 3558-1: GC/MS chromatogram on day 28 of emission testing on a latex-dispersion wall paint on glass plate.

Table 3558-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	5	16.4	2.3	-3.7	0.4
3	6	17.7	2.9	-3.1	0.7
10	5	16.7	3.1	-3.2	0.5
28	7	9.7	4.2	-2.0	1.9

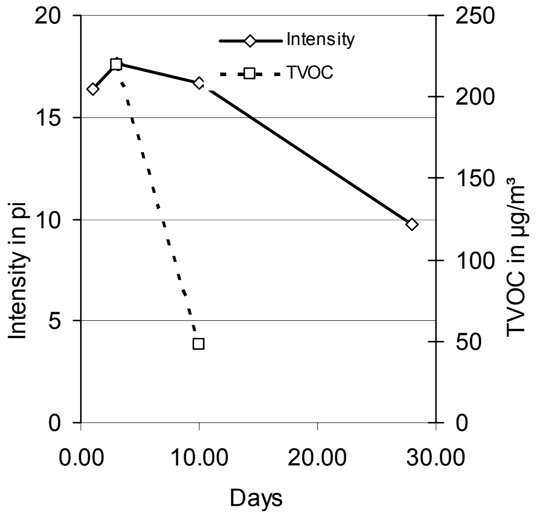


Figure 3558-2: Intensity and TVOC

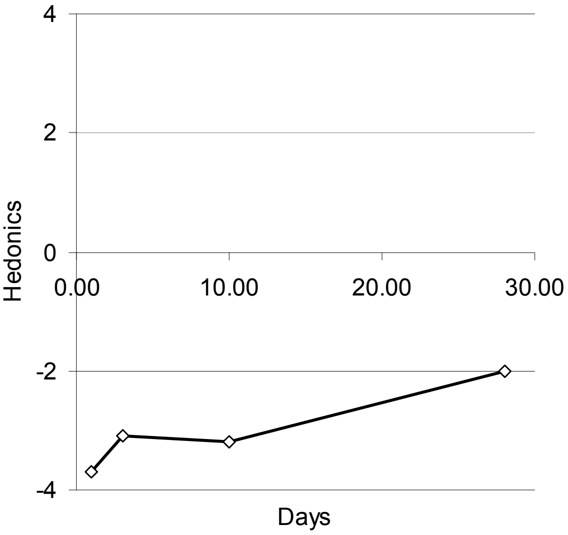


Figure 3558-3: Hedonics

3584 Dispersion wall paint (on plasterboard with primer), manufacturer 15

Table 3584-1: Concentrations of organic compounds analysed from a dispersion wall paint plasterboard 3546 with primer 3544; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances		CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid		64-19-7	6.36		10	n.d.	n.d.
1,2-ethanediol		107-21-1	7.87		n.d.	n.d.	n.d.
1,2-propanediol		57-55-6	8.7		16	n.d.	n.d.
2,2'-oxybis-ethanol		111-46-6	14.7		n.d.	n.d.	n.d.
2-(2-butoxyethoxy)-ethanol		112-34-5	21.99		n.d.	n.d.	n.d.
Dipropylene glycol-mon-n-butylether*		35884-42-5	24.21		11	n.d.	n.d.
Dipropylene glycol-mon-n-butylether*			24.67		20	n.d.	n.d.
Formaldehyde	DNPH	50-00-0	3.8	21	3	1	2
TVOC**					55		

* Suggestion of mass spectra library
** Without DNPH

Table 3584-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a dispersion wall paint on plasterboard 3546 with primer 3544.

Sample	Dispersion wall paint 3584			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.055	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.003	addit. inform.	0.002	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.025	key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.055	addit. inform.	0	addit. inform.

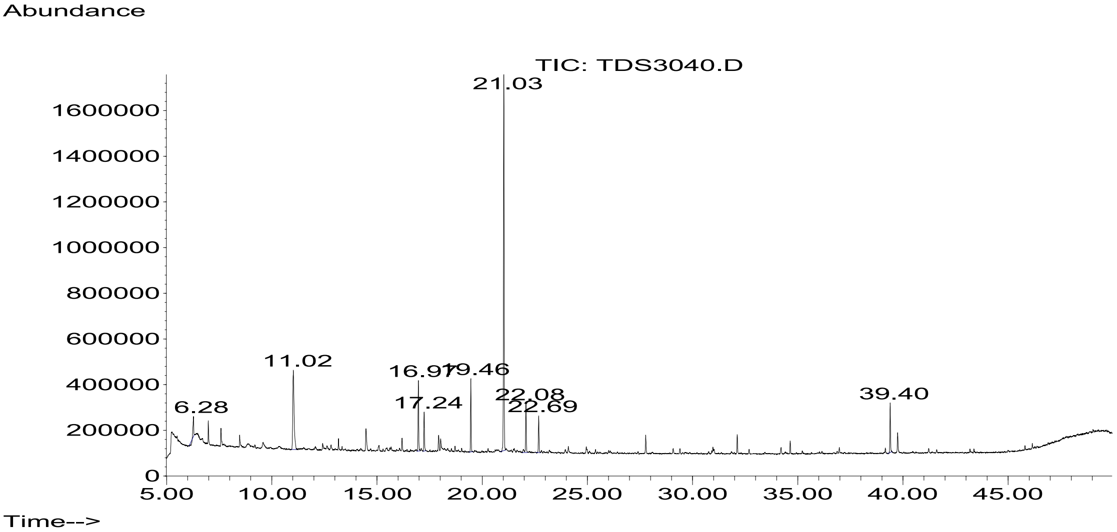


Figure 3584-1: GC/MS chromatogram on day 28 of emission testing on a dispersion wall paint on plasterboard 3546 with primer 3544.

Table 3584-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	5	9.4	3.9	-2.4	1.0
3	6	10.3	1.9	-2.2	0.2
10	8	8.2	3.1	-1.7	1.1
28	7	9.6	2.2	-1.9	0.5

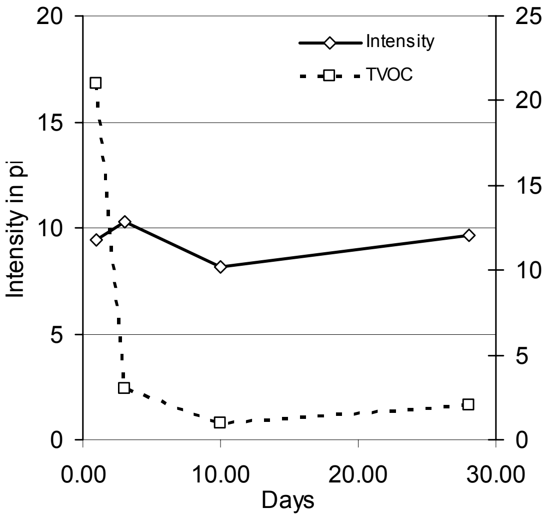


Figure 3584-2: Intensity and TVOC

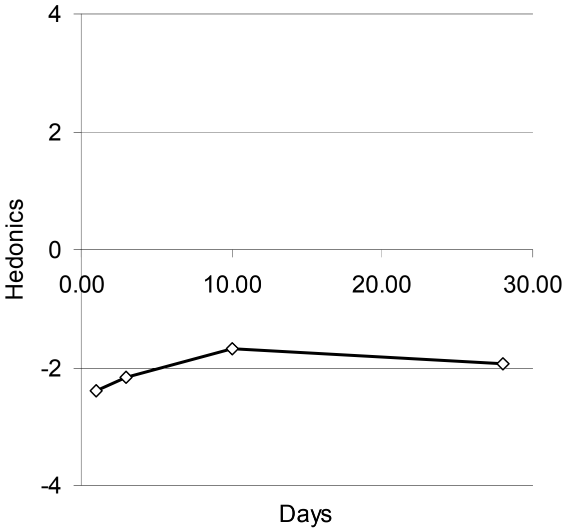


Figure 3584-3: Hedonics

3586 Dispersion wall paint 1, manufacturer 20

Table 3586-1: Concentrations of organic compounds analysed from a dispersion wall paint on glass plate; 20-litre chamber, $q = 1\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	6.36	140	130	32	2
2-methyl-(2H)-isothiazolone	2682-20-4	20.58	350	180	160	16
2-(2-butoxyethoxy)-ethanol	112-34-5	21.98	11	2	n.d.	n.d.
Decamethycyclopentasiloxane		22.09	1	n.d.	2	1
2-(2-hydroxypropoxy)-2-propanol*	106-62-7	23.94	15	1	n.d.	n.d.
2-(2-hydroxypropoxy)-2-propanol*		24.09	17	1	n.d.	n.d.
Unknown VOC**		30.98	5	3	2	n.d.
Unknown VOC mass 59, 117, 161**		32.33	8	5	6	1
Phthalate**		39.73	2	2	2	1
Formaldehyde DNPH	50-00-0	3.8	65	15	5	2
TVOC**			550	320	200	21

* Suggestion of mass spectra library
** Generalised name, no exact specification possible
*** Without DNPH

Table 3586-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a dispersion wall paint on glass plate.

Sample	Dispersion wall paint 3586			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.136	<= 10	0.018	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.016	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.015	addit. inform.	0.002	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.130	key in the value manually!	0.050	key in the value manually!
[H] Σ VOC with LCI	0.126	addit. inform.	0	addit. inform.

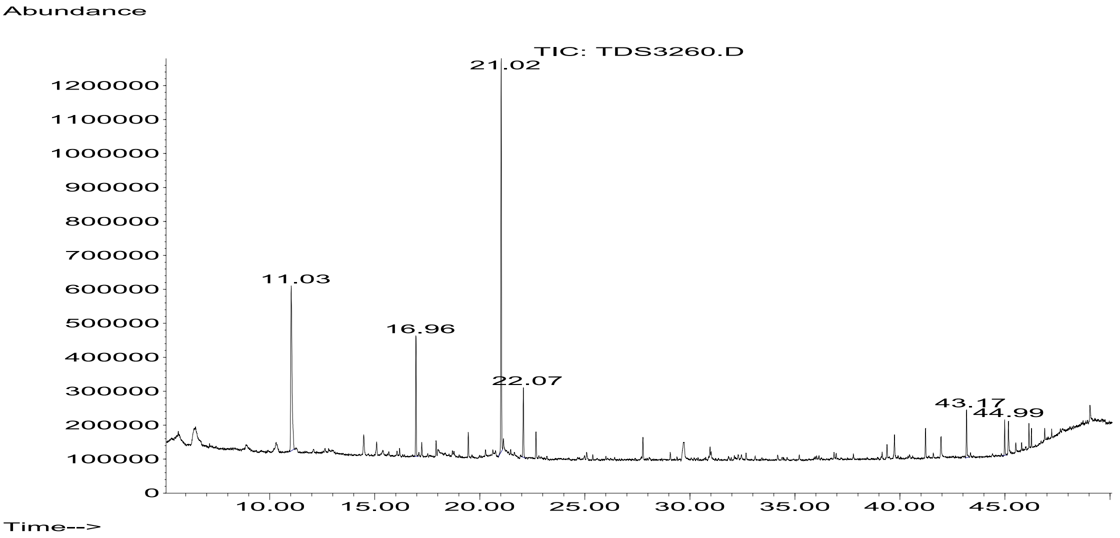


Figure 3586-1: GC/MS chromatogram on day 28 of emission testing on a dispersion wall paint on glass plate.

Table 3586-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	6	13.8	2.9	-2.9	0.6
3	9	13.4	2.3	-2.9	0.9
10	6	15.5	1.9	-2.9	0.8
28	5	9.0	1.4	-2.4	1.1

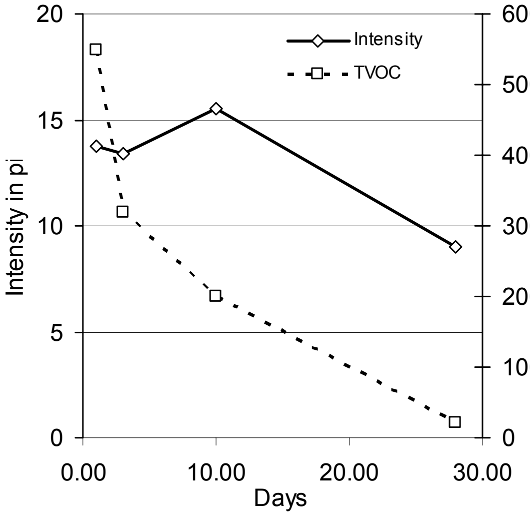


Figure 3586-2: Intensity and TVOC

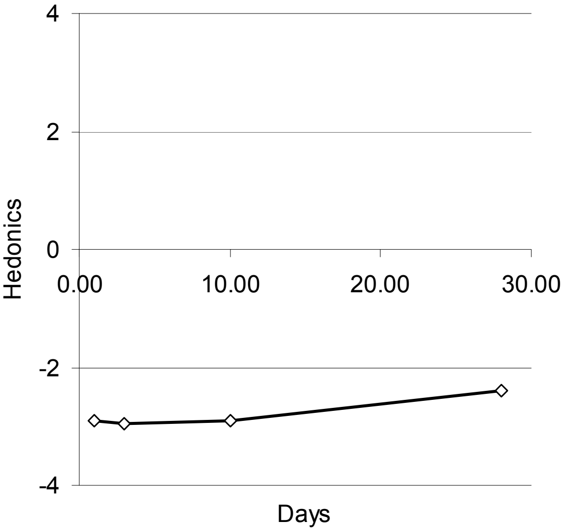


Figure 3586-3: Hedonics

3626 Dispersion wall paint 2, manufacturer 20

Table 3626-1: Concentrations of organic compounds analysed from a dispersion wall paint on glass plate; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	**CAS number**	**RT [min]**	**Day 1**	**Day 3**	**Day 10**	**Day 28**
Acetic acid	64-19-7	7.37	60	60	6	n.d.
Hexamethylcyclotrisiloxane	541-05-09	11.01	10	34	5	4
Octamethylcyclotetrasiloxane	556-67-2	16.94	2	4	1	n.d.
2-ethyl-1-hexanol	104-76-7	17.25	10	1	n.d.	n.d.
Acetophenone	98-86-2	17.89	3	5	1	n.d.
Nonanal	124-19-6	19.42	6	4	1	n.d.
2-methyl-(2H)-isothiazolone	2682-20-4	20.63	120	69	n.d.	n.d.
Decamethylcyclopentasiloxane	541-02-6	22.04	0	1	n.d.	n.d.
Decanal	112-31-2	22.64	3	2	n.d.	n.d.
Unknown VOC *		32.14	7	4	n.d.	n.d.
Unknown VOC *		32.28	12	8	n.d.	n.d.
Unknown VOC *		32.42	10	6	n.d.	n.d.
Formaldehyde DNPH	50-00-0	3.8	0	7	4	1
TVOC**			240	200	15	4

* Generalised name, no exact specification possible
** Without DNPH

Table 3626-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a dispersion wall paint on glass plate.

Sample	Dispersion wall paint 3626			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.193	<= 10	0.004	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.004	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001
This block provides additional information				
[F] VVOC (< C_6)	0.007	addit. inform.	0.001	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.343	key in the value manually!	0.024	key in the value manually!
[H] Σ VOC with LCI	0.062	addit. inform.	0	addit. inform.

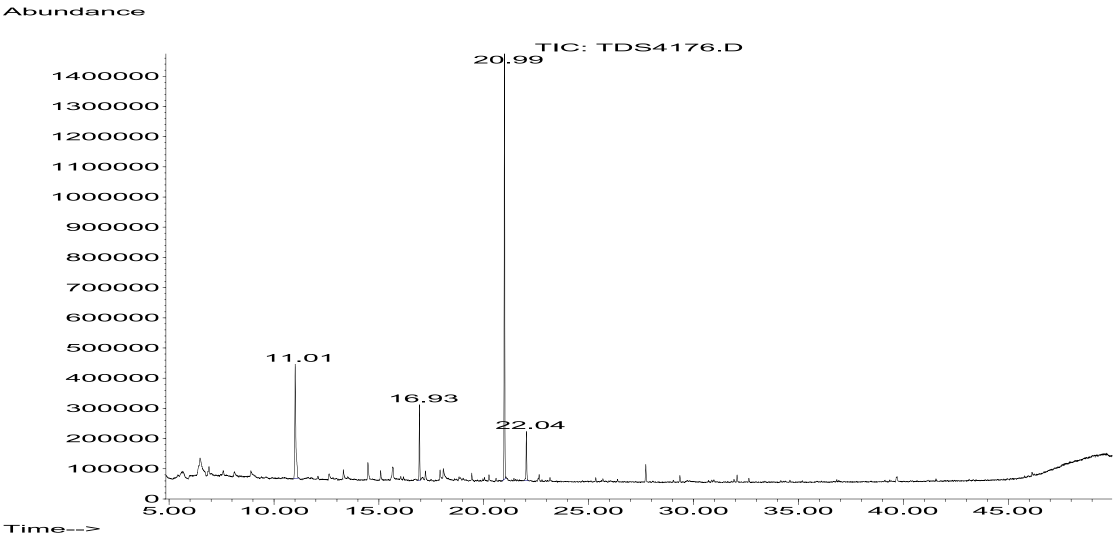


Figure 3626-1: GC/MS chromatogram on day 28 of emission testing on a dispersion wall paint on glass plate.

Table 3626-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	8	9.9	4.0	-1.8	1.1
3	8	8.3	1.7	-1.4	0.6
10	7	9.5	2.1	-0.6	1.2
28	7	9.3	2.9	0.8	1.5

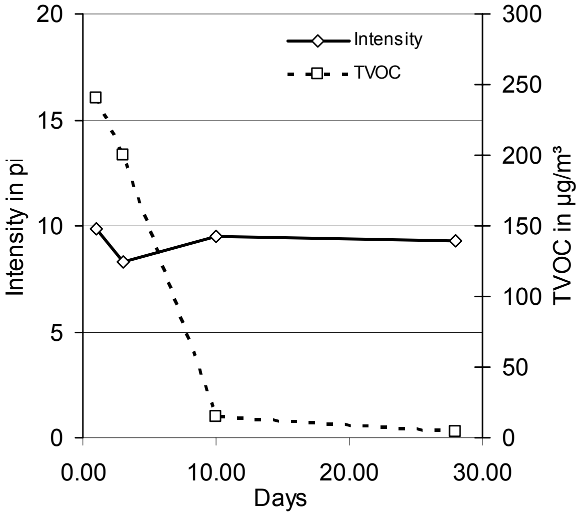


Figure 3626-2: Intensity and TVOC

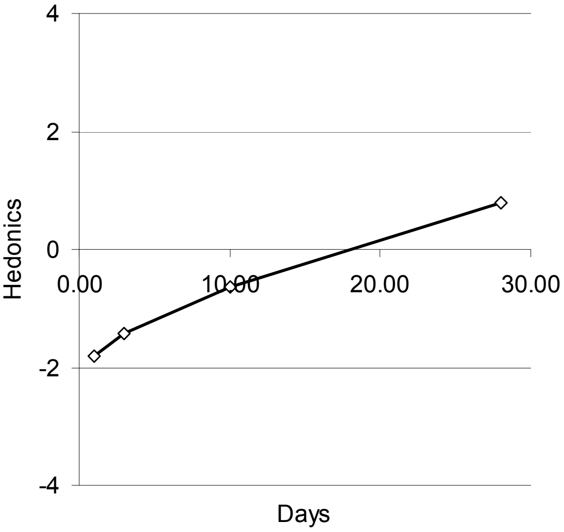


Figure 3626-3: Hedonics

3690 Latex dispersion wall paint, manufacturer 21

Table 3690-1: Concentrations of organic compounds analysed from a latex dispersion wall paint on glass plate; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Propanediol	4254-14-2	9.24	480	120	n.d.	n.d.
2-ethyl-1hexanol	104-76-7	17.21	20	10	n.d.	n.d.
2-ethylhexylacetate	103-09-3	21.01	56	26	17	7
2-propanoic acid ester*		23.55	2	0	n.d.	0
Propanoic acid ester*		23.88	9	6	n.d.	n.d.
Unknown VOC**		23.94	8	6	n.d.	n.d.
Unknown glycol**		24.03	13	8	n.d.	n.d.
Cyclooctane	292-64-8	24.95	17	15	n.d.	n.d.
Dimethyl phthalate	131-11-3	29.64	4	7	6	2
Glycol** 41, 59, 103, 117, 161		31.76	2	5	2	n.d.
Alkane**		31.94	3	5	3	n.d.
Glycol** 41, 59, 103, 117, 161		32.14	29	40	33	13
Glycol** 41, 59, 103, 117, 161		32.29	50	73	66	28
Glycol** 41, 59, 103, 117, 161		32.46	30	40	41	20
Glycol** 45, 59, 101, 117		32.52	1	3	4	3
Formaldehyde DNPH	50-00-0	3.8	30	14	8	3
TVOC***			710	350	170	72

* Suggestion of mass spectra library
** Generalised name, no exact specification possible
*** Without DNPH

Table 3690-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a latex dispersion wall paint on glass plate.

Sample	Latex dispersion wall paint 3690			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m^3]		Day 28 [mg/m^3]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.356	<= 10	0.073	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.066	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.014	addit. inform.	0.003	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent	0.363	key in the value manually!	0.173	key in the value manually!
[H] Σ VOC with LCI	0.047	addit. inform.	0.007	addit. inform.

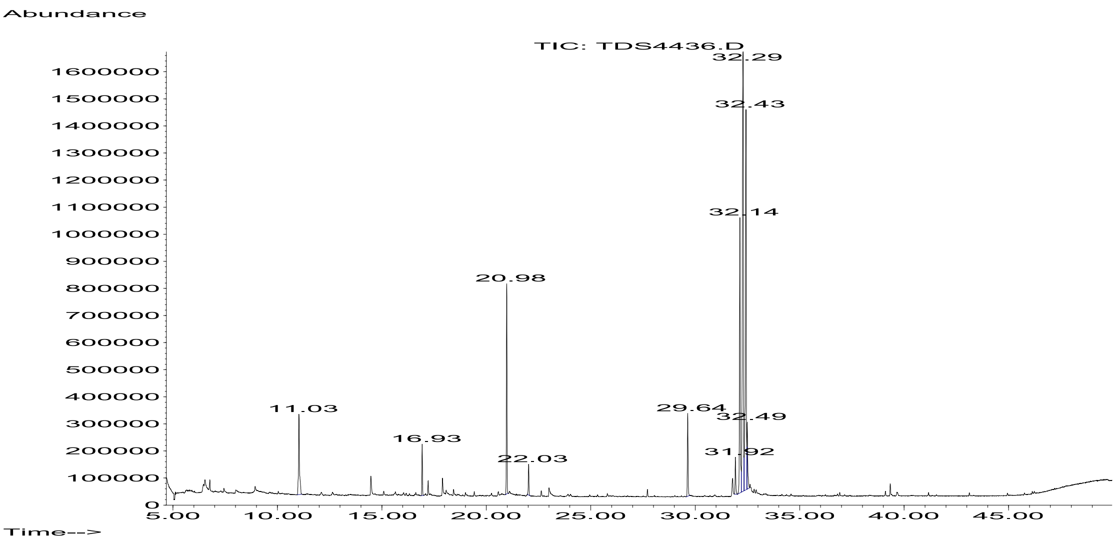


Figure 3690-1: GC/MS chromatogram on day 28 of emission testing on a latex dispersion wall paint on glass plate.

Table 3690-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	7	12.2	2.9	-1.8	1.5
3	9	8.5	1.8	-1.4	1.1
10	7	10.9	1.9	-2.0	0.6
28	9	8.9	1.2	-0.6	1.0

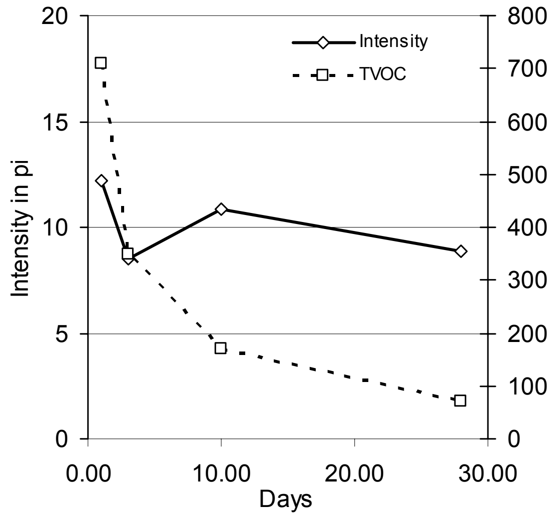


Figure 3690-2: Intensity and TVOC

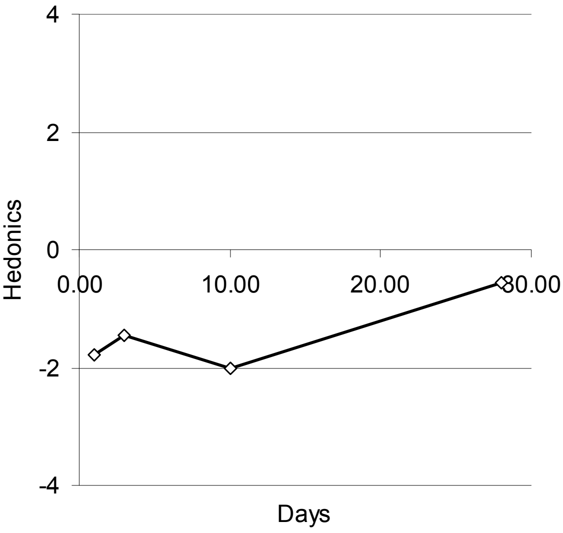


Figure 3690-3: Hedonics

Adhesives

3400 Flooring adhesive, manufacturer 1

Table 3400-1: Concentrations of organic compounds analysed from a flooring adhesive on glass plate; 20-litre chamber, $q = 3\ m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28	Day 67
Propylene glycol	57-55-6	9.70	120	53	38	17	n.d.
Acetic acid butyl ester	123-86-4	10.95	31	9	n.d.	n.d.	n.d.
n-butyl ether	142-96-1	13.54	18	6	n.d.	n.d.	n.d.
Propanoic acid butyl ester	590-01-2	14.03	16	8	n.d.	n.d.	n.d.
alpha-pinene	80-56-8	15.4	11	5	1	n.d.	n.d.
beta-pinene	127-91-3	16.74	3	1	n.d.	n.d.	n.d.
Butanoic acid butyl ester	109-21-7	16.94	4	2	n.d.	n.d.	n.d.
o-cumene	527-84-4	18.09	4	2	1	n.d.	n.d.
Acetophenone	98-86-2	18.81	4	2	2	1	n.d.
Terpene	113003-13-7	19.47	5	1	n.d.	n.d.	n.d.
Nonanal	124-19-6	20.32	3	2	3	2	n.d.
exo-fenchol	22627-95-8	20.87	3	1	n.d.	n.d.	n.d.
Octanoic acid methyl ester	111-11-5	21.04	3	1	n.d.	n.d.	n.d.
Terpene*	498-81-7	21.86	4	3	n.d.	n.d.	n.d.
Borneol	507-70-0	22.53	3	1	n.d.	n.d.	n.d.
Terpene*	562-74-3	22.96	4	2	n.d.	n.d.	n.d.
Terpene*	10482-56-1	23.32	23	13	5	1	n.d.
1-methoxy-4-(1-propenyl)-benzene	104-46-1	23.37	9	4	n.d.	n.d.	n.d.
Terpene*	128-50-7	26.29	71	40	17	5	2
Decanoic acid methyl ester	110-42-9	27.54	18	4	1	n.d.	n.d.
Nopyl acetate	128-51-8	30.56	16	9	4	1	n.d.
1,4-methanoazulene**	475-20-7	30.67	11	5	2	2	n.d.
Caryophyllene	87-44-5	30.97	9	4	1	n.d.	n.d.
alpha-caryophyllene	6753-98-6	31.87	5	3	n.d.	n.d.	n.d.
Pentadecane	629-62-9	33.09	2	2	1	n.d.	n.d.
Dodecanoic acid methyl ester**	111-82-0	33.20	18	15	12	4	2
Methyltetradecanoate**	124-10-7	38.03	8	7	9	7	8
Hexadecane acid methyl ester**	112-39-0	42.27	26	33	37	35	43
Octadecane acid methyl ester**		46.04	n.d.	n.d.	n.d.	n.d.	3
TVOC			459	220	123	40	3

* Generalised name, no exact specification possible
** Suggestion of mass spectra library

Table 3400-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a flooring adhesive on glass plate.

Sample	Flooring adhesive 3400			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.236	<= 10	0.041	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0.042	<= 0.1
[C] R (dimensionless)	no requirement		0.07	<= 1
[D] Σ VOC without LCI	no requirement		0.006	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.165	addit. inform.	0.033	addit. inform.

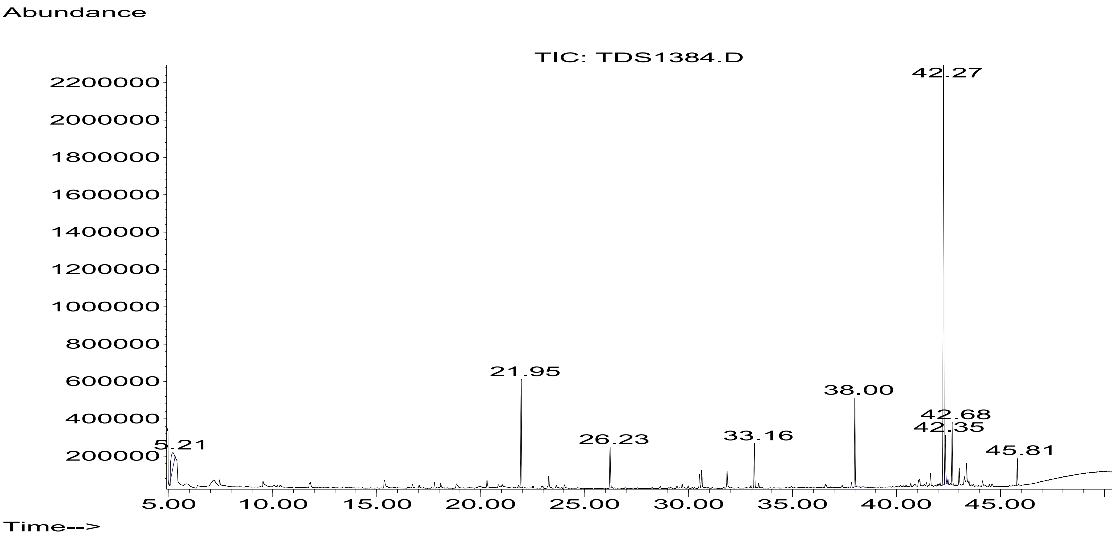


Figure 3400-1: GC/MS chromatogram on day 28 of emission testing on a flooring adhesive on glass plate.

Table 3400-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	9	18.4	3.9	-2.9	1.9
3	7	19.1	3.0	-3.3	0.9
10	9	17.9	2.4	-3.4	0.7
28	8	14.8	2.5	-2.6	1.3

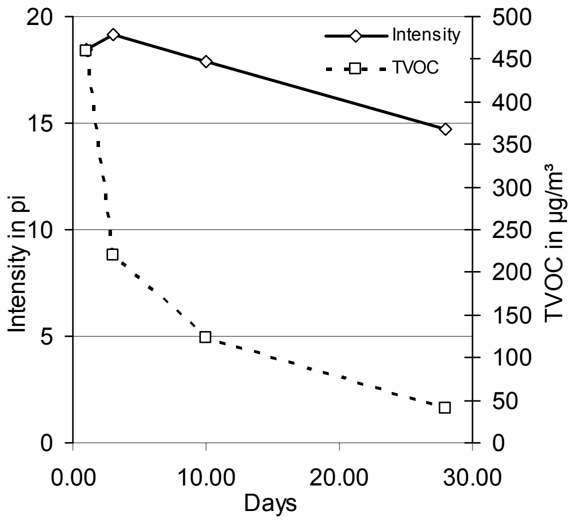


Figure 3400-2: Intensity and TVOC

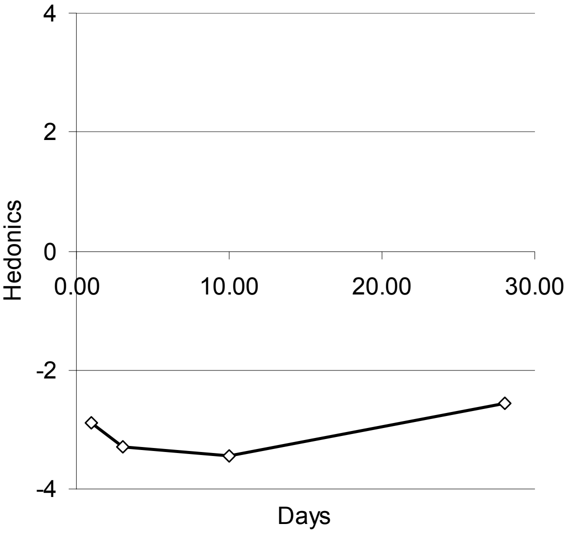


Figure 3400-3: Hedonics

3405 Flooring adhesive, manufacturer 14

Table 3405-1: Concentrations of organic compounds analysed from a flooring adhesive on glass plate; 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.9	58	4	n.d.	n.d.
1-butyl acetate	123-86-4	12.12	61	n.d.	n.d.	n.d.
n-butyl ether	142-96-1	14.99	291	1	n.d.	n.d.
Propanoic acid butyl ester*	590-01-2	15.52	86	12	n.d.	n.d.
3-methyl-4-heptanone*		16.29	46	15	8	10
Butanoic acid butyl ester	109-21-7	18.72	40	1	n.d.	n.d.
2-ethyl-1-hexanol	104-76-7	20.12	516	157	10	3
2-ethylhexyl acetat	103-09-3	24.36	10	n.d.	n.d.	n.d.
TVOC			1110	190	19	10

* Suggestion of mass spectra library

Table 3405-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a flooring adhesive on glass plate.

Sample	Flooring adhesive 3405			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³] measured val.	requirement	Day 28 [mg/m³] measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.188	<= 10	0.013	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.010	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.157	addit. inform.	0.003	addit. inform.

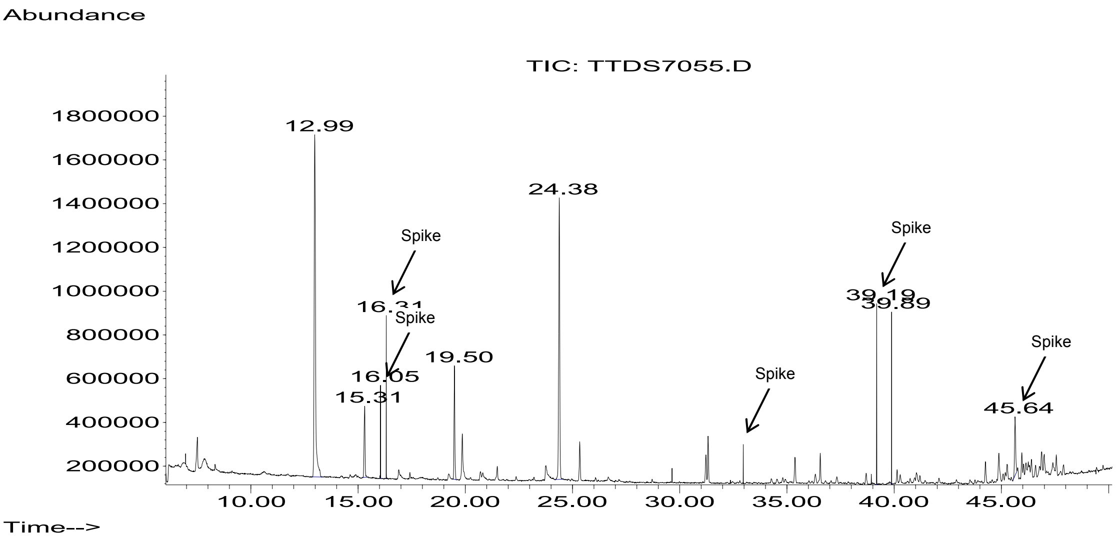


Figure 3405-1: GC/MS chromatogram on day 28 of emission testing on a flooring adhesive on glass plate.

Table 3405-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	10	17.1	3.2	-3.5	0.5
3	7	18.0	2.2	-3.6	0.5
10	9	13.7	1.8	-3.0	1.1
28	n.m.	14.0	n.m.	-3.0	n.m.

n.m.: not measured

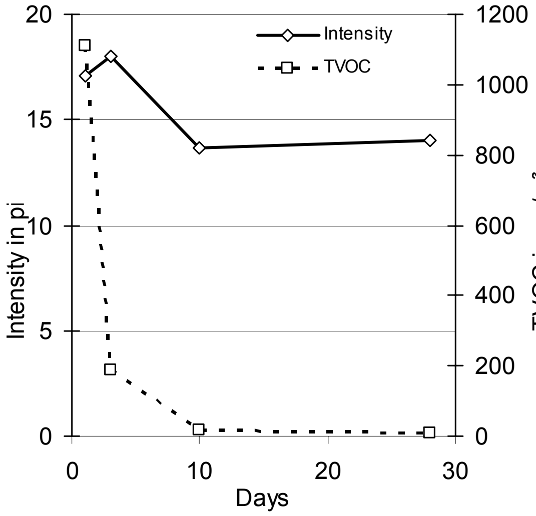


Figure 3405-2: Intensity and TVOC

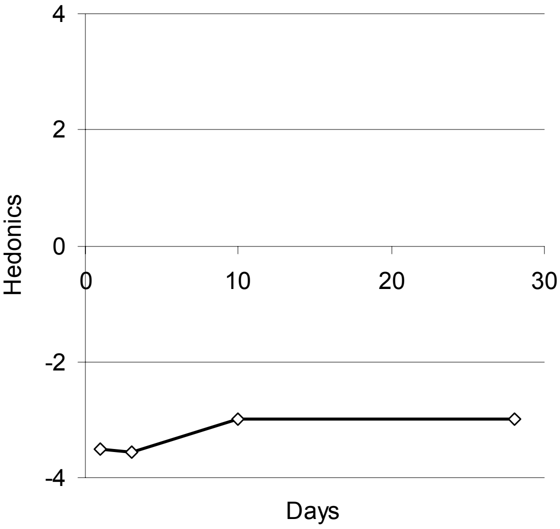


Figure 3405-3: Hedonics

3445 Adhesive for glass fibre non-woven fabric, manufacturer 15

Table 3445-1: Concentrations of organic compounds analysed from an adhesive for glass fibre non-woven fabric on glass plate 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.0	46	45	19	n.d.
Benzaldehyde	100-52-7	15.40	2	3	0	3
Butanoic acid-2-propenyl ester*	2051-78-7*	28.59	24	14	4	8
Dimethyl phthalate	131-11-3	30.67	12	9	6	13
2-butenedioic acid-(Z)-dibutyl ester*	105-76-0*	33.1	39	25	17	25
Formaldehyde DNPH	50-00-0	3.8	25	24	11	7
TVOC**			120	96	47	49

* Suggestion of mass spectra library

** Without DNPH values

Table 3445-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an adhesive for glass fibre non-woven fabric on glass plate.

Sample	Adhesive for glass fibre non-woven fabric 3445			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.096	<= 10	0.049	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0.049	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.024	addit. inform.	0.007	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.045	addit. inform.	0	addit. inform.

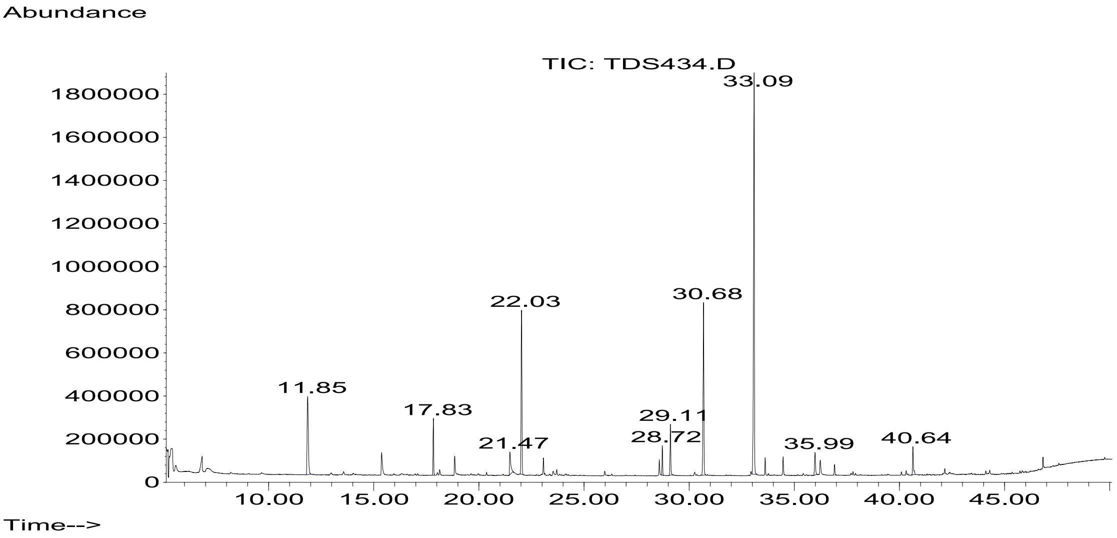


Figure 3445-1: GC/MS chromatogram on day 28 of emission testing on an adhesive for glass fibre non-woven fabric on glass plate.

Table 3445-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	13	2.7	1.7	-0.3	1.0
3	9	12.0	5.1	-2.9	0.9
10	13	13.5	3.5	-2.5	1.9
28	7	14.0	2.9	-3.0	0.9

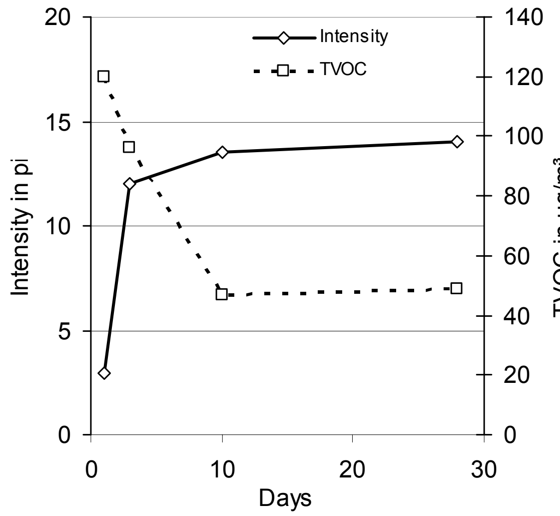


Figure 3445-2: Intensity and TVOC

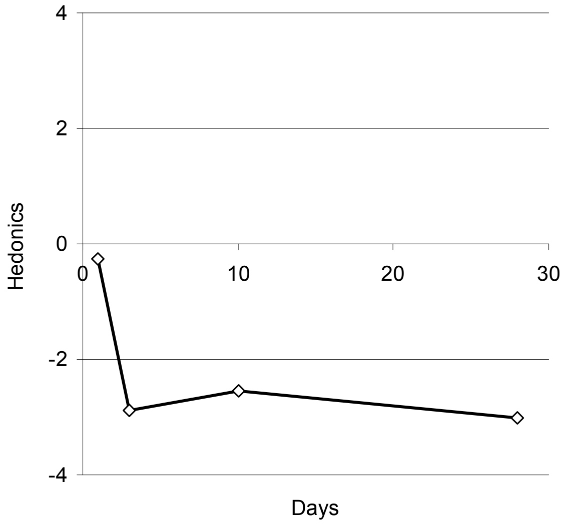


Figure 3445-3: Hedonics

3461 Adhesive for cork parquet, manufacturer 1

Table 3461-1: Concentrations of organic compounds analysed from an adhesive for cork parquet on glass plate 20-litre chamber, q = 1.25 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	6.87	34	n.d.	n.d.	n.d.
Propionic acid	79-09-4	8.13	70	n.d.	n.d.	n.d.
Ethyl benzene	100-41-4	11.35	25	1	n.d.	n.d.
p-xylene	106-42-3	11.45	2	n.d.	n.d.	n.d.
n-butyl ether	142-96-1	12.33	31	2	n.d.	n.d.
o-xylene	95-47-6	14.22	4	n.d.	n.d.	n.d.
Propanoic acid butyl ester	590-01-2	12.81	4	1	n.d.	n.d.
1-propenyl benzene	637-50-3	13.46	41	8	n.d.	n.d.
n-propyl benzene*	103-65-1	15.6	2	n.d.	n.d.	n.d.
n-propyl benzene*	103-65-1	14.43	13	2	n.d.	n.d.
Phenol	108-95-2	15.11	4	1	n.d.	n.d.
Isopropyl benzene	98-82-8	16.79	4	1	n.d.	n.d.
Butanoic acid butyl ester	109-21-7	15.72	7	2	n.d.	n.d.
Cyclohexane	110-82-7	15.81	2	n.d.	n.d.	n.d.
Diethylene glycol monobutyl ether*	112-34-5	21.5	21	13	5	n.d.
Dibutyl phthalate	100-52-7	39.26	7	5	2	n.d.
Formaldehyde DNPH	50-00-0	3.8	9	13	16	5
TVOC**			274	41	9	1

* Suggestion of mass spectra library
** Without DNPH values

Table 3461-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from an adhesive for cork parquet on glass plate.

Sample	Adhesive for cork parquet 2004 - 3461			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.027	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.013	addit. inform.	5	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0	addit. inform.	0	addit. inform.

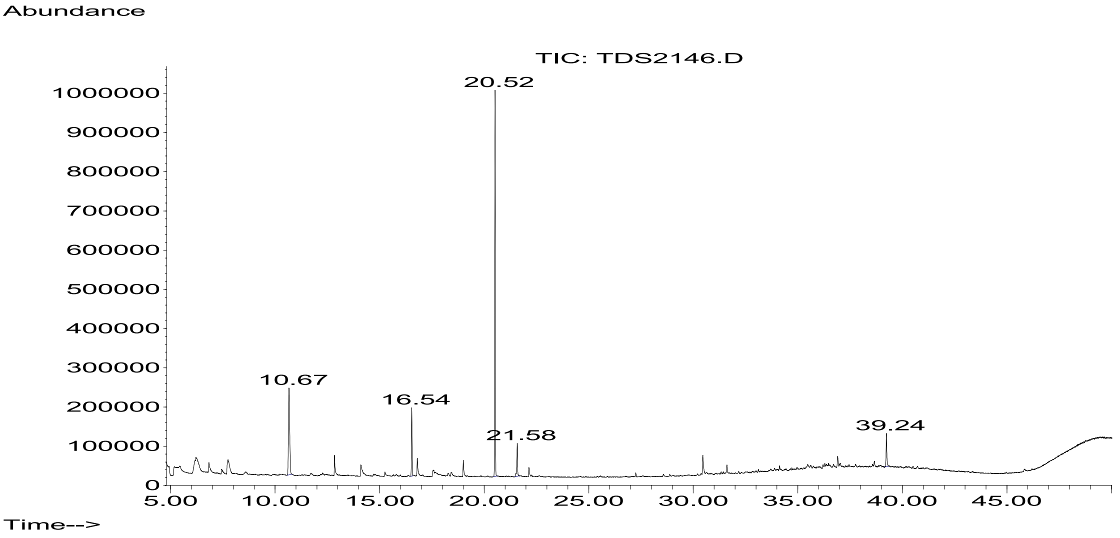


Figure 3461-1: GC/MS chromatogram on day 28 of emission testing on an adhesive for cork parquet on glass plate.

Table 3461-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	2	17.3	4.3	-4.0	0.0
3	5	12.5	1.6	-2.3	1.0
10	5	14.7	2.6	-3.1	0.7
28	6	14.4	1.7	-2.3	0.8

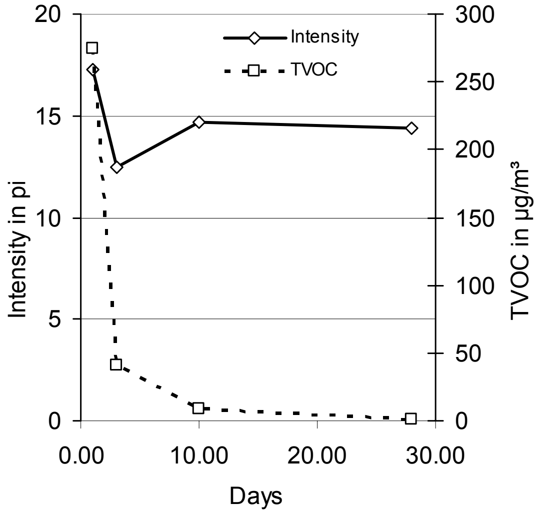


Figure 3461-2: Intensity and TVOC

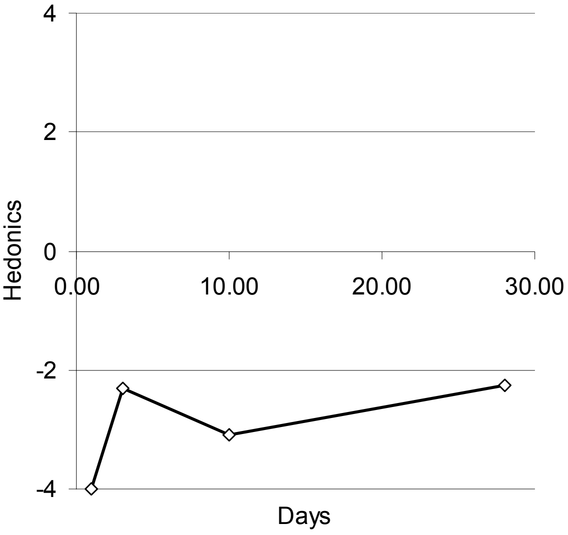


Figure 3461-3: Hedonics

Others

3444 Glass fibre non-woven fabric with adhesive, manufacturer 15

Table 3444-1: Concentrations of organic compounds analysed from a glass fibre non-woven fabric with adhesive (3445) on glass plate; 20-litre chamber, q = 1.25 m^{3}m^{-2}h^{-1}

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Acetic acid	64-19-7	7.01	220	20	3	2
Ethanediol	107-21-1	9.23	79	130	13	17
1-(2-propenyloxy)-2-propanol	21460-36-6	12.02	6	n.d.	n.d..	n.d..
n-butyl ether	142-96-1	13.5	2	n.d.	n.d..	n.d..
1-[1-methyl-2-(2-propenyloxy)ethoxy]-2-propanol	55956-25-7	22.09	4	n.d.	n.d..	n.d..
1-dodecanol	112-53-8	25.99	4	n.d.	n.d..	n.d..
2-methyl-2,.2-dimethyl-1-(2-hydroxy-1-methylethyl)propylester propanoic acid	74367-33-2*	28.62	87	12	4	4
2-methyl-3-hydroxy-2,4,4-trimethylpentylesterpropanoic acid	74367-34-3*	29.1	91	15	6	5
Tetradecane	629-59-4	30.4	5	1	n.d.	n.d.
Dimethyl phthalate	131-11-3	30.7	12	4	2	1
Butanedioic acid-bis(2-methylpropyl)-ester*	925-06-4*	31.7	9	n.d.	n.d.	n.d.
2-butenedioic acid-(Z)-dibutyl ester*	105-76-0*	33.08	42	12	7	3
Pentanedioic acid dibutyl ester*	6624-57-3	34.5	7	1	1	n.d.
2,2,4-trimethyl-1,3-pentandioldiisobutyrate*	6846-50-0	35.2	4	n.d.	n.d.	n.d.
Hexanedioic acid-bis(2-methylpropyl)ester*	141-04-8	36.9	2	n.d.	n.d.	n.d.
Formaldehyde DNPH	50-00-0	3.8	220	8.	2	2
TVOC**			570	200	38	34

acid-(Z)-dibutyl ester: is this Z or 2?

* Suggestion of mass spectra library

* Without DNPH values

Table 3444-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a glass fibre non-woven fabric with adhesive (3445) on glass plate.

Sample	Glass fibre non-woven fabric 3444			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.196	<= 10	0.029	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.065	<= 1
[D] Σ VOC without LCI	no requirement		0.012	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provide additional information

[F] VVOC (< C_6)	0	addit. inform.	0	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.153	addit. inform.	0.017	addit. inform.

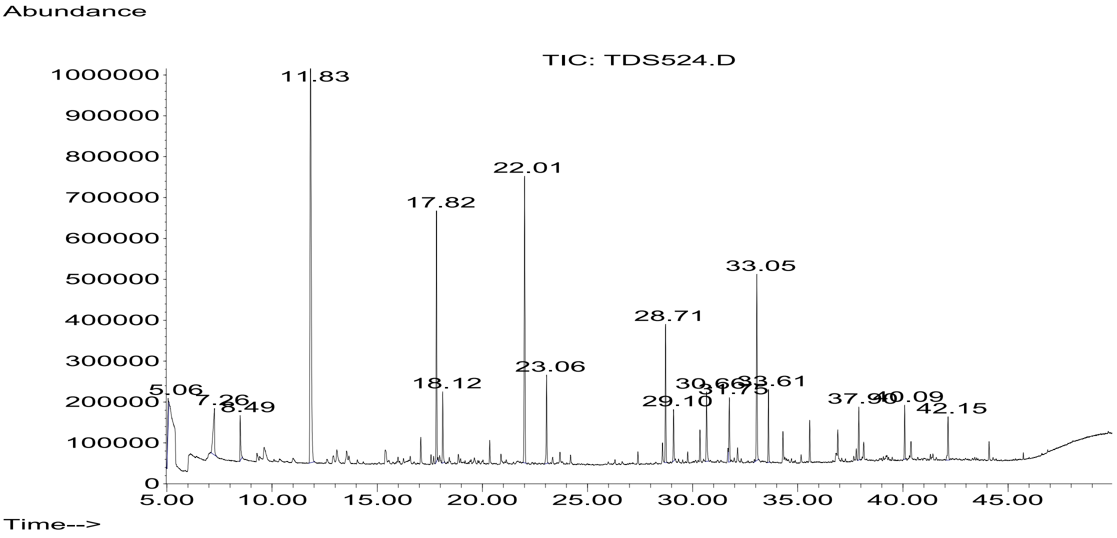


Figure 3444-1: GC/MS chromatogram on day 28 of emission testing on a glass fibre non-woven fabric with adhesive (3445) on glass plate.

Table 3444-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	12	15.3	3.8	-3.2	1.2
3	12	14.6	4.5	-3.5	0.8
10	10	13.2	5.2	-2.7	1.1
28	7	11.3	2.4	-2.9	1.1

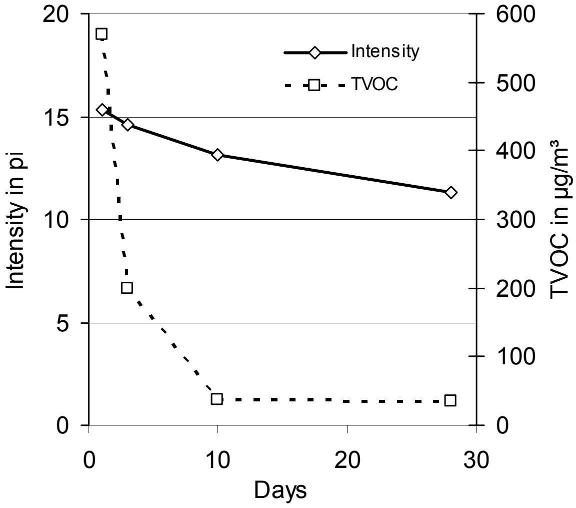


Figure 3444-2: Intensity and TVOC

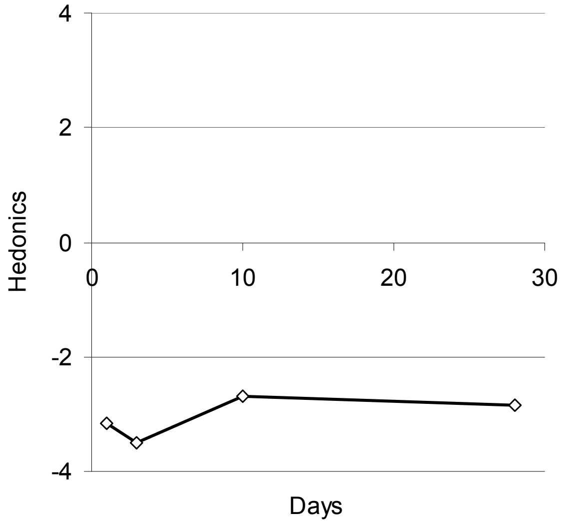


Figure 3444-3: Hedonics

3544 Primer on plasterboard, manufacturer 8

Table 3544-1: Concentrations of organic compounds analysed from a primer on plasterboard (3546); 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
2-ethyl-1-hexanol,	104-76-7	16.79	3	2	1	n.d.
1-dodecanol	112-53-8	30.46	33	17	5	n.d.
2,2,4-trimethyl-1,3-pentanediol-diisobutyrate*	6846-50-0	33.7	36	22	5	n.d.
Formaldehyde DNPH	50-00-0	3.8	6	6	3	4
TVOC **			72	41	11	

* Suggestion of mass spectra library
* Without DNPH values

Table 3544-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a primer on plasterboard (3546).

Sample	Primer on plasterboard 3544			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.045	<= 10	0	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.00	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.006	addit. inform.	0.004	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0	addit. inform.	0	addit. inform.

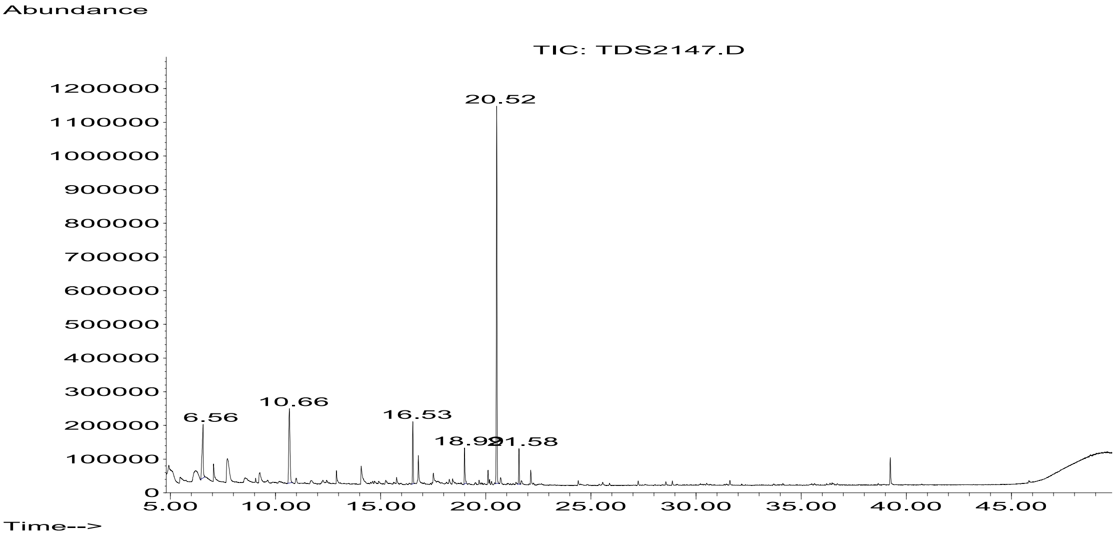


Figure 3544-1: GC/MS chromatogram on day 28 of emission testing on a primer on plasterboard (3546).

Table 3544-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	4	15.0	1.6	-3.1	0.5
3	5	7.3	1.9	-1.3	0.9
10	0				
28	6	6.3	2.5	-0.8	1.4

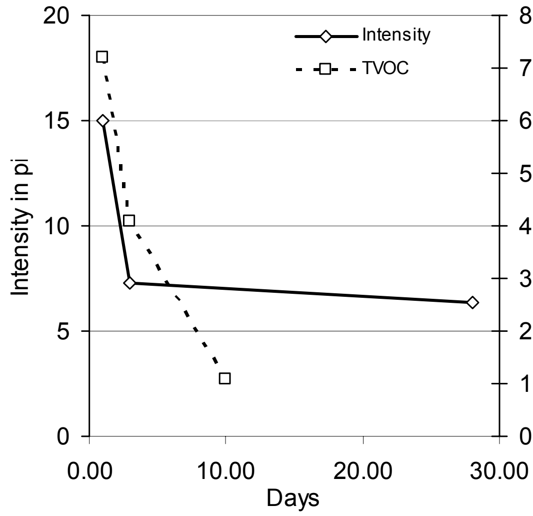


Figure 3544-2: Intensity and TVOC

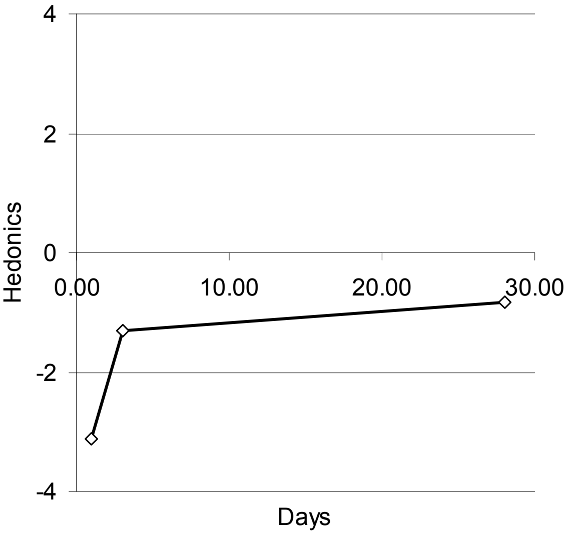


Figure 3544-3: Hedonics

3546 Plasterboard (humid surroundigs), manufacturer 8

Table 3546-1: Concentrations of organic compounds analysed from a plasterboard; 20-litre chamber, q = 1 $m^3m^{-2}h^{-1}$

Substances	CAS number	RT [min]	Day 1	Day 3	Day 10	Day 28
Triethylsilanol	1066-40-6	5.01	37	5	5	n.d.
Acetic acid	64-19-7	6.87	36	22	16	10
1-hydroxy-2-propane	116-09-6	7.45	3	1	1	n.d.
1-pentanol	71-41-0	8.57	15	8	1	n.d.
Hexanal	66-25-1	9.2	76	9	2	1
2-heptanone	110-43-0	12.05	9	4	n.d.	n.d.
Heptanal	111-71-7	12.43	8	2	n.d.	n.d.
Pentyloxirane*	5063-65-0*	12.75	1	n.d.	n.d.	n.d.
Benzaldehyde	100-52-7	14.08	8	6	1	1
m-cumene	535-77-3	15.15	1	n.d.	n.d.	n.d.
Octanal	124-13-0	15.58	6	3	n.d.	n.d.
Pentamethylheptane*	13475-82-6*	16.23	3	n.d.	n.d.	n.d.
o-cumene	527-84-4	16.77	3	n.d.	n.d.	n.d.
Nonanal	124-19-6	19.03	4	4	1	1
Formaldehyde DNPH	50-00-0	3.8	20	15	3	3
TVOC**			210	68	30	13

* Generalised name, no exact specification possible
** Without DNPH values

Table 3546-2: Comprehensive evaluation according to AgBB scheme using a DIBt reporting mask from a plasterboard.

Sample	Plasterboard 3546			
AgBB Overview of results Version: 8-f-2004	Day 3 [mg/m³]		Day 28 [mg/m³]	
	measured val.	requirement	measured val.	requirement
[A] TVOC (C_6 - C_{16})	0.058	<= 10	0.010	<= 1
[B] Σ SVOC (C_{16} - C_{22})	no requirement		0	<= 0.1
[C] R (dimensionless)	no requirement		0.02	<= 1
[D] Σ VOC without LCI	no requirement		0	<= 0.1
[E] Σ carcinogens	0	<= 0.01	0	<= 0.001

This block provides additional information

[F] VVOC (< C_6)	0.026	addit. inform.	0.007	addit. inform.
[G] TVOC (C_6 - C_{16}) given as toluene equivalent		key in the value manually!		key in the value manually!
[H] Σ VOC with LCI	0.045	addit. inform.	0.010	addit. inform.

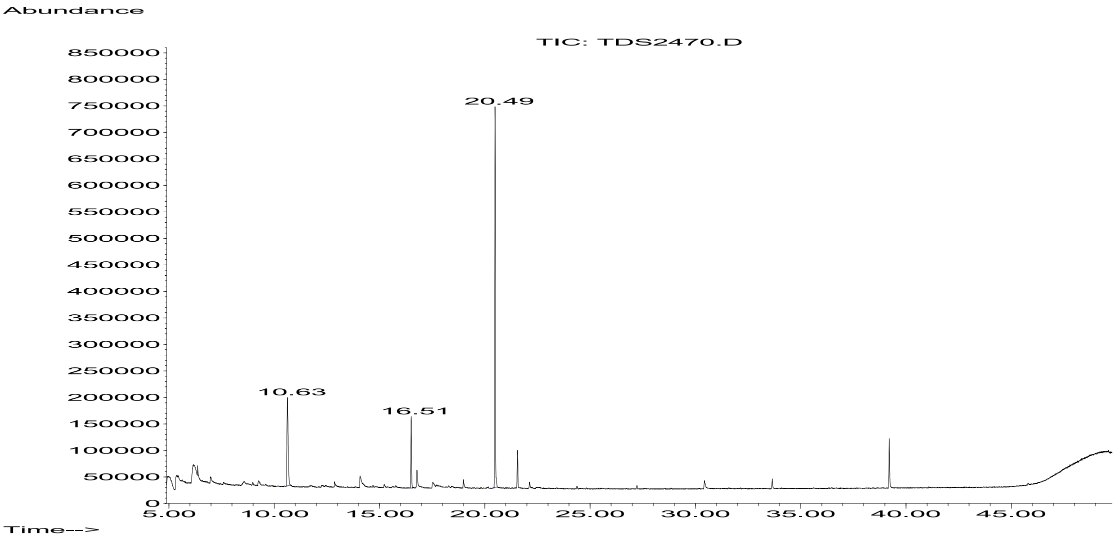


Figure 3546-1: GC/MS chromatogram on day 28 of emission testing on a plasterboard.

Table 3546-3: Comprehensive data of odour testing

Day	Number of test persons	Intensity Π		Hedonics	
		Mean	Standard deviation	Mean	Standard deviation
1	2	11.0	4.0	-2.0	1.0
3	5	14.6	3.4	-2.9	0.6
10	5	12.9	1.6	-2.0	1.1
28	6	11.1	3.0	-1.5	1.0

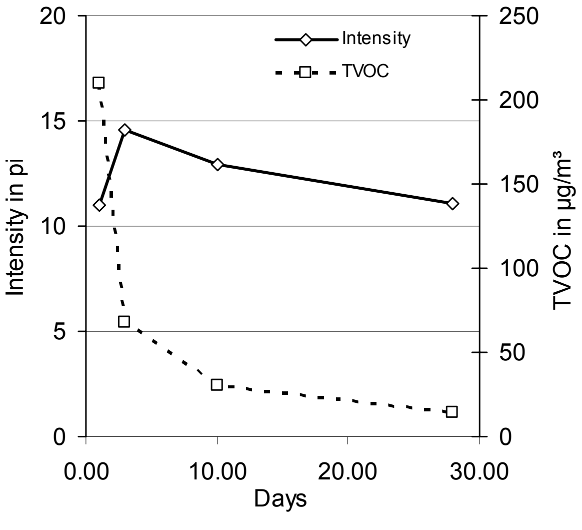


Figure 3546-2: Intensity and TVOC

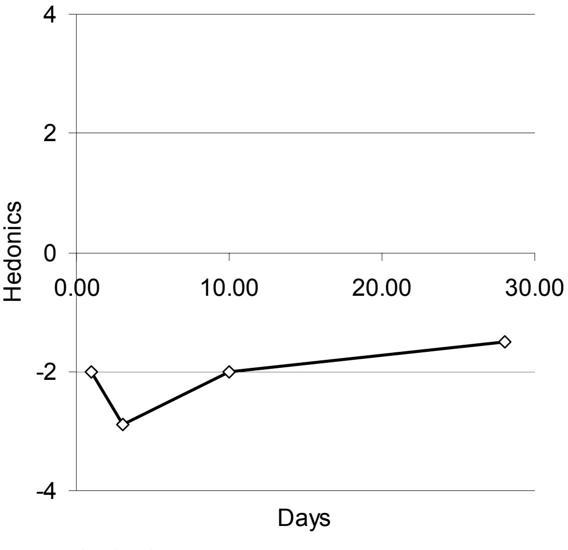


Figure 3546-3: Hedonics

Annex 1

Execution of interlaboratory test – odour emissions and emission chamber tests on an acrylic sealant

A7-1 PROVISIONS TO TEST ROOMS

Though the laboratory structure, as established in the Herrmann Rietschel Institute, is very well suited for olfactory investigations, the installations necessary are combined with considerable costs. Since all participants of this interlaboratory comparison cannot be expected to use exactly the same rooms for sample evaluation, the most important criteria for the test laboratory are summarized here. The criteria should guarantee that samples are evaluated under comparable conditions and conditions for the comparability of results are fulfilled.

A7-1.1 SPACE REQUIREMENT

A free area of approximately 2.5m * 2.5m is needed for the installation of the comparative scale including supply units and AirProbe II.

A7-1.2 DEVICES

The laboratory must provide

- a 220-V power supply,
- synthetic air supply (0.1-bar fine pressure reducer is provided by BAM/HRI) and
- a PC/laptop with Windows XP for recording and evaluation of the answers of the panellists

to ensure proper operation.

A7-1.3 REST AREA/TEST ROOM

Even if the panellists concentrate on their own perception, influencing by other panellists' assessment cannot be excluded, therefore it should be ensured that the waiting panellists cannot recognize the active panellist's assessment. Separation into a rest area and test room is therefore reasonable. Neither the rest area nor the test room should be directly within the laboratory, since impairment of the test procedure by current chemical analyses cannot be excluded.

A7-1.4 TEMPERATURE, HUMIDITY

Unlike with untrained panellists, investigations into the influence of humidity, temperature and enthalpy on odour assessment by trained panellists have shown that the assessment directly depends on relative humidity. Odours are perceived less strongly with rising relative humidity. 20 to 22°C and 40 to 50% relative humidity have been specified as guide values for the thermal conditions of laboratory air in this co-operative test. These values must be measured and recorded before sample provision.

A7-1.5 ODOUR LOAD

The odour load of the room air should fall far below the intensity of building materials to be expected in order not to influence their assessment. A room with as neutral an odour impression as possible should be selected for the test. An air-conditioned or ventilated room is optimal whose room air conditions are independent of the ambient conditions of the laboratory.

According to tests carried out in the HRI an approximate independent assessment of the ambient air can be performed, as long as the perceived intensity of the room air does not exceed a value of 2 pi at a specified temperature and humidity. When the comparative scale is installed, a staff member of the HRI assesses the perceived intensity of the test room.

The room air of the test room should be tested by chemical analysis and recorded for the test procedure. For this purpose, a room air sample, e.g. 3 litres, is collected on Tenax under the conditions intended for odour determination, but without switching on the acetone source. Please convey to BAM the evaluation of the key components (e.g. above 5 µg/m³) of this room air together with other results.

A7-2 SHORT TRAINING OF PANELLISTS

The training consists of two test days. An overview of the training programme is shown in the table below.

Training day	Topic	Sample content	Tested feature
Day 1	Introduction Training AirProbe II	6 acetone samples Blank sample	Intensity
Day 2	Training AirProbe II	6 acetone samples Butanol	Intensity Intensity/hedonics

Short training for the setting up a trained panellist group

A7-2.1 TRAINING DAY 1

The training schedule to determine odour intensities and the structure and operation of the comparative scale and AirProbe II are explained to the test panellists on the first training day. The assessment methodology must particularly be emphasised: the comparative scale should facilitate the assessment of odour intensity for the panellists, hedonics is only supposed to play a subordinate role in the determination of intensity. Afterwards each panellist must determine six different acetone concentrations: the test manager adjusts the acetone concentrations to position 7 of the comparative scale according to the record sheet and covers the micro metering valve with the brass fitting provided to prevent the panellists from gaining any visual information of the valves. For a clear relation of the assessments, integer multiples of 20 mg/m³ (60, 80, 100, 120…) should be adjusted on the comparative scale. It is up to the panellists whether they first smell the sample or the comparative scale. However, the test manager should draw their attention to the adapting capability of the human nose: high intensities dampen the perception ability for low intensities.

The panellist first expresses his estimate of the sample intensity and registers it on his record sheets. The actual intensity of each individual sample is told to the panellists immediately after the test. If the assessment by a panellist differs greatly from the actual value, he is given the chance of determining the sample once again knowing the actual value. Thus the panel is given the option of adapting their internal scale to the accurate values for the next sample determination.

In order to learn how to handle the AirProbe II, the panellists should evaluate a sample bag filled with synthetic air at the end of their first training day. Since the 300-l sample bags are limited in volume, the panellists should learn to perform an assessment rapidly. The test manager gets an empirical value of how much time each panellist can have at the evaluation funnel of AirProbe II.

A7-2.2 TRAINING DAY 2

On the second training day, the intensities of acetone concentrations are determined in coincidental order. The panellists only receive direct feedback of the true values for the first two assessments.

Since the panellists have so far only compared acetone concentrations with one another, a sample bag of synthetic air with 10 micro litres butanol is given to them to determine in AirProbe II at the end. Butanol is injected directly into the bag using the microlitre syringe provided for at least half an hour. If the laboratory possesses a suitable analysis facility, the butanol concentration can be determined in the bag, though this analysis is not absolutely necessary. The butanol sample can be used by the panellists to practice intensity determination on an odour which is somewhat different to acetone. In addition hedonics, which is always determined on the regular test days, is also queried for the first time.

Ringversuch Bauprodukte

Bewertungsbogen – Training (1)

Institut:______________________________ **Trainingstag : 1**

Proband:______________________________ **Datum :**________________

Bewerten Sie die Intensität Π des Geruchseindrucks der Probenluft in PI anhand des Vergleichsmaßstabes und tragen Sie die Bewertung in der linken Spalte „Intensität“ ein.

Ihnen wird die tatsächliche Intensität mitgeteilt und Sie dürfen noch einmal an der Probe und am Vergleichsmaßstab riechen. Tragen Sie die tatsächliche Intensität in die rechte Intensitätsspalte ein. So können Sie Ihren inneren Maßstab an den Vergleichsmaßstab anpassen.

	Intensität Π in PI	
	bewertet	tatsächlich
Probe 1		
Probe 2		
Probe 3		
Probe 4		
Probe 5		
Probe 6		
Probe 7		■

Geruchsringversuch Bauprodukte

Bewertungsbogen – Training (2)

Institut:______________________________ **Trainingstag : 2**

Proband:______________________________ **Datum :**________________

Bewerten Sie die Intensität Π des Geruchseindrucks der Probenluft in PI anhand des Vergleichsmaßstabes und tragen Sie die Bewertung in der Spalte „Intensität“ ein.

Ihnen wird die tatsächliche Intensität für die ersten zwei Proben nochmals mitgeteilt und Sie dürfen noch einmal an der Probe und am Vergleichsmaßstab riechen. Tragen Sie die tatsächliche Intensität in die rechte Intensitätsspalte ein. So können Sie Ihren inneren Maßstab erneut an den Vergleichsmaßstab anpassen.

	Intensität Π in PI	
	bewertet	tatsächlich
Probe 1		
Probe 2		
Probe 3		■
Probe 4		■
Probe 5		■
Probe 6		■
Probe 7		■

Ringversuch Bauprodukte

Protokollbogen – Training (1)

Institut:______________________________ **Datum :**_______________

Versuchsleiter:________________________ **Trainingstag: 1**

Prüfraum:

	Zu Beginn	**Am Ende**
Temperatur in °C		
Feuchte in % r.F.		

Vergleichsmaßstab:

Nr:	**Empfundene Intensität Π**		**Messwerte der Azetonkonzentration in mg/m³**				
1	1 PI	20 mg/m³					
2	3 PI	60 mg/m³					
3	6 PI	120 mg/m³					
4	9 PI	180 mg/m³					
5	12 PI	240 mg/m³					
6	15 PI	300 mg/m³					

Proben:

	Stoff/Material	**Probenbeutel (PB)** **Vergleichsmaßstab (VM)**	**Beschreibung der Probe z.B.** **Konzentration in mg/m³**
Probe 1	Aceton	VM	100 mg/m³ = 5 PI
Probe 2	Aceton	VM	280 mg/m³ = 14 PI
Probe 3	Aceton	VM	120 mg/m³ = 6 PI
Probe 4	Aceton	VM	60 mg/m³ = 3 PI
Probe 5	Aceton	VM	220 mg/m³ = 11 PI
Probe 6	Aceton	VM	100 mg/m³ = 5 PI
Probe 7	Synth. Luft	PB	Neutralluft

Ringversuch Bauprodukte

Protokollbogen – Training (2)

Institut:______________________________ **Datum :**________________

Versuchsleiter:________________________ **Trainingstag: 2**

Prüfraum:

	Zu Beginn	Am Ende
Temperatur in °C		
Feuchte in % r.F.		

Vergleichsmaßstab:

Nr:	Empfundene Intensität Π		Messwerte der Azetonkonzentration in mg/m^3				
1	1 PI	20 mg/m^3					
2	3 PI	60 mg/m^3					
3	6 PI	120 mg/m^3					
4	9 PI	180 mg/m^3					
5	12 PI	240 mg/m^3					
6	15 PI	300 mg/m^3					

Proben:

	Stoff/Material	Probenbeutel (PB) Vergleichsmaßstab (VM)	Beschreibung der Probe z.B. Konzentration in mg/m^3
Probe 1	Aceton	VM	80 mg/m^3 = 4 PI
Probe 2	Aceton	VM	220 mg/m^3 = 11 PI
Probe 3	Aceton	VM	80 mg/m^3 = 4 PI
Probe 4	Aceton	VM	240 mg/m^3 = 12 PI
Probe 5	Aceton	VM	140 mg/m^3 = 7 PI
Probe 6	Aceton	VM	40 mg/m^3 = 2 PI
Probe 10	Butanol	PB	10 µl in vollen Probenbehälter

A7-3 EXECUTION OF CHAMBER LOADING

A7-3.1 SAMPLE APPLICATION

Depending on the chamber dimension and air exchange rate, the length of the standard aluminium channel is chosen in such a way that q = 44 m³/m²h is obtained (DIN-EN-13419-1). Unfortunately, the supplied standard aluminium channels do not fully correspond to the provisions of DIN-EN-13419-3 which requires a width of 10 mm and a flank height of 3 mm. The profiles of Alfer have a flank height of 6 mm. However the profile is completely filled for the test. The aluminium foil supplied is used to cover the cut ends of the profiles.

Examples of a q of 44 m³/m²h:

Air exchange rate 1 h^{-1}, chamber volume 1 m^3, => length = 227 cm

Air exchange rate 6.25 h^{-1}, chamber volume 0.02 m^3, => length = 28.4 cm

Air exchange rate 0.5 h^{-1}, chamber volume 0.2 m^3, => length = 22.7 cm

L	=	loading (m²/m³)	V	=	chamber volume (m³)
n	=	air exchange rate (h^{-1})	q	=	area-specific air flow rate (m³/m²h)
A	=	surface of the sample (m²)			

Equation 1: $$L = \frac{A}{V}$$

Equation 2: $$q = \frac{n}{L} = \frac{n*V}{A}$$

Equation 3: $$A = \frac{n*V}{q}$$

One or both cartridges are normally opened by a knife and an applicator nozzle whose opening can also slightly be expanded is attached to the cartridge.

Both ends of the profiles cut to size are covered with an aluminum foil, they are weighed and filling of the profiles with the acrylic mass can begin. Afterwards the mass is levelled by a trowel over the edge of the profile and weighed again. Now a waiting period of 2 hours follows, then the chamber is loaded with the sample e.g. by placing the profiles on the bottom of the chamber.

A7-3.2 LOADING THE CHAMBER:

The chamber should be tested both with bags (olfactory) and using normal chemical analysis. The method used should be TENAX thermodesorption. A calibration solution has been prepared for this purpose which is supposed to contain the key components of the VOC analysis in methanol. You will be provided with this solution together with other material.

Common chamber conditions:

23 °C and 50 % R.H., analogous to DIN-EN-13419-1.

In addition, the chamber should have a sufficiently high flow rate in order to be able to fill the air sample containers (bags) within a relatively short time. Cells are not suitable. Higher flow rates should be used in smaller chambers: 125 litre air volume per hour has proved to be a practicable lower limit.

The measurements (VOC and odour) should be performed at 24 h, 72 h and 192 h after loading. If the chamber is loaded for instance on Monday at 11 am, the first sampling should take place on Tuesday around 11 am (double sampling in each case). The next sampling takes then place on Thursday morning and the last one on Tuesday morning (8 days later). Also see the following table:

Mo 0.	Tu 1.	We 2.	Th 3.	Fr 4.	Sa 5.	So 6.	Mo 7.	Tu 8.
Loading	Measurement		Measurement					Measurement
Small chamb. →		→					→	

The arrows in the table indicate the dynamic flushing of the odour bags when smaller chambers are used. 1-m³ chambers enable direct work.

A7-3.3 FILLING THE BAGS:

1-m³ chamber (flow rate about 1 m³/h):

Air in the bags should be flushed about 3 times, i.e. the bag should be emptied twice and only the third filling should be offered to the panellists when working with 1-m³ chambers (filling time: 20 min at $n = 1\ h^{-1}$). The inlet of the bag can firmly be connected to the oulet pipe of the chamber using a normal package cord (wound around several times) - cable ties can also be used (all other openings, e.g. sampling connecting piece etc. must be closed). It suffices to keep the outlet of the bag closed using the office clamps supplied. This side is only opened when the bag is being emptied and it is then reclosed.

20-m³ chamber (flow rate approximately 0.12 m³/h):

When working with small chambers, the flow goes through the bag, i.e. it is attached to the outlet, while the other end of the bag and the other outlets of the chamber are kept closed. In about 2.5 to 3 hours the bag is completely filled, a tube is attached to the end of the bag which must have a much smaller diameter than the inlet. 14 mm tubes for the inlet and 6 mm tubes for the outlet have proved suitable in our experiments (outside diameters). The inlet of the bag can be connected firmly to the tube by a normal package cord (wound around several times), cable ties can also be used but they must be cut through when being removed (risk of damage to the bag material). It suffices to keep the outlet of the bag closed by office clamps as tightly as possible with the 6 mm tube or teflon hose (see pictures).

Glass tube in bag outlet

Folding the bag outlet towards the tube

Fixing the glass tube by the "paper clip"

The filling of the sample container starts on the day before and is filled by a through-flow over night. The bag can then be removed next morning and be used for olfactory assessment.

A7-3.4 SIMULTANEOUS TENAX TESTS

After agreeing on the time, we will send you four Tenax tubes (spiked with our internal standard) of which you should please take samples simultaneously to your sampling at your chambers. We would like to have a blank value of the chamber before the test (e.g. 2 x 4 litres on Tenax on Monday before loading) and a double sample on the 3rd measurement day with 1 litre of sample in each case. Please return these laden tubes to us by separate post. I would like to ask you not to touch the glass tubes used by us directly by hand. We usually use cotton gloves for handling the tubes.

A7-4 EXECUTION OF THE ODOUR ASSESSMENT

Please make sure that you read BAM’s test description in preparation for the test procedure.

A7-4.1 PREPARATION OF THE BAGS

It is absolutely necessary to anneal the Tedlar bags before sampling using the laboratory dryer provided for at least two hours.

Please take the method of filling the sample container from the BAM document: "Execution of the interlaboratory test odour emissions and chamber tests using an acrylic mass".

A7-4.2 DOCUMENTS/PREPARATORY WORK

Please note that the preparations begin 12 hours before the actual test. The acetone source cooling system needs about 12 hours to reach operating temperature. The cooling does not need to be turned off during the test period of 21 days.

A period of 2 hours should be taken into account for the preparation and regulation of the comparative scale.

You need the following documents for the execution of the test:

- Test protocol
- A PC with data acquisition software
- Evaluation sheets (if the answers are not recorded by the PC)
- Thermo-/hygrometer

A7-4.3 TEST PROCEDURE

In order to get the panellists accustomed to the odour assessment at the beginning of a test day, 3 assessments are first performed using the comparative scale at different acetone concentrations. The panellists record the results on their questionnaires or key them in into the PC. In addition to the perceived intensity, hedonics is also assessed. These data are later evaluated at the HRI to assess the individual efficiency of the panellists.

The sample bag for an assessment must first be attached at AirProbe II (see instruction). Since the amount of air in the sample bag is limited, it is reasonable for the panellists to queue up to achieve a rapid assessment.

Immediately after the assessment the panellists record the intensities determined by them and additionally indicate a value for hedonics.

A7-4.4 ASSESSMENT- AND RECORD SHEETS

Bitte nur verwenden, wenn nicht mit der Datenerfassungssoftware gearbeitet werden kann.

Ringversuch Bauprodukte

Bewertungsbogen

Institut:____________________________

Proband:____________________________ **Datum :**_______________

Bewerten Sie die Intensität Π des Geruchseindrucks der Probenluft in PI anhand des Vergleichsmaßstabes und tragen Sie die Bewertung in der Spalte „Intensität“ ein.

Bewerten Sie den Geruchseindruck der Probenluft von äußerst angenehm (+4) bis äußerst unangenehm (-4). Kreuzen Sie das entsprechende Feld an.

	Intensität Π **[PI]**	**Hedonik**								
		angenehm				**neutral 0**	**unangenehm**			
		äußerst +4	**sehr +3**	**mittel +2**	**leicht +1**		**leicht -1**	**mittel -2**	**sehr -3**	**äußerst -4**
Außenluft										
Prüfkabine										
Probe 1										
Probe 2										
Probe 3										
Probe 4										
Probe 5										
Probe 6										
Probe 7										
Probe 8										
Probe 9										
Probe 10										

Interlaboratory test building products

Record sheet

Institute:______________________________ **Date:**______________

Operator:______________________________

Testing room:

	Start	End
Temperature in °C		
Relative Humidity in %		

Comparative scale:

No:	Perceived intensity π		Aceton concentrations in mg/m^3				
1	1 PI	20 mg/m^3					
2	3 PI	60 mg/m^3					
3	6 PI	120 mg/m^3					
4	9 PI	180 mg/m^3					
5	12 PI	240 mg/m^3					
6	15 PI	300 mg/m^3					

Samples:

	Material	Sample bags (SB) Comparative scale (CS)	Details of the sample e.g. Concentration in mg/m^3
Sample 1			
Sample 2			
Sample 3			
Sample 4			
Sample 5			
Sample 6			
Sample 7			
Sample 8			
Sample 9			
Sample 10			

A7-5 OPERATING INSTRUCTIONS COMPARATIVE SCALE

The system of the comparative scale has been developed for odour tests in air quality investigation.

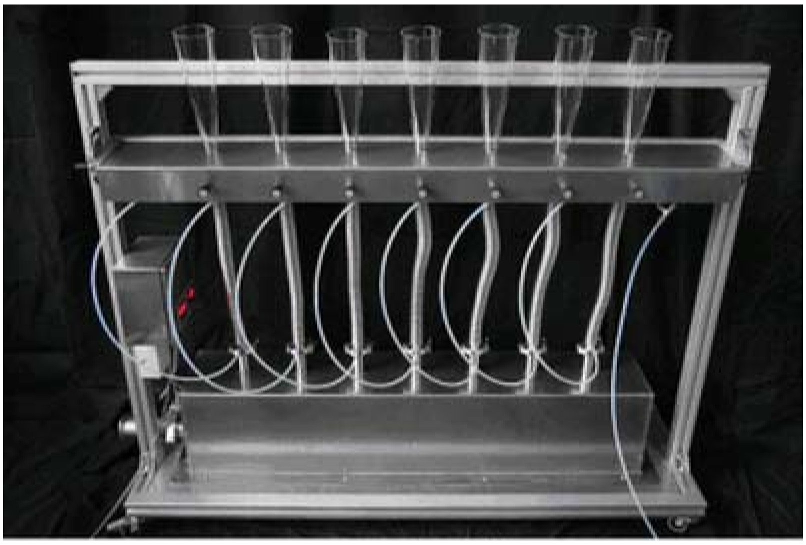
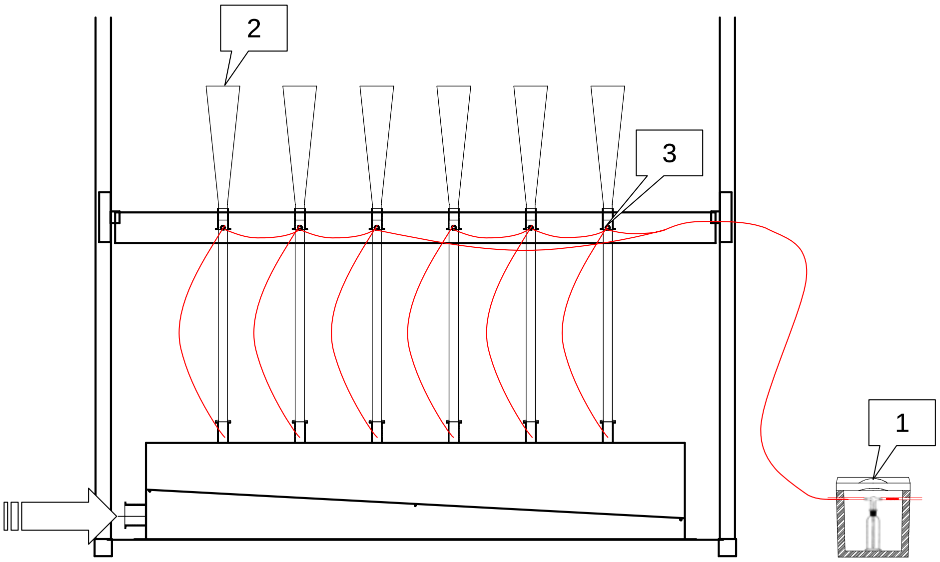


Figure 1: Comparative scale

Different concentrations of the reference substance acetone are available to the panellists as a comparative scale.

Pressure reducers, acetone source (item 1), funnel (item 2), micro metering valves (item 3) and fans are the components of the device (see scheme).



Scheme: Comparative scale

The funnels used in the assessment are made of glass since this material barely emits impurities and adsorbs only small amounts on its surface.

A7-5.1 START-UP

A fan, a filter, a flexible tube, a differential pressure gauge and a control unit provide air to the comparative scale.

A flow rate of 0.9 l/s is available at each of the seven funnels. The flow rate in the system is measured by the differential pressure gauge.

The system is attached to the 220 V main for the start-up of the comparative scale and the switch of the control unit (Figure 2) is actuated.

A fan performance of approximately 65% (left reading) indicates that the required flow rate of 6.3 l/s (right reading) is available. The fan performance can be varied with the help of the control unit which is connected to the fan. The flow rate can be corrected up or down by pressing the “Set” key and ▲ or ▼ at the left reading.

Figure 2: Control unit

In order to avoid odours from the system affecting the assessment, it is necessary to switch on the fan as early as two hours before beginning the test. The switch is attached to the side of the casing.

The constant source of acetone (item 1), consisting of a pressure resistant wash bottle and cooling equipment, must be started at least twelve hours before the beginning of the test in order to reach the operating temperature (about 20 K under the ambient temperature).

Figure 3: Constant source of acetone

The wash bottle is supplied with synthetic air. The pressure reducer (Figure 4) is adjusted to 0.06 bar at the beginning of the test for this purpose. Compressed air is transported through the wash bottle filled with acetone and is thus enriched.

Figure 4: Pressure reducer

Cooling prevents an oversaturation of the compressed air and consecutive condensation in the pipes. Acetone fog is separated from the enriched air by a high-grade steel filter (Figure 5).

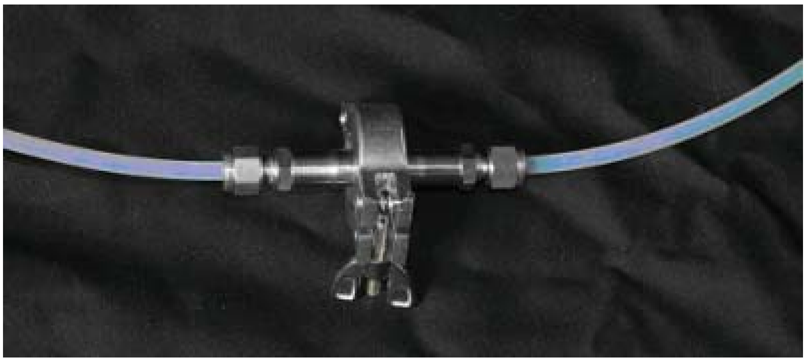


Figure 5: High-grade steel filter

The amount of acetone in the wash bottle should not exceed 0.4 litre, thus only small quantities of acetone are used in a test. To ensure that air takes up a sufficient amount of acetone while circulating through the wash bottle, after each test it must be checked to see that the level did not drop below 350 ml.

The seven funnels (item 2) are supplied with a constant air/acetone mixture via a hose distribution system. A micro metering valve (item 3) controls the amount of air/acetone mixture added to the sample air within a range of 0 to approximately 1200 mg/m³.

The sample air is supplied by a fan (Figure 6) which takes air from the surroundings.

Figure 6: Fan

A flow rate of 0.9 l/s is provided to the funnels.

The design of the supply ensures a homogenous mixing of acetone in the sample air.

In order to ensure constant acetone provision through the funnels, compressed air should be switched on at least 15 minutes before the beginning adjusting the measurement.

If the supply of constant air flow rate and constant compressed air is guaranteed, the desired amount of acetone is adjusted using the metering valves (Figure 7).

Figure 7: Micro metering valve

The comparative scale is adjusted in such a way that the concentrations 1, 3, 6, 9, 12 and 15 pi (20, 60, 120, 180, 240 and 300 mg/m³) are available to the panellist for the entire period of the test.

After all valves have been adjusted, the concentrations in the funnels are measured again and the final values recorded in the protocol sheets.

The seventh funnel can be variably adjusted. However, it should be a whole number between one and 15 PI. To prevent the panellist from getting any visual information by the valves, the micro metering valve is covered by a brass fitting provided. Finally, it must be checked that the guide values for the thermal conditions of laboratory air (20 to 22°C and 40 to 50% relative humidity) are maintained.

It should be noted that the adjustment of the valves should not be started earlier than an hour before the beginning of the test because acetone enriches rapidly in the test room and impairs the assessment.

A7-5.2 SHUTDOWN

After completing the test, the measurement instrument and pressure reducer are switched off. The level of acetone in the wash bottle should be checked and corrected if necessary.

A7-5.3 SHORT INSTRUCTION ACETONE SOURCE

Acetone-Source

	time	todo
❶	- 12 h	Switch cooler on
❷	- 1 h	Turn the compressed gas cylinder on (0,06 bar)
❸	- 45 min	Beginning of calibration-measurement
❹	0 min	Beginning of Test
❺	End of test	Turn the compressed gas cylinder on
❻		Inspection of the Acetone-Level

A7-5.4 SHORT INSTRUCTION COMPARATIVE SCALE

Comparative Scale

	time	**todo**
①	- 2 h	Switch controller unit ON Ventilator Power 100%
②	- 1 h	Adjust Power Unit Flow rate 6.3 l/s
③	Until test start	Adjust micro metering valves

Pos	**1**	**2**	**3**	**4**	**5**	**6**	**7**
PI	1	3	6	9	12	15	?
mg/m^3	20	60	120	180	240	300	?

④	- 15 min	Measure each position and record each value
⑤	Execution of the test	Variation of 7th position
⑥	End of test	Switch controller unit OFF

A7-6 OPERATING INSTRUCTIONS OF BRÜEL & KJAER

The multi-gas monitor 1302 is turned on by the switch on the back. It first performs an automatic self-check for about ten minutes. Subsequently, the measurement can be started.

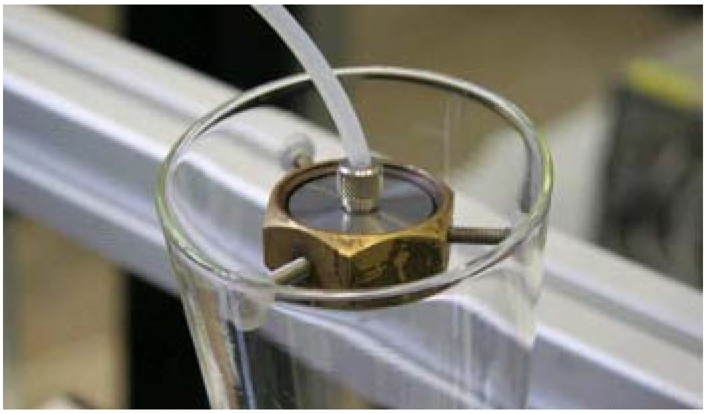


Figure 8: Measuring head in funnel

The measuring head (Figure 8) is placed into the first funnel and the key combination Measurement S1 S1 is pressed.

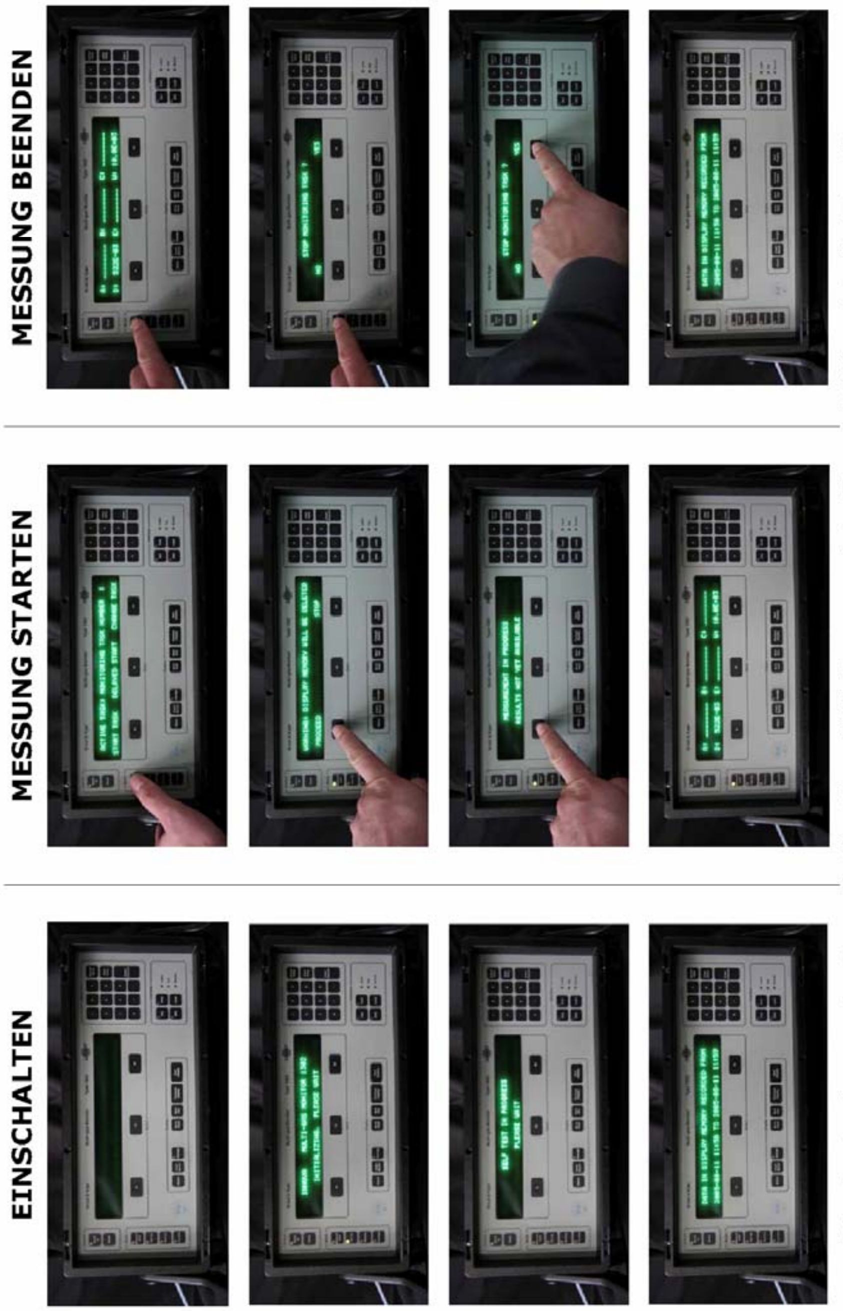
The multi-gas monitor needs about a minute to determine a measured value, which is then shown on the display at position D. The measuring head can be placed in the next funnel in this time interval. The measured values should not deviate more than five mg/m³ up or down from the specified values of the comparative scale. The measurement will be stopped by the key combination Measurement S3 and the multi-gas monitor switched off.

A7-6.1 SHORT INSTRUCTION BRÜHL & KJAER

Bruel & Kjaer

	time	**todo**
①	- 1 h	Switch unit ON (Backside)
②	- 45 min	Beginning of the calibration Measurement (Measurement S1 S1)
③		Adjusting micro metering valves
④	- 15 min	Measure each position and annotate each value
⑤	Execution of the Test	Measuring of the 7th position
⑥	End of test	Abortion of Measurement (Measurement S3)
⑦		Switch unit OFF

A7-6.2 INSTRUCTION WITH IMAGES BRUEL & KJAE



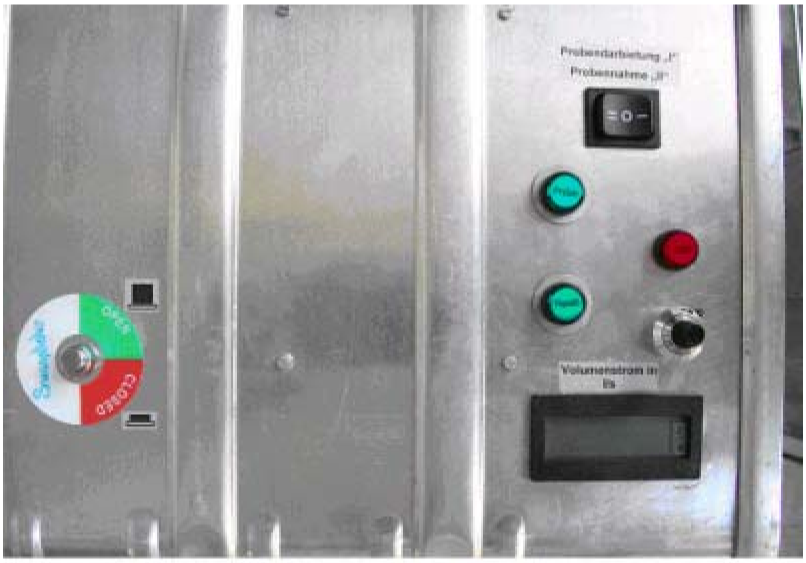
Die Azetonkonzentration wird in Messfeld D angezeigt, Messfeld W zeigt die Feuchte an.

A7-7 OPERATING INSTRUCTIONS OF AIRPROBE II

AirProbe II is a sampling and a sample provision unit which is loaded with sample containers made from Tedlar. AirProbe II operates according to the principle of a press. The sample container is placed between two plates, one of which is mobile and can be pressed together at a constant speed. The air flow thus leaving the outlet of the sample container is channelled through high-grade steel pipes to a glass evaluation funnel at the exterior of the body.

The power supply socket is on the side of AirProbe II. Please do not use any other power supply unit but the one provided.

The control elements of AirProbe II are on the top and include a selector switch "Sampling/Sample provision" (black rocker switch II/O/I), a red "Stop" key, a green "Reset" key, a green "Sample (Probe)" key and a silver "Open/Closed" key. In addition, air flow can be adjusted by the rotary switch (0.0 - 10.0) which can be read off on the display in litre/s (reading somewhat retarded).



CONTROL ELEMENTS OF AIRPROBE II

Detail view of rotating knob in position 8.00

A7-7.1 START-UP

Please attach the power supply unit provided to a normal 220 V socket. Subsequently, establish connection to AirProbe II: please put the round plug of the power supply unit into the socket (13-13.5V DC) on the top of the back of AirProbe II. When removing the power supply unit, the mains plug must first be pulled out. Only pull the round plug from the socket of AirProbe II after the red status LED at the power supply unit has gone out.

A7-7.2 SAMPLE PROVISION

Switch the black rocker switch to "I". With the "Open/Closed" key in position "Open" please operate the "Reset" key. Thus the mobile plate is driven downward. Wait until no more noise can be heard from the drive. The mobile plate has then reached the lower limit switch. Please now open AirProbe II and place the sample container between the two plates.

If the sample container is entirely filled, it should fill the space between the two plates. If this is not the case, the lower plate should be driven upward by operating the "Sample (Probe)" key until the sample container completely fills the gap. Please stop the lower plate by pressing the "Stop" key. Please remove the upper catch of the sample container and invert its neck over the connecting piece at the upper plate.

The neck must be completely inverted over the connecting piece and fastened by a flexible Velcro strip.

Be careful when closing AirProbe II that the edges of the sample container are not squeezed in.

Frontal view of AirProbe II with its door open

Before the sample is provided, an evaluation funnel must be placed on the teflon connecting piece. Please turn the rotating knob to 8.00. The panellists should now queue up in a line. The press is set in motion by operating the "Sample (Probe)" key. It takes a short while until ".700" is exceeded on the display. The panellists can start their assessment starting from this value: they smell successively at the evaluation funnel ("Open/Closed" key on "Open") and switch the "Open/Closed" key to "Closed" when they stop smelling at the funnel. Now please compare the odour on the comparative scale. The panellists also can smell the sample a second time if the procedure is repeated. After a break, the flow rate reading needs a certain time for the value to exceed .700 again, but this is based on the measurement principle and can be ignored. The assessment can be made directly after opening the "Open/Closed" key. The press will be switched off by the "Stop" key after the last assessment. If the drive switches off before the last assessment, then the top limit stop is reached and the assessment must be stopped. A fully filled container realistically enables the assessment by 12 panellists.

After terminating the assessment, the "Reset" key should be actuated to drive the lower plate to the lower limit stop so that AirProbe II can be refilled.

The panellists should queue up in a line to carry out the assessment in a rapid succession, otherwise the amount of sample air may not be sufficient.

A7-7.3 SAMPLING (INFORMATIVE, NOT INCLUDED IN THE COMPARATIVE TEST)

Please switch the black rocker switch to "I" and release the "Open/Closed" key. Turn the rotating knob to 10 and actuate the "Reset" key. The lower plate is at the bottom limit stop as soon as no noise can be heard from the drive. Switch the black rocker switch to "O". Take an annealed empty sample container and remove its top catch. Invert its neck over the connecting piece at the top plate. The neck must be completely inverted over the connecting piece and then fastened by a Velcro strip. Be careful when closing AirProbe II that the edges of the sample container are not squeezed in. Switch the black rocker switch to "II". The fan produces a vacuum in the body and thus ensures that air is sucked into the sample container from the environment. To completely fill a sample container, you can run the fan for 4 minutes or to listen to the noise which is caused by the sample container being filled. If this noise cannot be heard any longer, the container is as full as possible. Switch the black rocker switch to "O" and open AirProbe II. Remove the container and seal it up hermetically.

A7-7.4 SHORT INSTRUCTION AIRPOBEII

AirprobeII

todo

①	Attach the power supply Switch the black rocker switch to „0“
②	black rocker switch to „I“ „OPEN/CLOSED“-Key to „OPEN“ Operate „RESET“-Key If drive switches off: ready
③	Place the Sampling Bag
④	Turn rotating Knob to 8.00
⑤	Operate „PROBE“-Key until 0.7 l/s (dispay): assessment
⑥	Sniffing: „OPEN/CLOSED“-Key „OPEN“, otherwise „CLOSED“
⑦	Limit Switch or „Stop“-Key abort assessment
⑧	See 2 Displace the Sampling Bag Switch the black rocker switch to „0“

Hermann-Rietschel-Institut
Fachgebiet Heiz- und Raumlufttechnik

Manual for the Measurement of Perceived Air Quality

Indoor Air Quality

November 2004

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Preface

Perceived air quality in buildings is gaining an internationally increasing importance. However, concepts for improvements of the perceived air quality are often difficult to implement in the planning and operation of buildings, since in addition to cost implications, both a continuous planning methodology and a manageable measurement technique are missing.

This first version of the manual for measuring the perceived air quality is a summary of internal documents on this topic, which were compiled at the Hermann Rietschel Institute in the last years. The objective of this manual is the explanation of the basic concepts of air quality determination in interiors and a short representation of the direction of current research at the Hermann Rietschel Institute. The intention of the manual is to provide a simple introduction for the reader to the interdisciplinary topic "perceived air quality".

The methodology of Prof Ole Fanger of the University of Denmark for the determination of the perceived air quality indoors has generally become accepted in the international literature. Parts of his research results have already been integrated in the German, European and international standards. Fanger suggests that all odour sources can be treated as equivalent, so that the total room load can be calculated by summing emissions from persons, building materials and installations.

Tests on building materials at the Hermann Rietschel Institute show a very different behaviour of various odour-generating substances with regard to the perceived intensity of the odour as a function of their concentration. Not all odours can be halved by doubling the air exchange rate. Therefore, a concept is being developed for the olfactory evaluation of building materials, which can be used to determine and to image these characteristics of odour-generating substances.

In addition to the avoidance of discomfort in buildings by a well perceived air quality, first studies also show a positive correlation between perceived air quality and productivity. Thus, apart from the attribute "desirable", this topic also contains an economic component, which should be considered in planning and operating buildings in addition to all conventional comfort requirements of air conditioning.

Terminology

Term	**Definition in the sense of this manual**
Acceptability	Measure for the satisfaction with ambient conditions.
Adaptation	Sensitivity adjustment of sensory cells or sensors to a constant stimulation strength. Temporary change of the sensitivity of a sensory organ due to constant and/or repeated stimulation /DIN EN 13725.
Anosmia	Missing sensitivity to smell stimuli ('smell blindness'). There is partial and total anosmia.
Detection threshold	Smallest odorous substance concentration at which 50% of panel members can detect an odour.
Hedonic odour effect	Assessment of an odour impression within the range from "extremely pleasant" to "extremely unpleasant".
Individual detection threshold	The individual detection threshold refers to the smallest concentration of an odorous substance in air that can be detected by a person.
Odour intensity	Strength of an odour impression.
Odour thresholds	Odour thresholds describe minimum concentrations of an odorous substance at which the odour is detected (detection threshold) or recognised (recognition threshold) by the majority of the panel.
Olfactometry	Measurement of the reaction of the panel to odour stimuli.

Perceived air quality	Magnitude of quantitative determination of the air quality perceived by humans. The perceived air quality is determined with an untrained panel.
Perceived intensity	Odour intensity, which is determined by a trained panel. It represents the determined magnitude in intensity measurements with a trained panel in comparison with a scale.
Percentage Dissatisfied (PD)	Percentage of panel members dissatisfied with ambient conditions.
Recognition threshold	Smallest odorous substance concentration at which 50% of panel members can recognise the smell.
Room air quality	Room air quality covers all non-thermal effects of room air which have an effect on comfort and health of humans.
Sick Building Syndrome (SBS)	Term for health complaints which occur during stay in a building and diminish or disappear on leaving the building. The complaints include headache, skin and eye irritations and dry mucous membranes.

Contents

1 Introduction

Odours result from a number of chemical substances. Those materials that trigger an odour perception in humans are far from being identified. Up to 8000 different substances can be detected in the room air, however a quantitative determination of each single material cannot provide information on the odour effect of any combination.

Earlier, the term air quality primarily included pollutant content. Today, perceived air quality is also established in nearly all fields of application and it can be used to assess odour in a room. Car companies employ odour specialists of their own to trace odour sources. Environmental laboratories test odour nuisances caused by industrial facilities and large agricultural plants. German and European standards contain procedure instructions and minimum requirements for the evaluation of perceived air quality in the external air but not for indoor air quality.

Strong odour nuisances can impair the comfort and work efficiency of people.

Despite steadily improving analytical possibilities and the development of sensor systems, the so-called "artificial or electronic noses", it is still not possible to replace the human nose in the determination of perceived air quality.

1.1 History of the air quality research

As early as in the mid 19th century **Max von Pettenkofer** carried out investigations into air quality (von Pettenkofer, 1858)[1]. Under the condition that odour sources can be fully eliminated by cleaning the room, he considered humans as the exclusive sources of contamination in the room. He introduced the CO_2 content in room air as the indicator of contamination by persons. CO_2 is odourless and humans cannot directly perceive it.

Pettenkofer derived the criterion for indoor air quality from his investigations. He suggested not exceeding a maximum carbon dioxide concentration of 0.1 % by volume or 1000 ppm of CO_2. This value is also called **Pettenkofer number** and still exists today in the German national and international standards. He assumed a basis level of 500 ppm of CO_2 in the external air.

Yaglou et al. were first to introduce a subjective method to evaluate room air quality in their room climate investigations in 1936/1937 (Yaglou, 1936)[2]. The intensity of the air sample was assessed by an untrained panel on a scale from 0 to 5. Their investigation was organised in such a way that the persons were required to assess air quality immediately after entering the room, i.e. in a non-adapted condition. Since each person judges the air quality in a different way, reference points had to be found about air quality through a statistical evaluation

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[1] Von Pettenkofer, Max: Über den Luftwechsel in Wohngebäuden (On the Air Exchange Rate in Residential Buildings), Literarisch-Artistische Anstalt der J.G. Cotta'schen Buchhandlung, München, 1858

[2] Yaglou, C P.; Riley, E. C; Coggins, D I.: Ventilation Requirements (Part 1), ASHVE Transactions, Vol. 42, 1936, 133-162

of the dissatisfaction of the users. When the air quality is good, only a small number of the panel members are dissatisfied, while this number rises as air quality decreases. This kind of evaluation is not easy to handle, since with an untrained panel an correspondingly large number of members must be questioned in order to obtain statistically reliable results.

Based on his investigations Yaglou[3] set up the following theses:

- In a crowded room a higher person-related ventilation rate is necessary than in a sparsely occupied room.
- Carbon dioxide exhaled by room users is not a suitable parameter to assess body odour.
- Body odour is very unstable.

Ole Fanger of the University of Denmark in Copenhagen introduced two new units for the evaluation in 1988 (Fanger, 1988)[4]. He assumed in his studies that the evaluation of indoor air should preferably be made by a visitor. Someone already in the room is less suitable from his point of view, since he is already adapted to the room air. Fanger worked with panels in order to eliminate individual evaluation peculiarities as far as possible. The participants make their evaluation immediately after entering the room to be assessed, and the evaluations are recorded in questionnaires. In addition to the question of acceptability, odour intensity and air freshness can also be assessed by the panel members.

At the **Hermann Rietschel Institute**[5] a new, two-stage system was introduced for the evaluation of perceived air quality. A material emanates different chemical substances to the ambient air. In the first evaluation stage the nose detects the odour-generating substances emitted by the material and evaluates them due to a different sensitivity with the perceived intensity Π. Relative humidity affects the evaluation of the intensity impression of the odour. Trained panellists arrange the odour intensity of a sample using reference samples (acetone) to the reference scale. Acceptability of odour impression is not queried in this evaluation.

In the second stage of the smelling procedure the brain evaluates the signals sent by the nose. Apart from the intensity, odour hedonics provides information about its effect on the test person.

1.2 Sick Building Syndrome (SBS)

The term Sick Building Syndrome (SBS) summarises disturbances in well-being and comfort which are in a close relationship with the residence time in certain buildings. Most complaints are of non-specific nature and can also occur in other

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[3] Yaglou, C P.; Witheridge, W. N.: Ventilation Requirements (Part 2), ASHVE Transactions, Volume. 43, 1937, 423-436

[4] Fanger, O. P.: Introduction of the olf and the decipol Units to Quantify Air Pollution Perceived by Humans Indoors, Energy and Buildings, 12, 1988, 1 - 6

[5] Müller, D; Bitter, F.; Böttcher, O.; Kasche J.; Müller, B.: Neue Systematik zur Bewertung der empfundenen Luftqualität (New System for Evaluation of Perceived Air Quality); Berlin, HLH 2004

areas of life (e.g. tiredness, concentration disturbances, headache). Thus SBS can only primarily be identified as a collective phenomenon by systematic comparative questioning about comfort. In contrast to SBS, the diagnosable symptoms in individuals are termed Building Related Illness (BRI), if a clear causal relationship can be established with the locality.

Sick Building Syndrome chiefly occurred at the beginning of the 1980s, when the ventilation rates were reduced to save energy in office buildings as a reaction to the energy crises in the 1970s. The internal air pollution load was not reduced, resulting in an increased pollution load in the rooms.

1.3 Overview of measuring methods

Many different measuring methods for air quality tests have been developed. The procedures, as shown in Fig. 1., can be divided into person-related and technically-related procedures. A number of measuring methods have been developed, particularly in the field of person-related methods, where results are not comparable.

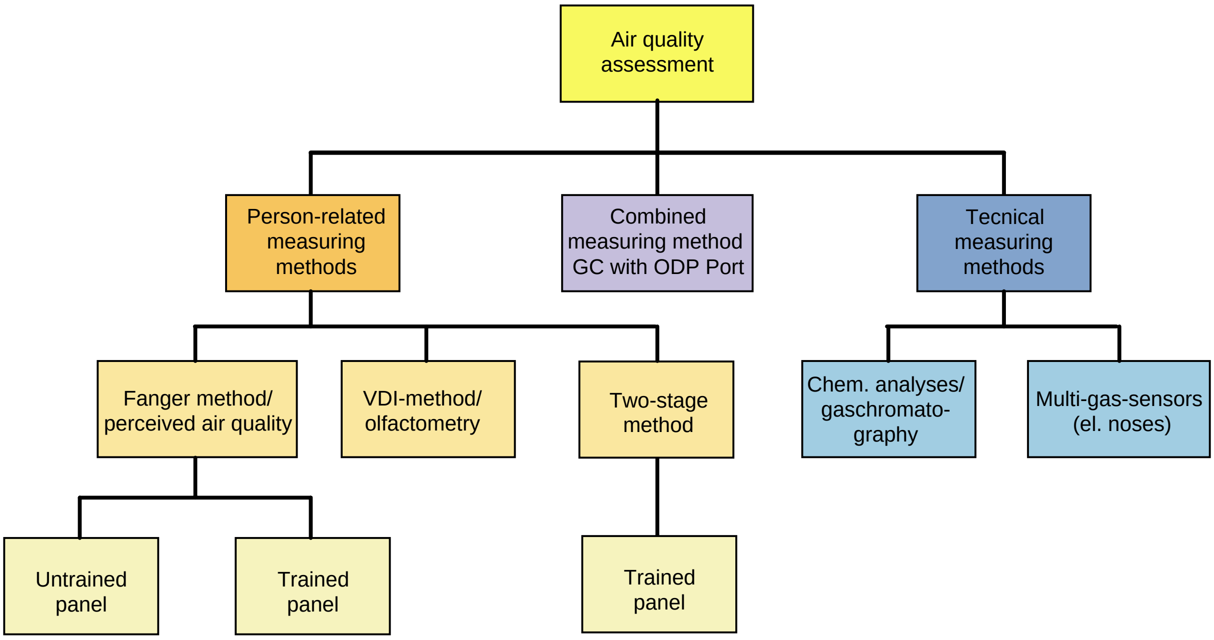

Fig. 1: Methods for air quality evaluation

The manual should provide a short description of the various methods and contribute to the clarity in the field of research of perceived air quality.

1.4 Fields of deployment for air quality measurements

The methods for evaluating air quality described in this manual essentially refer to the following three areas of application:

Air quality in interiors

In direct evaluation, the panel members enter the room to be assessed and perform the evaluation of air quality in the room.

Because a number of external factors may influence the evaluation (visual and acoustic influence, internal expectations), an indirect evaluation method has been developed to obtain an objective result. Containers are filled with the room air to be assessed and evaluated using suitable equipment under controlled laboratory conditions.

Evaluation of odour sources

Odours in rooms can be related to a number of sources. The odour-related evaluation of the emission behaviour of building materials, furnishings, cleaning agents, paints, lacquers etc. can be performed in the laboratory under optimum conditions. The interior, just like the environment, is a static area only in exceptional cases, since source strength, climatic conditions and possible absorbents constantly change the concentration of odorous substances. The use of measuring chambers enables these factors affecting source strength to be controlled.

Evaluation of equipment components

Ventilation equipment consists of individual modules which are primarily optimised based on their function. Optimisation of the materials used (metal, synthetic, rubber) concerning emission behaviour has only recently been performed.

Direct evaluations are difficult to perform, since ventilation equipment is not usually in an ideal environment and sample air can only be obtained from the equipment at a disproportionately high cost. Model equipment, where the components are in contact with air consist exclusively of glass and stainless steel with no odour emitting sealing materials and paints, enable the evaluation of individual components under reproducible ambient conditions.

2 The human sense of smell

The nose moistens and warms the inhaled air. At the same time it serves as a reflex organ (e.g. sneezing if dust is inhaled) and houses the smell receptors. During breathing air is inhaled into the external nose and flows into the internal nasal area. This is almost completely lined with mucous membrane. Air arrives through the nasopharyngeal cavity into the lower respiratory system. The olfactory region is responsible for smell perception (olfactory epithelium, olfactory bulb). This is an approx. 2 x 2.5 cm² (Deetjen, 1992)[6] to 2 x 5 cm² (Schmidt, 2000)[7] large area of the olfactory epithelium. The smell receptors, the so-called cilia, are on the olfactory epithelium. Fig. 2 shows the structure of the olfactory epithelium. According to Schmidt, the olfactory epithelium comprises, the olfactory receptor cells, supporting cells, cilia, apical knobs, and some serous glands.

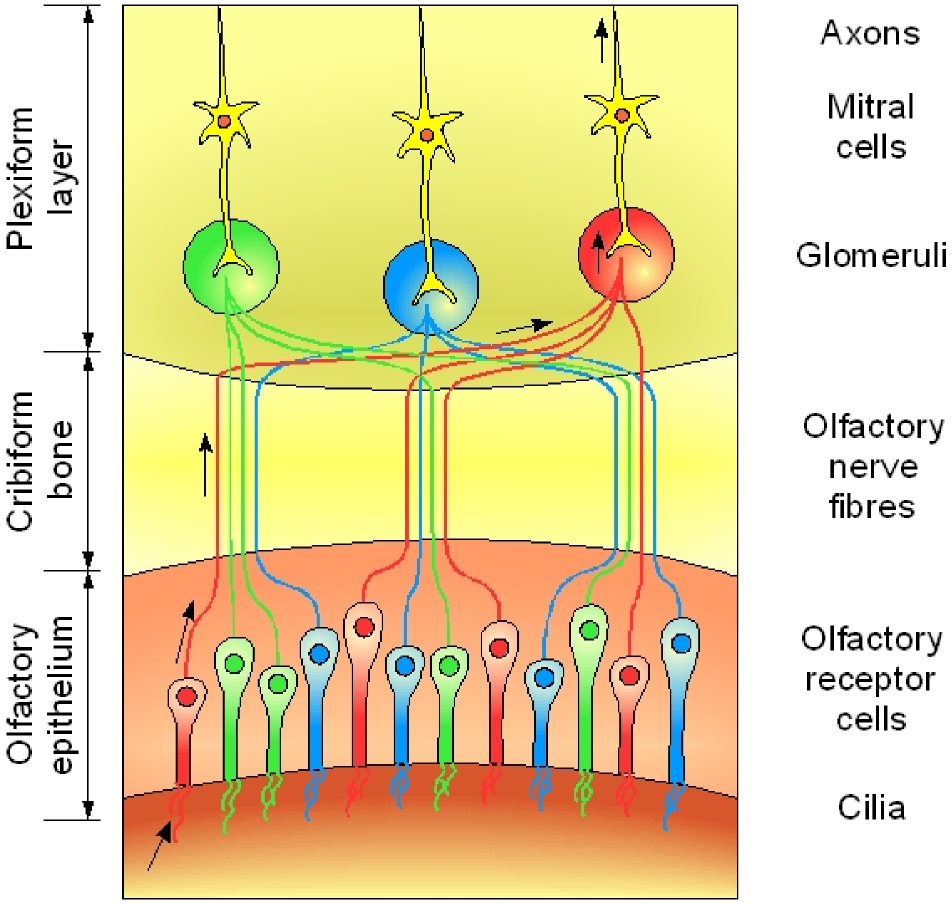

Fig. 2: Schematic structure of the olfactory epithelium with the connections to the olfactory bulb

According to Schmidt the smell receptors (cilia) produce electrical impulses and pass them on over the olfactory nerve fibres. At the Glomeruli between the

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[6] Deetjen, P.; Speckmann, E.-J.: Physiologie (Physiology); Urban & Schwarzenberg, München, 1992

[7] Schmidt, R. F.; Schaible, H.-G.: Neuro- und Sinnesphysiologie (Neuro and sense physiology), 4th Edition, Springer Publishing House Berlin-Heidelberg, 2000

receptors and the brain cortex the odour information is converged and transferred to a mitral cell of the olfactory bulb. From the olfactory bulb the odour information is then passed by nerve tracts (axons) to the brain. The brain recognises the odour through interaction with other brain regions (thalamus, limbic system). Existing memories are activated and the received stimulation is integrated. Various other functional circles are also activated in humans through the smell sensation. Thus there is a highly emotional component of smell perception due to the close connection to the limbic system. Smell perception can very rapidly evoke pleasant or unpleasant feelings. These feelings are called hedonic components of smell perception.

Fig. 3 shows the transformation of chemical smell stimuli into electrical signals. This transformation (transduction) begins with the contact of an odour molecule with a specific receptor protein in the cilia membrane.

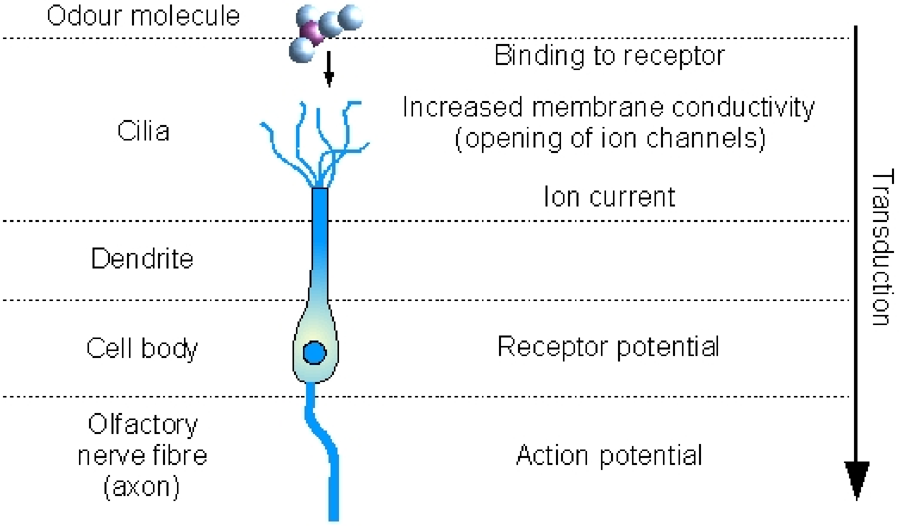

Fig. 3: Transduction of an odour stimulus

Fig. 3 shows the steps from the binding of the odour molecule to the receptor protein leading to the generation of the action potential. With the binding the membrane conductivity is increased by opening up the ion channels and an ion current is produced (Na pump). This ion current causes a cell polarisation. A receptor potential develops in the cell body producing an action potential, which is passed on through the axon.

Schmidt describes the principle of signal transduction in the cilia membrane. If an interaction occurs between an odorous substance and a receptor (R), the signal transduction mechanism is triggered. A G_s protein (G) activates the enzyme (AC, adenylate cyclase), which in turn increases the concentration of the messenger substance cAMP in the cell. Odorous substances can generate thousands of these messengers. A G_s protein is a **s**timulating (s) **G**uanine nucleotide binding protein (G), which is a regulatory protein. The abbreviation cAMP stands for "**c**yclic **a**denosine **m**ono **p**hosphate". The cAMP molecules open cation channels in the cell membrane. Influx of cations (sodium, calcium) through this channel into the cells generates a receptor potential.

According to Deetjen et al. the cilia are in a mucous layer, which must be first penetrated by the odour molecules. For this purpose the odorous substances must be sufficiently volatile and sufficiently water soluble and must also exhibit certain fat-solubility.

The influx of calcium and sodium ions into the cell increases the calcium concentration. The ions are bound to the channel, blocking it, so turning it off.

Consequently the odour will no longer be detected. This explains the process of adaptation at a molecular level. Adaptation is understood to be the process of getting used to odours and the associated reduction in perception strength. After a long period in the same environment, odours become much less noticeable or completely unnoticeable. If the receptor is not provoked any longer, the original sodium and calcium concentration is restored.

2.1 Smell perception

The perception by the sensory organs was investigated by E. H. Weber in the mid 19th century (Weber, 1850)[8]. Smell perception belongs to the sensory perceptions. Weber found in his experiments that the intensity of the stimulus must rise by a certain fraction of the initial stimulation, so that a change is perceived.

Formerly, this stimulus increase was called difference limen (DL); today the abbreviation "**jnd**" (just noticeable difference) is frequently used. Large stimuli must differ by a greater absolute quantity than smaller ones, but the necessary percentage-increase remains constant within a medium range of sense modality. Weber specified the so-called Weber quotient:

$$c = \frac{\Delta R}{R}, \qquad \text{(Eq. 1)}$$

with c: Weber quotient
ΔR: stimulus increase
R: initial stimulus.

This sensory quotient, depending on the sensation, is between 0.07 and 0.12 (e.g. stimulation increase between 7 – 12 %), to notice an appreciable stimulation difference. This equation though is not applicable for small stimuli at the detection limit.

Weber's equation was further developed by G. T. Fechner (Fechner, 1860)[9]. He established a general law between source strength and perception strength. He took the quotient determined by Weber as a basic unit and determined the perception strength as a number of the difference stages exceeded. The relationship, which he received, is known as Weber-Fechner law:

$$E = k \cdot \log(\frac{R}{R_0}) \qquad \text{(Eq. 2)}$$

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[8] Weber, E. H.: Der Tastsinn und das Gemeingefühl, Wagner Handwörterbuch Physiologie (Sense of Touch and General Feeling, Wagner Manual Physiology), 2nd dep., Vol. 3, 1850, p. 481-588

[9] Fechner, G. T.: Elemente der Psychophysik (Elements of Psychophysics), Vol. 2, Breitkopf und Härtel, Leipzig, 1860

with k: Weber-Fechner coefficient
E: perception strength
R: source strength
R_0: source strength at the odour threshold.

A logarithmic increase in the source strength thus results in a linear increase in perception strength. Fechner defined an absolute stimulus threshold where the stimulus is first noticed.

Fechner assumed in his formula that the relationship from stimulus increase to basic stimulus remains equal over the entire intensity range. This was criticised by Stevens in the fifties (Stevens, 1957)[10].

In order to obtain satisfactory data about the perception strength of a sense modality, Stevens introduced the method of quantitative estimation of the perception strength. The type of quantitative relationship between source and perception quantity depends clearly on the scaling technique. Stevens performed his experiments exclusively based on a comparative scale. The subjects were asked to indicate when a stimulus, e.g. a smell stimulus, was twice as strong as a comparative stimulus. The distinction was not important, but an indication concerning the subjective intensity of perception.

He carried out tests for the determination of the functions between source strength and perception strength and determined a power function from the results of measurement of the distance of the source strength from the detection threshold of the stimulus. This function is also called Stevens power function and has the following form:

$$E = k \cdot (R - R_0)^n \qquad \text{(Eq. 3)}$$

with k: constant
E: perception strength
R: source strength
R_0: source strength at the odour threshold
n: exponent.

Concerning the sense of smell, the exponent n is within the range of 0.2 to 0.7 for most odorous substances, it is thus smaller than 1. This means that when the odour load is reduced, the perceived odour does not decrease to the same extent.

These considerations refer to the intensity of the odour. In addition to the intensity, the odour perception is also determined by the hedonic effect, i.e. whether an odour is perceived as pleasant or unpleasant. The hedonic note of an odorous substance can also turn around with the intensity. Thus for instance coffee flavour is perceived as pleasant in low concentrations, however, as unpleasant in high concentrations. It can be assumed that emissions from air conditioners are perceived as unpleasant and the intensity is of importance only in the investigations.

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[10] Stevens, S. S.: On the Psychophysical Law, Psychological Review, Vol. 64, 1957, p. 153-181

The Weber-Fechner law became generally accepted in the description of stimulus transmission for the sense of touch, hearing, vision and the sense of taste. However, for the description of the sense of smell, Stevens's relationship between perception strength and source strength has been used until now.

2.2 Odour thresholds

Cain et al. (Cain, 1996[11]) showed that even small concentrations of a volatile organic material are sufficient to cause mucous membrane irritations in humans. The results of the investigations are illustrated in Fig. 4.

Fig. 4 also explains that the odour thresholds of the tested materials were under the threshold concentrations for mucous membrane irritation in the nose and eyes by 3 to 4 orders of magnitude. The odour threshold of individual people is the smallest, just noticeable, odorous substance concentration. It is defined for groups of persons by DIN EN 13725[12] as the concentration at which 50 % of the subjects questioned notice the odour. Furthermore it is assumed that the odour threshold decreases with the chain length of the molecules, i.e. with the number of carbon atoms within a molecule family.

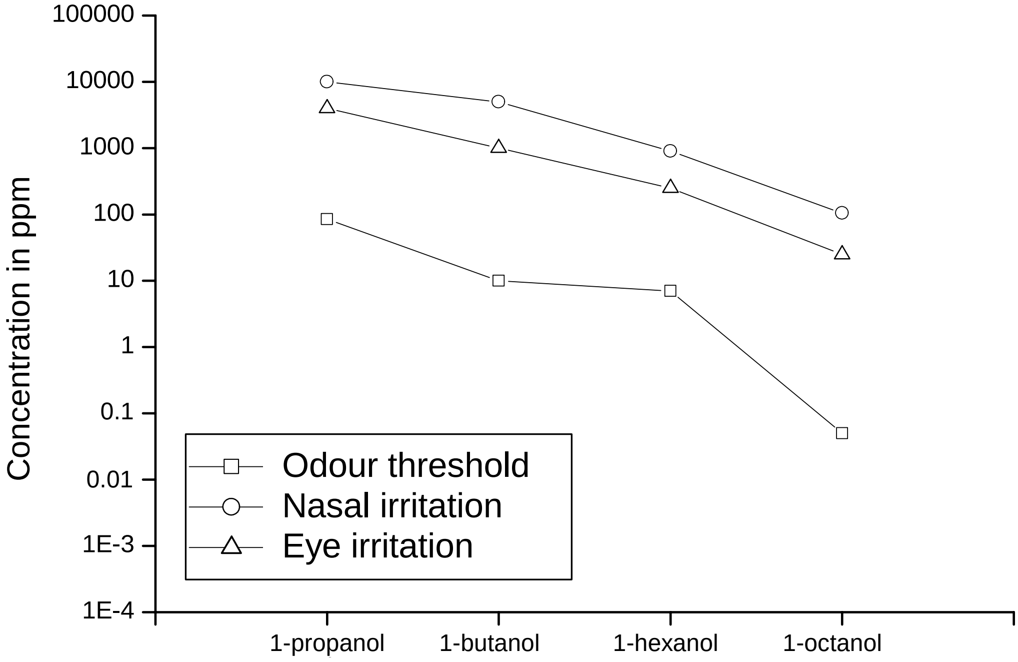

Fig. 4: Odour and irritation thresholds of aliphatic alcohols according to Cain et al. (Cain, 1996)[11]

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[11] Cain, W.S.; Cometto-Muniz, J. E.: Sensory Irritation Potency of VOC's Measured through Nasal Localization Threshold, Proceedings of Indoor Air 1996, Vol. 1, 1996, p. 167-172

[12] DIN EN 13725: Bestimmung der Geruchsstoffkonzentration mit dynamischer Olfaktometrie (Determination of the Odorous substance Concentration using Dynamic Olfactometry), Beuth Publishing House, Berlin, 2003

Extensive investigations on aliphatic alcohols by Jensen et al. (Jensen, 1996)[13] confirm this result. However, they also demonstrate that this only applies up to a certain chain length. Afterwards changes in the odour threshold are insignificant. The lowest odour threshold was obtained in these investigations for hexanol (molecule weight 102 g/mol). At only 10^{-3} ppm, the odour threshold lies far below the measuring range of analytical methods.

The characteristics of the investigated alcohols change with the molecule size. This also applies to other organic odorous substances, at least qualitatively. Fitzner (Fitzner, 1998)[14] concluded from other investigations that not only the odour threshold, but also other characteristics, such as adsorption and emission, depend on the molecule size. Relying on the work of Wolkoff (Wolkoff, 1995)[15] and Levsen et al. (Levsen, 1993)[16] he found that many substances with a large molecule weight have a high boiling point and thus a low vapour pressure. They are therefore emitted slowly, and even if the source strength is small, it remains preserved over a long time. In addition they are better adsorbed at surfaces, so that secondary sources of pollution can develop in the room.

The investigations mentioned show that odour can serve as an indicator for the presence of volatile organic components in the room air. Based on substances whose sum is perceptible with the nose, people can evaluate the room air quality and impurities in the air caused by materials and technical equipment.

However, the results of the evaluations about the perceived air quality fail to provide a suitable basis for the precise calculation of the exterior air flow rates for mechanically ventilated rooms as a function of existing and/or expected pollutants. The reason is due to the large number of influences on the emergence and perception of odours, the small number of measurement data of different sources and the inadequately known laws of addition of air pollutants.

2.3 Influence of humidity and temperature

In the human body the nose does not only serve for the perception of odorous substances from the environment, but also fulfils important tasks in the breathing apparatus. It is responsible for conditioning the breathing air, i.e. keeping a moderate temperature, humidification or dehumidification and cleaning. The mucous membranes lining the entire nasal cavity serve this purpose. The smell receptors are in the mucous membranes. They detect odour molecules, which diffuse from the air into the mucous layer. Depending upon the condition of the breathing air, the blood circulation and water content of the

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[13] Jensen, B.; Wolkoff, P.: VOCBASE: Odor Thresholds, Mucous Membrane Irritation Thresholds and Physico-Chemical Parameters of Volatile Organic Compounds, National Institute of Occupational Health, Denmark, 1996

[14] Fitzner, K.: „Perceived Air Quality” und Molekülgröße flüchtiger organischer Substanzen (VOC) ("Perceived Air Quality" and Molecule Size of Volatile Organic Substances (VOC)), VDI Berichte 1373, VDI Verlag Düsseldorf, 1998, p. 41-49

[15] Wolkoff, P.: Volatile Organic Compounds – Sources, Emissions, and the Impact on Indoor Air Quality, Int. Journal of Indoor Air and Climate, 3/95, Munksgard, Copenhagen, 1995, p. 1-73

[16] Levsen, K., Sollinger, S.: Textile Floor Coverings as Sinks for Indoor Air Pollutants, Proceedings of Indoor Air ’93, Vol. 2, 1993, p. 395-400

mucous membranes are varied, whereby its thickness changes. These fluctuations in thickness and composition of the mucous membrane may have an influence on the diffusion of the odorous substance molecules and thus on the perception of odorous substances.

The relationship between the odorous substance perception and the thermal condition of air was investigated by Fang (Fang, 1997)[17]. He found that the perceived air quality depends on its specific enthalpy. The higher the enthalpy of the air, the worse the air quality became. Fang used untrained persons in the tests, who evaluated the acceptability of the air. The results determined by Fang are shown in Fig. 5 using the material-specific approximate straight lines for the tested materials. The straight lines describe the correlation between the acceptability and the specific enthalpy of the air.

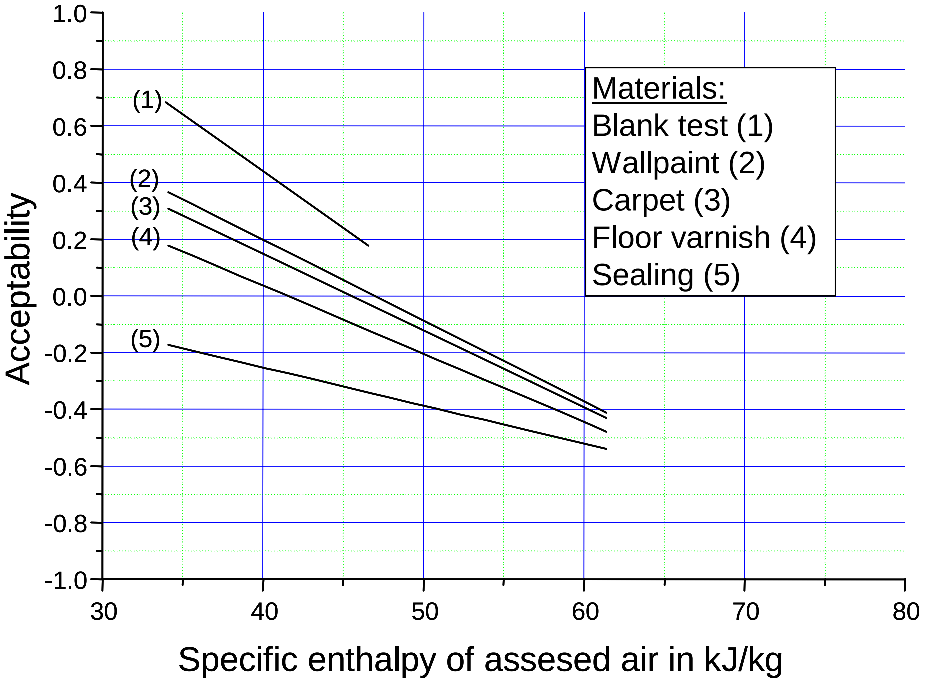

Fig. 5: Relationship between specific enthalpy of air and acceptability according to Fang (Fang, 1997)[17]

The enthalpy of the air was varied in two separate test series. In the first test series the enthalpy was influenced by changing the air temperature while keeping the humidity constant. In the second test series the humidity content of the air was changed and the temperature kept constant. For all investigated materials a degradation of the acceptability values was experienced with increasing specific enthalpy of the assessed air. The kind of enthalpy variation did not have any influence on the test results.

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[17] Fang, L.: Impact of Temperature and Humidity on Perceived Indoor Air Quality, Ph.D. Thesis, Technical University of Denmark, Copenhagen, 1997

3 Odorous substances

3.1 VOCs

Numerous volatile organic substances (VOC – volatile organic compounds) can be found indoors. They originate from furnishings, building materials, supply air and from people. The VOCs are divided into classes according to their boiling temperatures. The class of the VOCs is based on the boiling point.

Class	Designation	Abbrev.	Range of boiling point
1	Very volatile organic substance	VVOC	<0 to 50-100 °C
2	Volatile organic substance	VOC	50-100 to 240-260 °C
3	Semivolatile organic substance	SVOC	240-260 to 380-400 °C
4	Particulate organic matter	POM	> 380 °C

Table 1: Division of VOCs in four classes

3.2 Micro-organisms

The organisms of the earth are divided into plants and animals based on their morphologic and nourishment-physiological characteristics. The photo-synthesizing plants are called phototrophic, the animal organisms heterotrophic. In addition to plants and animals, micro-organisms developed sharing common early stages of life. They belong neither to the plants nor to animals, since they are not capable of photo-synthesizing or have organs which would serve for food intake of organically fixed energy.

Based on their cell structure, micro-organisms are divided into higher and low protists. The low protists do not possess a cell core with a membrane. The DNA lies freely in the cytoplasm as a circular molecule. Bacteria (prokaryotes) belong to the low protists. In the higher protists the cell core (nucleus) is surrounded by a double membrane and contains the genetic material. The fungi (eukaryotes) are representatives of this group.

Micro-organisms are characterised scientifically with two names, which originate from Latin or Greek. The first name designates the kind (genus), second the type (species). For the mushroom *Aspergillus Niger*, *Aspergillus* characterises the kind and *Niger* the type within the kind of the *Aspergilli*.

Micro-organisms occur in nature practically everywhere. They are an important member in the food chain, since they degrade perished organic material while also serving as a source of nourishment for other organisms. During their growth, micro-organisms may deliver metabolic products (e.g. mycotoxins, antibiotics, allergens), which may be a nuisance or impair human health.

3.3 Fungi

The kingdom of fungi covers a large variety in form of more than 120,000 species. The eukaryotic cell structure of the fungi resembles plants more than the bacteria, although it is perfectly carbon heterotrophic. Fungi differ from the bacteria by having a real cell nucleus.

Fungi grow either as single cells (yeasts) or as multi-cellular colonies (moulds). A division of labour between vegetative and reproductive organs is characteristic of the fungi. The vegetative organs consist either of threadlike cells, the hyphae, or round to oval buds, which secure nutrition and growth in a nutritive substance. The hyphae expand their volume longitudinally by tip growth. Side hyphae may emerge by lateral protuberances, i.e. genuine branches and form a hyphae matrix (mycelium). Some fungi divide the hyphae by septa into individual cells.

The life cycle of fungi contains two phases of reproduction: the generative (sexual) and the vegetative (asexual) phase. Fungi, of which both reproduction phases are known, are classified as perfect fungi. If only the asexual phase is known, the fungus is called imperfect.

The reproductive organs of the fungi are termed spores. They are formed as conidiums at the tip of special hyphae or as sporangium spores within bag-like structures at the end of special hyphens. Sexual spores develop as a final product after fusing two cell cores.

Spores are a permanent form of fungi and occur everywhere in the environment. They can last long periods under unfavourable conditions. When favourable climatic conditions and sufficient nutrient supply becomes available, the spores form the centre of new fungal colonies.

The growth of nearly all kinds of fungus depends on the availability of water. The relative air humidity or water activity must also be as high as possible. Water activity a_w is understood as

$$a_w = \frac{p_{d,M}}{p_{d,0}} \qquad \text{(Eq. 4)}$$

with: $p_{d,M}$: vapour pressure of water in the nutritive substance

$p_{d,0}$: vapour pressure of pure water.

Fungi can be divided based on their preferential humidity conditions into xerophile, mesophile and hydrophilic species. Xerophile fungi prefer dry conditions, hydrophilic funguses however require very high a_w values of over 0.95.

Fungi frequently cause problems in the field of heating and air conditioning if the air is too damp in closed rooms. Usually low external air flow rates coupled with thermal bridges are the causes of fungi growth. Table 2 displays a list of fungus types occurring in damp rooms.

Kind	Place of occurrence
Alternaria alternata	Moist walls, moist window sills
Aspergillus versicolor	Moist wood
Aureobasidium pullulans	
Cladosporium herbarum	Moist walls, moist window sills
Cladosporium cladosporioides	Moist walls, moist window sills
Cladosporium sphaerospermum	Moist walls, moist window sills
Eurotium repens	Furniture, wallpaper
Penicillium brevicompactum	Moist drywall panels
Penicillium chrysogenum	Moist wallpaper, behind coats of paint
Penicillium expansum	Drywall panels, mineral wool
Rhodotorula spp	Moist cellar walls
Stachybotris chartarum	Drywall panels
Trichoderma viride	Moist wood

Table 2: Some fungus species frequently occurring in damp buildings

Exterior air and room air in buildings contain airborne fungi. Table 2 displays some of the most frequently occurring fungus species. These species settle in the household dust and can be detected there. Some kinds of fungus can cause allergies and asthma attacks or result in chronic asthma after longer exposure.

4 Sampling and Sample Provision

4.1 Sampling

Two kinds of sampling can be distinguished: static sampling (indirect sampling) and dynamic sampling (direct sampling or on-line measurement).

Static sampling

No measuring method with the possibility of static sampling has been defined in the field of perceived air quality so far. Static sampling requires a system ensuring odour-neutral storage of air samples. The Hermann Rietschel Institute was first to develop this kind of device, see AirProbe I.

Dynamic sampling

Sampling takes place directly at the odour source. Ambient conditions can impair the measurement result. The sampling is coupled with the sample provision and is described in the following chapter. No storage of the samples is necessary.

4.1.1 Direct assessment of rooms

The panel members enter the room to be assessed and must immediately make their assessment for the perceived air quality. The disadvantage of this simple method is that the panel members develop an attitude of expectation due to the surrounding stimuli such as other people, installed equipment and type of room, which can affect the evaluation of room air quality. In addition, adaptation takes place to the basic odour of the building on the way through a building complex to the test room.

4.1.2 FLEC method

The FLEC method (Field and Laboratory Emission Cell) was developed in Denmark by Peter Wolkoff at the Danish National Institute for Occupational Health in 1991. The special feature of this measuring chamber is the fact that the material to be tested (e.g. furniture surface) becomes the bottom of the chamber. Thus FLEC can be used in buildings or in production lines to determine the emissions from individual building materials without destroying the object. In addition, when analysing an individual building material, the interference with other sources of emission in the room is also avoided.

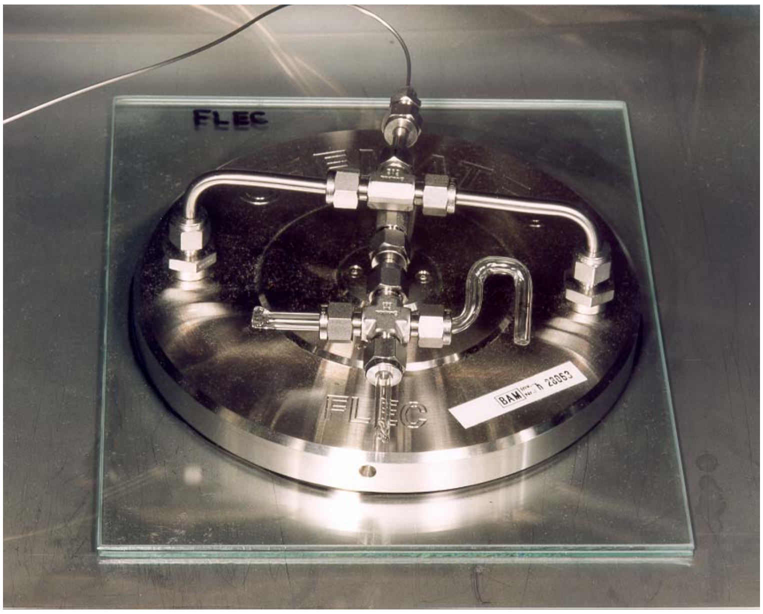


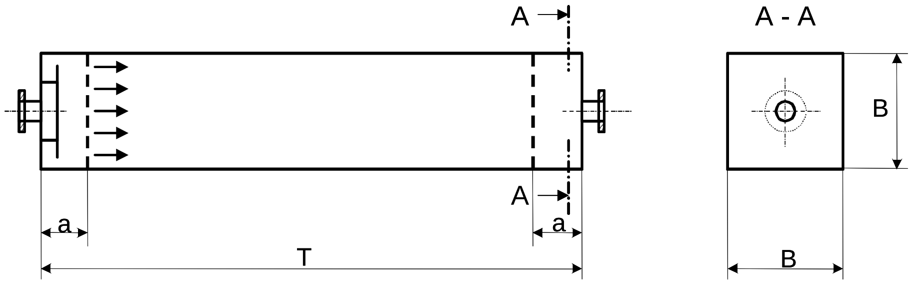
Fig. 6: Photo of a FLEC (Field and Laboratory Emission Cell)

The round FLEC (Field and Laboratory Emission Cell) has an outside diameter of 20 cm and consists of solid stainless steel. With a height of 2 cm (without connections) the FLEC weighs 4 kg and creates a chamber volume of only 35 cm³. The bottom of the FLEC leaves an area of 177 cm² open for the test material. The connections for supply air and exhaust air are on the top of the cell. Air is distributed through a narrow slot to the entire cell and collected again in the centre. Contamination of the cell from the outside is avoided by a positive pressure within the cell.

4.1.3 Emission chamber (CLIMPAQ)

A CLIMPAQ is a special test chamber, which has increasingly been used in investigations of perceived air quality world-wide for some years. The name "CLIMPAQ" is derived from the expression "**C**hamber for **L**aboratory **I**nvestigations of **M**aterial, **P**ollution and **A**ir **Q**uality". The test chambers were developed by Gunnarsen, Nielsen and Wolkoff at the Technical University of Denmark in Copenhagen in 1994. As in all investigations of pollution sources, such materials were used to build these test chambers that possess only an extremely small source strength.

These test chambers have also been used in a slightly modified form at Hermann Rietschel Institute since 1999. The structure of a chamber is depicted in Fig. 7. The direction of air flow is indicated by arrows in the figure. The majority of the kinetic energy of the supply air is dissipated immediately after entering the chamber by an impact plate. This plate is followed by the first of two laminarisator plates. This provides for an even distribution of the air flow over the entire chamber cross-section. The actual test chamber with the material to be tested is the space between the two laminarisators.



B = 0.210m
T = 0.985m
a = 0.090m

Fig. 7: Structure of a test chamber

At the exit of the test chamber the air is contaminated by the material to be tested. The laden air is assessed by a trained smell panel either directly or after dilution with clean air (Fig. 8). The chambers are used in investigations of the relationship between the concentration of individual odorous substances or odorous substance combinations and their perception by humans. These investigations help determine material-specific characteristics, which describe the sought after relationship.

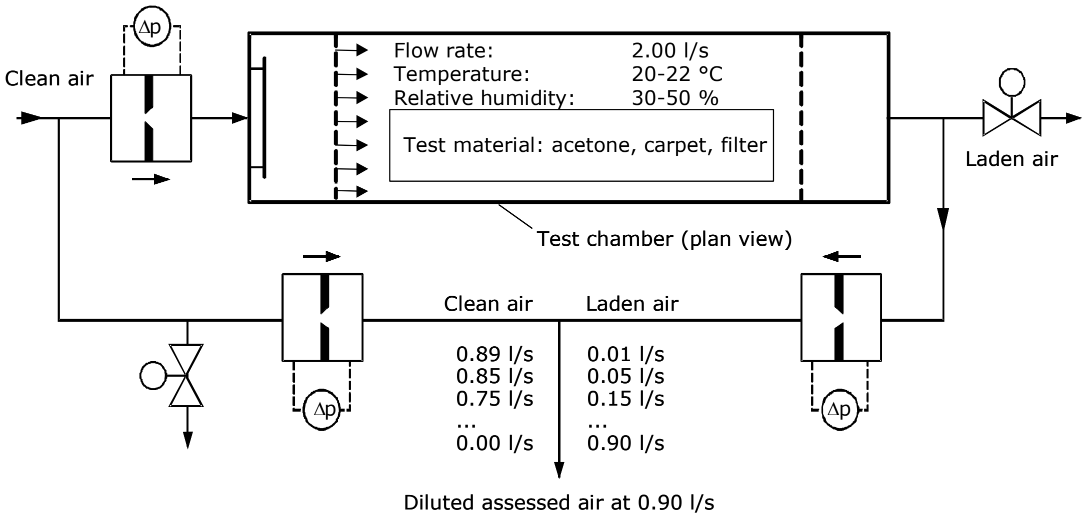


Fig. 8: Experimental setup for individual materials tests (Please use decimal points.)

The investigation of odorous substance combinations serve to determine the calculation rules for the perceived air quality, which enable the determination of the expected air quality in a room with several sources of pollution based on the data from individual materials (Böttcher, 2003)[18]. The exterior air flow rate, needed for the removal of the contamination, can then be determined from this.

4.1.4 AirProbe I

AirProbe I is a sampling and sample provision system developed at the Hermann Rietschel Institute in 2001 (Müller, 2002)[19]. It encompasses filling and emptying sample bags made from polymer foil. Pumps may impair air samples due to their own emissions or lubricant emissions. Adsorption and/or desorption processes can take place in the pumps or at the walls of the feeder pipes, also affecting the air sample composition. Therefore no pump is installed in AirProbe I for air sample transport, and supply and exhaust pipes are kept short. Instead, air transport is facilitated by two integrated fans in the casing. One of the fans produces a vacuum in the casing, and another a positive pressure and they fill or empty the sample container. The sample container is fastened inside the casing to a short stainless steel pipe through which the sample air enters the sample container. In sample provision modus the air is transported in the opposite way, i.e. outward. Fig. 9 shows the principle sketch of the sampling equipment "AirProbe I".

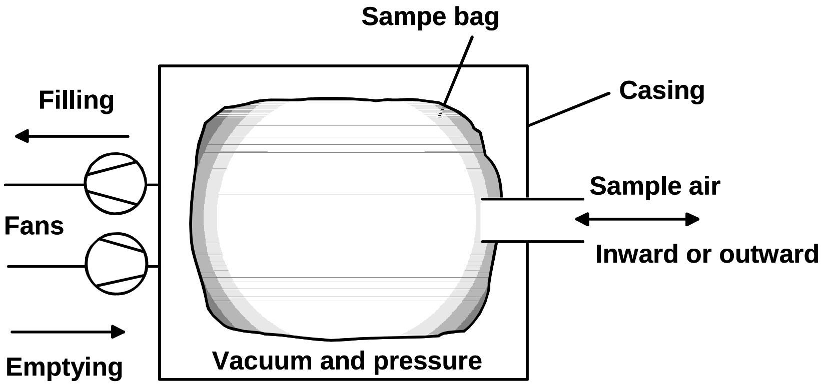


Fig. 9: Principle sketch of the sampling device

Fig. 10 and Fig. 11 show photos of the developed sampling and sample provision device. The casing is 700 mm wide x 700 mm deep and 600 mm high. This corresponds to a volume of 294 litres. This volume is needed to provide sufficient sample air for a panel of 10 persons.

When choosing the size it has to be born in mind that one or two people should be able to handle the equipment and it should fit through normal doors. The sampling equipment illustrated here is manufactured from laminated plywood.

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[18] Boettcher, O.: Experimentelle Untersuchungen zur Berechnung der Empfundenen Luftqualität (Experimental Investigations for Calculation of Perceived Air Quality), Thesis, Technical University Berlin, 2003

[19] Müller, B.: Entwicklung eines Gerätes zur Entnahme und Darbietung von Luftproben zur Bestimmung der empfundenen Luftqualität (Development of Equipment for Sampling and Provision of Air Samples for the Determination of Perceived Air Quality), Fortschritt-Berichte VDI, VDI Publishing House, Düsseldorf, 2002

For future equipment of this kind, low-emission and light materials such as aluminium should be selected. On the one hand lighter devices are easier to handle and on the other hand it cannot be excluded that materials can permeate from the equipment into the sampling container.

Fig. 10: Sampling and sample provision equipment AirProbe I

Fig. 10 shows the sample provision equipment with smell funnel. The panel members can evaluate the sample air at the smell funnel. The connecting pipe from the funnel to the case consists of stainless steel. It can also be used for sampling if the funnel with the T-fitting is removed, creating an opening through which air can flow into the equipment.

Fig. 11: View of the sampling device with the fans which can produce pressure or a vacuum in the casing

In Fig. 11 two adjustable fans can be recognised on the rear wall of the casing. The arrows on the fans indicate whether air is pumped in or sucked from the casing. The filling status of the sample container can be observed through the perspex cover.

As the investigations have shown, the volume of this device is sufficient to perform a test with ten panel members. Before the panel members start work on this device they must be advised that the measurement should be performed briskly.

4.2 Sample storage

If samples are not taken directly but assessed or evaluated later, great importance must be attributed to sample storage and site conditions.

Special requirements have been developed in VDI 3881[20] for sampling and sample storage. The standard differentiates between a dynamic method (in-situ sampling and assessment) and static sampling, where the odorous substance sample is taken in a suitable container/foil bag. The sample volume needed for the olfactometer measurement depends essentially on the following factors:

- Odorous substance concentration,
- Air flow rate,
- Number of panel members,
- Type and number of measurement series.

For a simple smell threshold investigation using Olfactometer TO7, a minimum of eight litres of sample air is needed. The retention time of the sample between sampling and measurement should be as short as possible and not exceed 24 hours. Changes in the sample can be checked by olfactometry after different retention times. However, chemical analysis using gas chromatography is more suitable.

The following requirements are made to the material of the sampling bags:

- odour-neutral,
- chemically inert,
- minimum adsorption inclination toward odorous substances,
- minimum permeability toward odorous substances,
- opacity if the sample to be tested shows light sensitivity,
- capable of bearing mechanical loads,
- weldable.

VDI 3881 specifies potential materials for sampling containers which have proved unsuitable for the storage of sample air in the investigations of Müller[21]. The Hermann Rietschel Institute uses PTFE foils for short term sample storage, while

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[20] VDI 3881, Sheet 2: Olfaktometrie. Geruchschwellenbestimmung: Probenahme, VDI-Richtlinie (Olfactometry. Odour Threshold Determination: Sampling, VDI Guideline). Beuth Publishing House, 1987; replaced by DIN EN 13725 in July 2003.

[21] Mueller, B.: Entwicklung eines Gerätes zur Entnahme und Darbietung von Luftproben zur Bestimmung der empfundenen Luftqualität (Development of Device for Sampling and Provision of Air Samples for the Determination of Perceived Air Quality), Progress Report VDI, VDI Publishing House, Düsseldorf, 2002

pre-treated TEDLAR® has proved to be best suited for long-term storage. Re-use of TEDLAR® sample bags is possible after careful annealing.

4.3 Sample provision

4.3.1 Required amounts of air

In order to ensure a perfect odour assessment, funnel design and amount of air sample must be co-ordinated.

According to Silbernagel et al. (Silbernagel, 1991)[22] resting humans breathe approximately 15 times a minute and inhale a volume of 7.5 l/min. This means that, on average, humans have a breathing volume of 0.5 l. At least this volume must be provided to the panel members during the tests.

Knudsen investigated the evaluation of perceived air quality as a function of flow rate at the nose of the panel members and/or at the exit of the funnel (Knudsen, 1994)[23]. He let panel members smell a sample with an odour load of 10 decipol and varied the flow rate from 0.2 to 1.5 l/s.

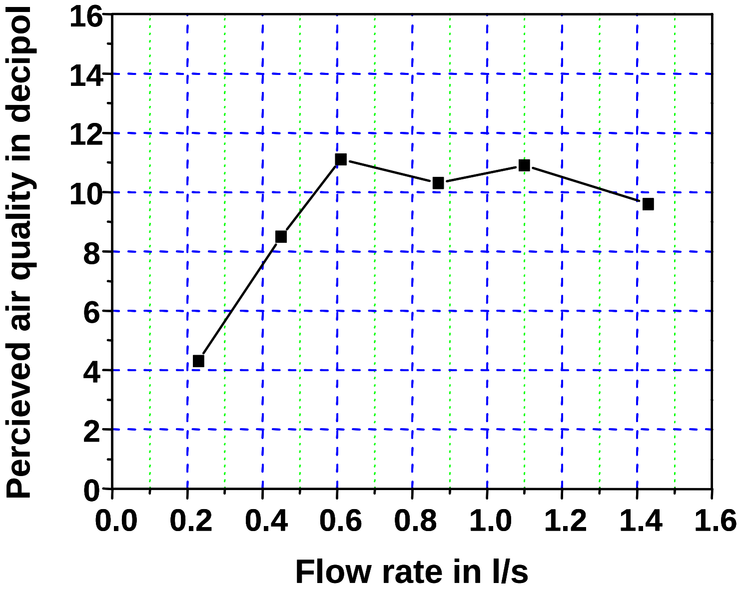

Fig. 12: Investigation of Knudsen on the influence of flow rate on the evaluation of perceived air quality (Knudsen, 1994)
(Please use decimal points.)

The investigation showed that measurement accuracy for the assessment of perceived air quality is only constant from a flow rate of approx. 0.5 l/s to 0.6 l/s at the funnel end. Smaller flow rates fail to ensure an exact assessment of perceived air quality.

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[22] Silbernagel, S.; Despopoulos, A.: Taschenbuch der Physiologie (Pocket Manual of Physiology, Thieme Publishing House, 4th Edition, 1991

[23] Knudsen, H. N.: Modelling af indeluftkvalitet (Modelling of Indoor Air Quality), Ph.D. Thesis, Technical University of Denmark, 1994

Usually a flow rate between 0.9 to 1 l/s is adjusted at the funnel exit of markers and samples.

4.3.2 Assessment funnel

The panellists must assess samples from different sources in the air quality laboratory. Decipolmeter, CLIMPAQ and AirProbe I are designed in such a way that they can provide approx. 3 m³/h sample air. To ensure a uniform evaluation of sample air, the Hermann Rietschel Institute uses glass funnels for the various sources. Glass emanates no or negligibly small quantities of pollution into the sample air and conversely only small quantities of odorous substances settle on the surface. The design of the measurement funnel ensures that no ambient air is sucked in and mixed with the sample air, see Fig. 13. An opening angle of 12° ensures an homogeneous outflow of sample air. The funnels have a top opening of approx. 80 mm in diameter, a bottom opening of 23 mm in diameter and a height of 310 mm.

Fig. 13: Assessment funnel for Fanger's method

4.3.3 Air quality laboratory at the Hermann Rietschel Institute

The sketch of the laboratory built in autumn 1997 is shown in Fig. 14. It consists of two cabins connected to each other. In the test cabin the test individuals make their assessment of the air quality. The resting cabin serves as a lounge between the assessments and for the recovery of their sense of smell. No assessment of air quality takes place in this cabin.

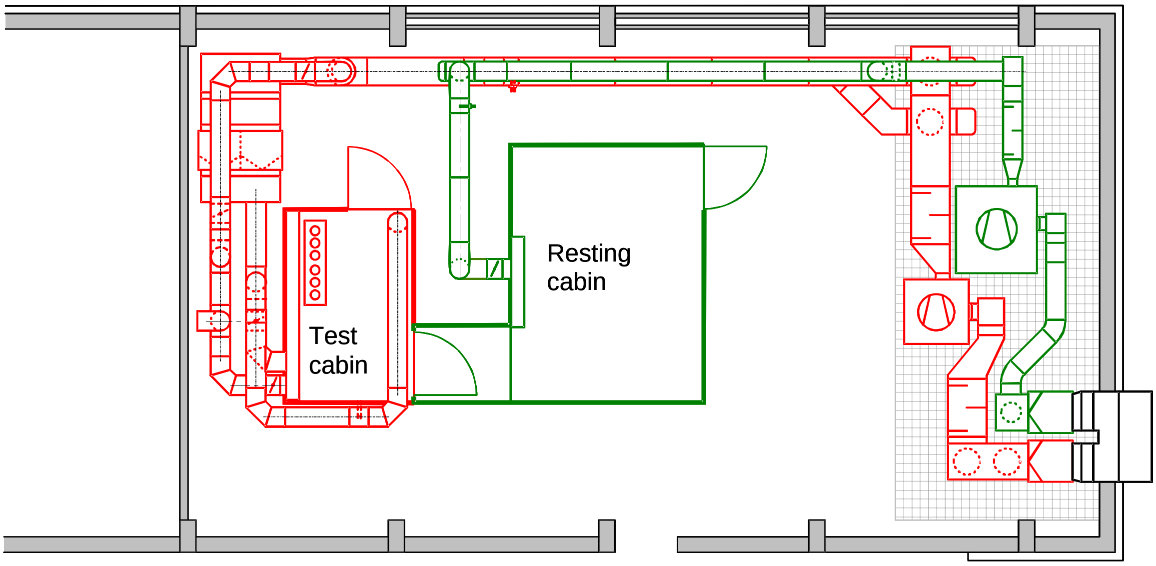

Fig. 14: Sketch of the laboratory

Training of the panels and laboratory tests on material samples and components of air conditioning systems are also performed in this laboratory. The measurements based on the VDI method using an olfactometer are also carried out in this laboratory since good ambient air is provided.

The interior dimensions of the test cabin are 2.0 m x 3.0 m and a height of 2.0 m. The frame of the test cabins consists of steel profiles. The walls are constructed of 8 mm safety glass. The windowpanes have the advantage that they are easy to clean and emanate only very little to no odorous substances. A positive pressure prevails in the test cabin, maintained by the supply air flow rate, thus the joints between the windowpanes do not have to be sealed. That sealing materials are omitted is an advantage, since an additional source of odour emission is eliminated. No exhaust air system is needed, as air can escape from the test cabin through the leakages into the environment due to the positive pressure.

The interior dimensions of the resting cabin are 2.80 m x 3.80 m and a height of 2.05 m. The two cabins are connected by a 1.0 m x 1.60 m x 2.05 m connecting corridor. Any air exchange between the cabins during the tests is prevented by a door in the connecting corridor. This is necessary to keep the odorous substances of the test cabin away from the resting cabin. A second door enables direct access to the test cabin for the supervising personnel.

The entire air supply system consists of glass pipes. Other installations e.g. filter housing, butterfly valves and connecting pieces are made of stainless steel. No sealing material is used to avoid possible impurities in the supply air. The air supply to the two cabins is provided by two independent RLT units. Air supply flow rate, temperature and humidity can be separately adjusted and regulated in both air supply systems. The resting and test cabins are conditioned at a temperature of 20°C and 50 % relative humidity during tests.

Exterior air for both units is drawn in at a height of 6 m. Both RLT plants have a weather protection grating and a pre-filter (F7 for the test cabin and F5 for the resting cabin). The supply pipe for the test cabins branches into two glass pipes with a diameter of 400 mm behind the fan due to the required large air supply flow rate. The pipes enter a mixing box, followed by a double filter housing. The filter housing is used for both filtering the air supply and the investigation of new and used filters from the RLT units.

The air supply is heated and cooled on the exterior of the glass pipes by capillary pipe mats in which water circulates. Heat is provided by remote heating and cooling by a compression refrigerator. To be able to regulate the air supply temperature in both cabins independently, each air supply system is equipped with a separate water circuit. A steam humidifier is installed in each plant to humidify the supply air. The fan of the resting cabin ensures a maximum air flow rate of 1,800 m³/h. In most test series a flow rate of 900 m³/h was applied, which corresponds to a 40-fold air exchange rate. The fan of the air supply system can produce a maximum air flow rate of 2,700 m³/h. The impellers and the casings of the fans are made of stainless steel.

Target values can be entered and actual values read off for air temperature and humidity in the cabins at a display of the control box. A frequency converter limits the output power for the fans. The frequency/limit can be set by potentiometers at the control box.

An electronic data logger enables the determination of temperature and humidity in the RLT plants and exterior air automatically in a number of measuring points.

4.3.4 Sample provision for the VDI method

Due to its design, the VDI method requires considerably smaller flow rates. Prerequisite for a fast change between sample air and clean air (see Chapter VDI method) is a small volume of the assessment funnel. The olfactometer used at the Hermann Rietschel Institute provides an air flow rate of 1.2 m³/h at the assessment funnel. Therefore the funnel should be designed in such a way that the air flow surrounds the nose.

The Hermann Rietschel Institute has developed its own nasal funnel for the olfactometer with a top opening of approx. 40 mm, a bottom opening of 18 mm, a height of 110 mm and an opening angle of approx. 12°, see Fig. 15.

This design ensures an homogeneous, pleasant flow around the nose and effectively prevents dilution by secondary air.

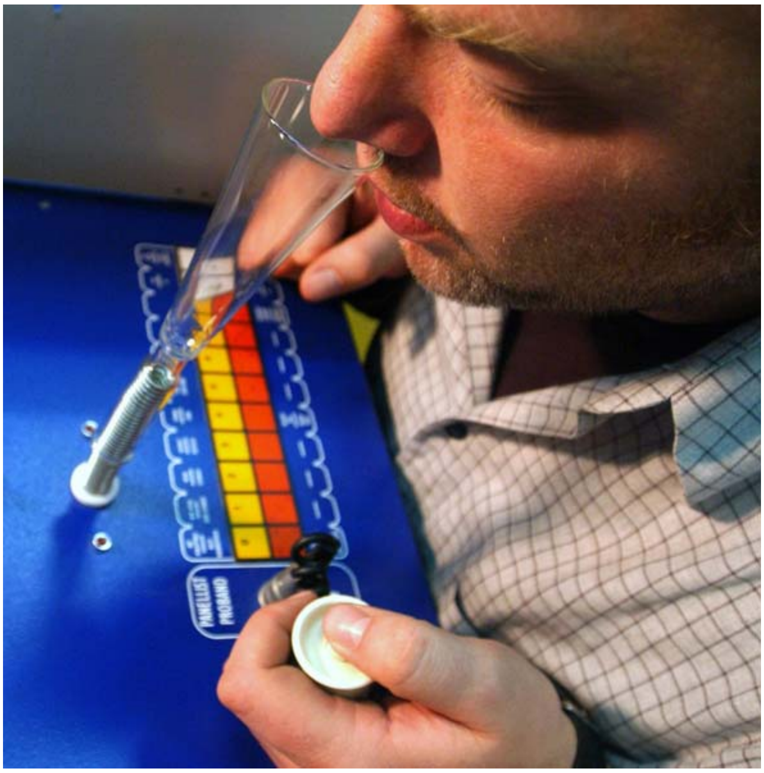

Fig. 15: Assessment funnel for the VDI method

4.3.5 Decipolmeter

In Fang's method the samples for training (acetone samples) and material samples are provided in so-called decipolmeters. A decipolmeter consists of a glass test bottle, which contains the sample (Fig. 18). A fan pumps air from the box into the glass bottle. The air circulates and takes up the odorous substances from the sample surface and leaves through the assessment funnel. The assessment of air contaminated with the sample is carried out at the top rim of the assessment funnel. Acetone samples are provided in small bottles with special holes in the cap to allow acetone to enter the air to be assessed. The size and number of the holes in the cap determine the amount of evaporated acetone which can mix with the exterior air in the large test bottle. If material samples are tested, the acetone bottle is replaced with the sample in the glass test bottle.

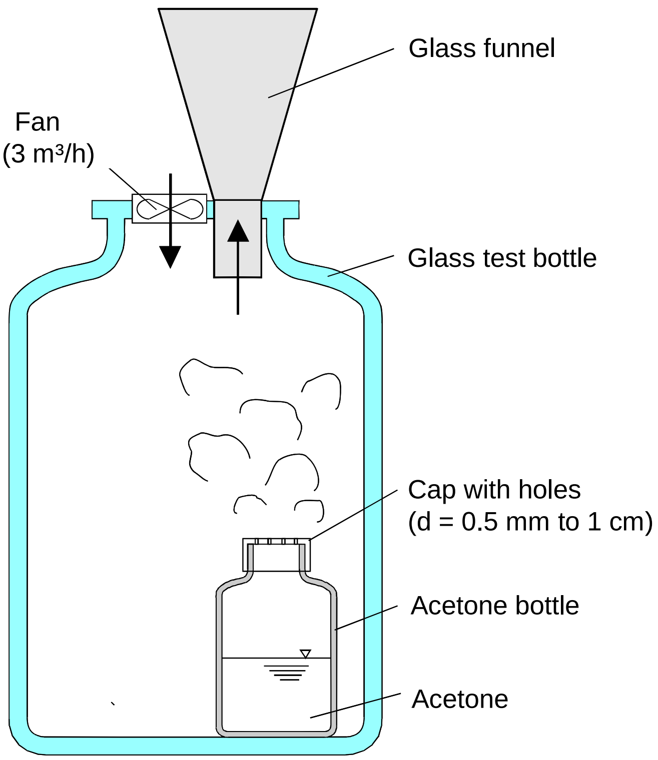

Fig. 16: Scheme of a decipolmeter

At the Hermann Rietschel Institute the test bottles have a volume of 5 l with a top opening diameter of 8 cm. This opening is covered by a plastic cap with an integrated fan of 3 m^3/h capacity.

4.4 Comparative scale (markers)

When assessing perceived intensity of unknown samples, panel members can rely on a comparative scale of acetone/air mixtures, the so-called markers, which help to determine intensity.

Unlike the acceptability method with untrained panels, the intensity of odorous substances in the air is determined by a comparison with different specified intensities of the reference material acetone. The smelling capability varies from human to human. Training and use of comparative sources ensure that the influence of subjective perception of the test result is reduced since all panel members evaluate air quality based on the same scale.

Previously, the comparative scale with the decipolmeters was provided (see 4.3.5). The pattern of the comparative scale used today was developed anew at the Hermann Rietschel Institute. The objective of the development was a adjustable stable acetone concentration independent of the ambient conditions in the sample air. The design scheme of the comparative scale is illustrated in Fig. 17.

The markers are in essence composed of three parts: sample air circulation, source of acetone and dosing device. The units in contact with air are almost wholly manufactured from stainless steel and glass, which are practically smell-neutral.

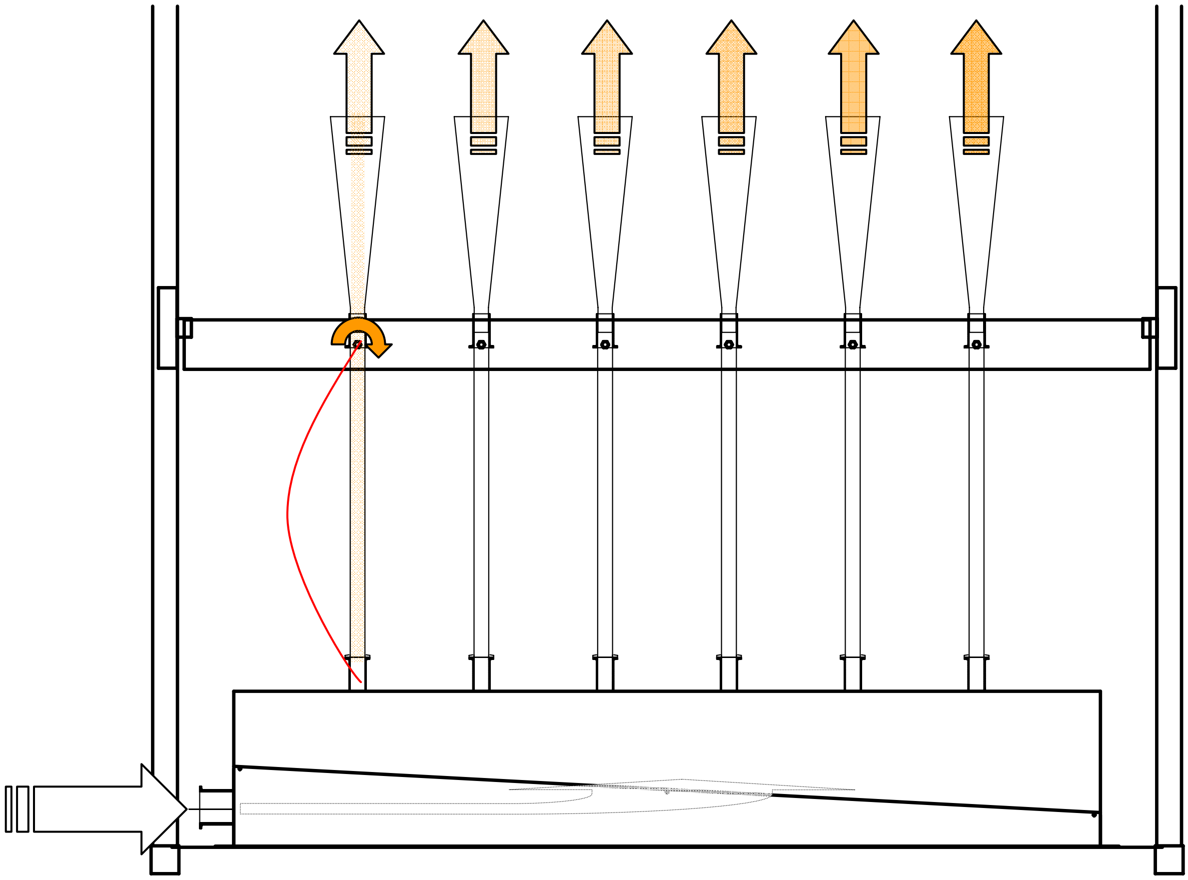

Fig. 17: Scheme of comparative scale

Sample air circulation is connected via a flange to a suitable smell-neutral air supply. The sample air circulation provides constant flow rates between 0.9 and 1.0 l/s per marker (5.4 to 6.0 l/s for six markers) which ensures an undisturbed operation. The constant source of acetone consists of a pressure-resistant wash bottle and a cooling device. It must be started at least 9 hours before commencing the tests in order to reach the correct operating temperature. The wash bottle is supplied with synthetic air.

Compressed air is pumped through the wash bottle filled with acetone and then enriched. Cooling prevents an over saturation of the compressed air and a consecutive condensation in the pipes. The acetone fog is effectively separated by a cellulose filter from the enriched air.

The six markers are supplied with the constant air/acetone mixture via a distribution hose. A metering valve per marker regulates the amount of the acetone/air mixture added to the sample air within the range of 0 to 1150 mg/m³.

The design of the air supply ensures a homogeneous mixing of the acetone in the sample air.

If the air supply of the comparative scale with constant flow rate and constant pressure is ensured, the desired quantity of acetone for the markers can be adjusted by the metering valves. It takes some time to adjust the desired target value for the first time. The adjusted concentrations have to be tested with a suitable measuring instrument. If the gradations of the marker are not changed for several days during the test, time requirement for adjustment is reduced considerably.

5 Person-related measuring methods

In the person-related air quality measurements human perception is defined as a substantial measure for the evaluation of air quality with the nose being used as a measuring instrument. Since smell perception is shaped by subjective experiences of each person, depending upon the method of measurement, various panel sizes are needed to be able to generalise the results of questioning.

A relatively large number of test persons (> 40) is needed for tests with untrained panels, while a much smaller number of panel members (~10) can provide statistically reliable results when trained tests persons are employed.

5.1 Fanger's method

Fanger developed a method to determine the indoor air quality with test persons. He introduced two new quantities with units for the quantitative determination. The pollution load G is indicated using the olf unit (Greek: olfactus) (Fanger, 1988)[24]. One olf is the pollution load caused by a standard person. Since pollution caused by persons depends on activity, clothing and hygiene, he defined a standard person as a healthy adult at a comfortable ambient temperature with a hygiene standard of 0.7 baths per day and seated. However, the pollution load cannot be directly measured, instead it is deduced through the perceived air quality C. This is indicated in the pol unit (Latin: pollutio).

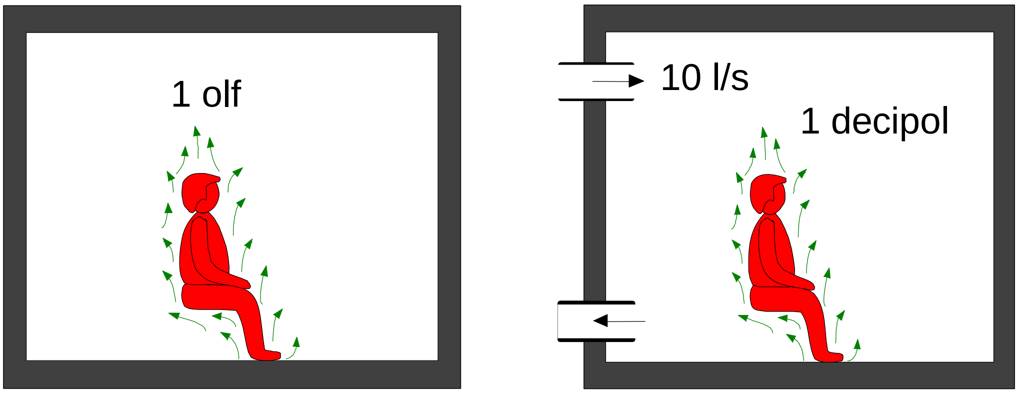

Fig. 18: Illustration of the units olf and decipol

One pol corresponds to the perceived air quality at a pollution load of one olf and a ventilation rate of 1 l/s. For the evaluation of room air qualities, one tenth of the olf unit, i.e. decipol, is more suitable:

$$1\ decipol = 0.1\ \frac{olf}{l/s}. \qquad \text{(Eq. 5)}$$

Thus the perceived air quality can be determined from the pollution load as

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[24] Fanger, P.O: Introduction of the Olf and Decipol Units to Quantify Air Pollution Perceived by Humans Indoors and Outdoors, Energy and Buildings, 12, 1988, p. 1-6.

$$C = C_{out} + 10 \cdot \frac{\sum G}{\dot{V}} \,. \qquad \text{(Eq. 6)}$$

with C: perceived air quality [decipol]
C_{out}: perceived air quality of exterior air [decipol]
G: pollution load [olf]
$\dot{V}$: exterior air flow rate [l/s]

Fanger established a relationship between the number of dissatisfied people, PD (Percentage Dissatisfied) and sources of pollution referred to the flow rate. He employed an untrained panel. The determined relationship is represented in Fig. 19.

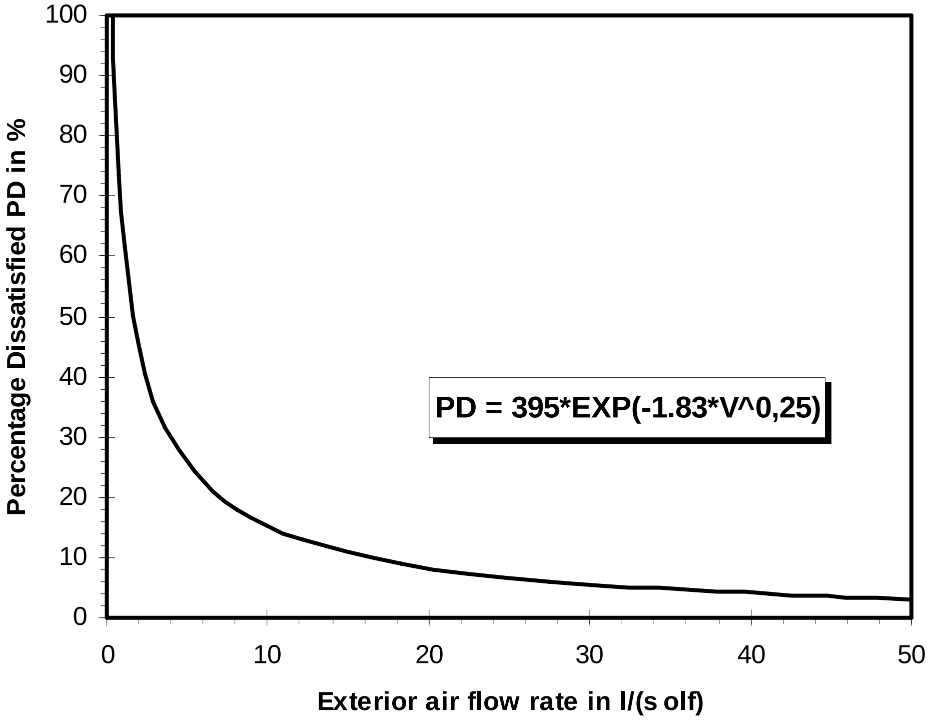


Fig. 19: Percentage dissatisfied as a function of person-related exterior air flow rate

Assuming the connection between olf and decipol from the equation definition, the following relationship is obtained between perceived air quality (C) and the number of dissatisfied people (PD):

$$PD = 395 \cdot EXP(-3.25 \cdot C^{-0.25}) \qquad \text{(Eq. 7)}$$

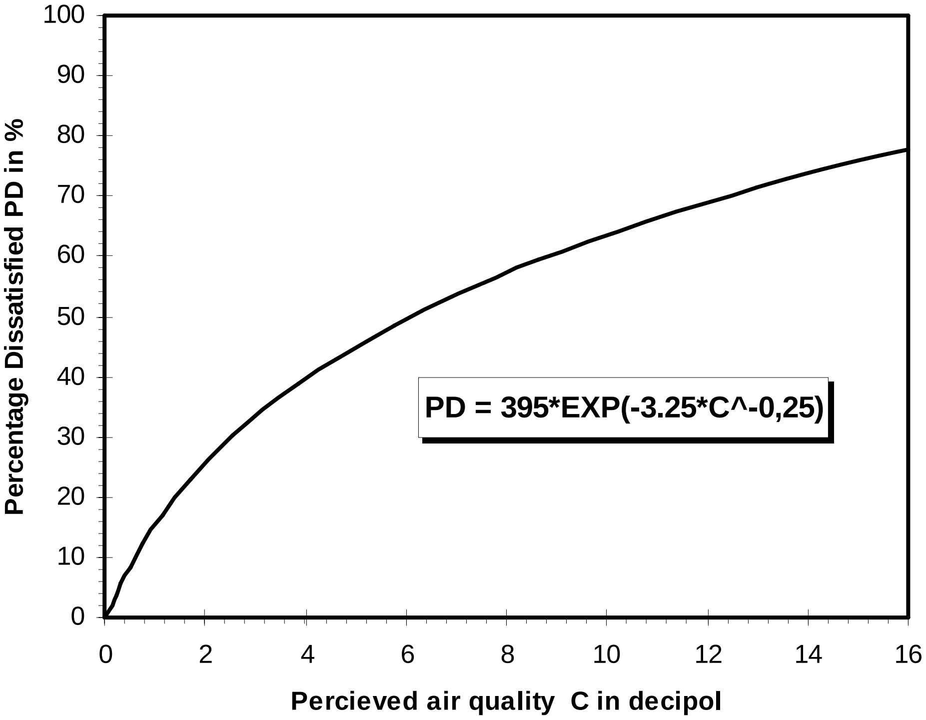


Fig. 20: Percentage dissatisfied as a function of perceived air quality C

Based on this function it is possible to determine the perceived air quality with a panel. However, in order to gain a reasonable result, large groups of test persons are necessary.

5.1.1 Odour investigations with untrained panels

The panel members are asked whether or not they are satisfied with the room air. The smaller the groups, the greater the weight of the evaluation of the individual persons and the more error-bound the determined percentage dissatisfied. This means an evaluation accuracy of 10% of PD for a panel of 10. The evaluation of a panel member causes a change in the percentage dissatisfied by 10%. For 50 persons this is only 2 %.

The method with untrained panels requires much effort, since large groups are needed and the method is expensive, since the panellists must be paid. For these reasons a method was developed to train the panels to ensure that an evaluation of the perceived air quality can be made directly in decipol units.

5.1.2 Odour investigations with trained panels

The panel members learn in a training session lasting several days to arrange perceived air quality of unknown samples on a comparative scale. The air quality is indicated by the panel members directly in decipol units introduced by Fanger. Acetone is used as a source of comparison. The panel members are provided with markers (decipolmeter) with different acetone concentrations. The method for training the panels and the use of acetone samples as a comparative scale for the determination of air quality was developed by Bluyssen at the Technical University of Denmark in 1989 (Bluyssen, 1990)[25]. She established a linear relationship between perceived air quality and acetone concentration:

$$C = 0.84 + 0.22 \cdot [c]_{acetone} \qquad \text{(Eq. 8)}$$

with C : perceived air quality [decipol]

$[c]_{acetone}$: acetone concentration of sample air [ppm].

The relationship is graphically represented in Fig. 22. Four markers with different acetone concentrations are provided for training and laboratory tests. These correspond to 2, 6, 10 and 17 decipol. In the odour investigation the sample to be tested is evaluated by comparison with the markers, see Fig. 21. The samples and the comparison samples are in a stainless steel box so that the panel members cannot see the samples. The acetone concentrations are produced in the decipolmeters.

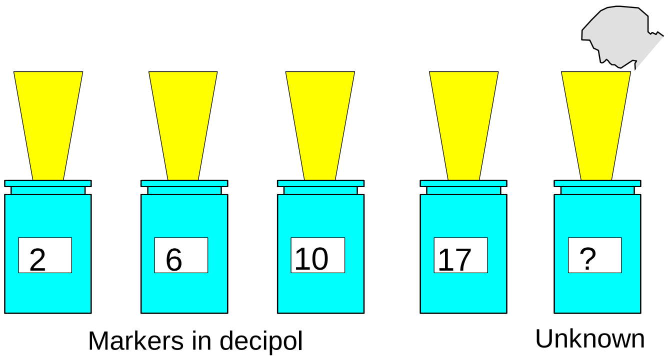
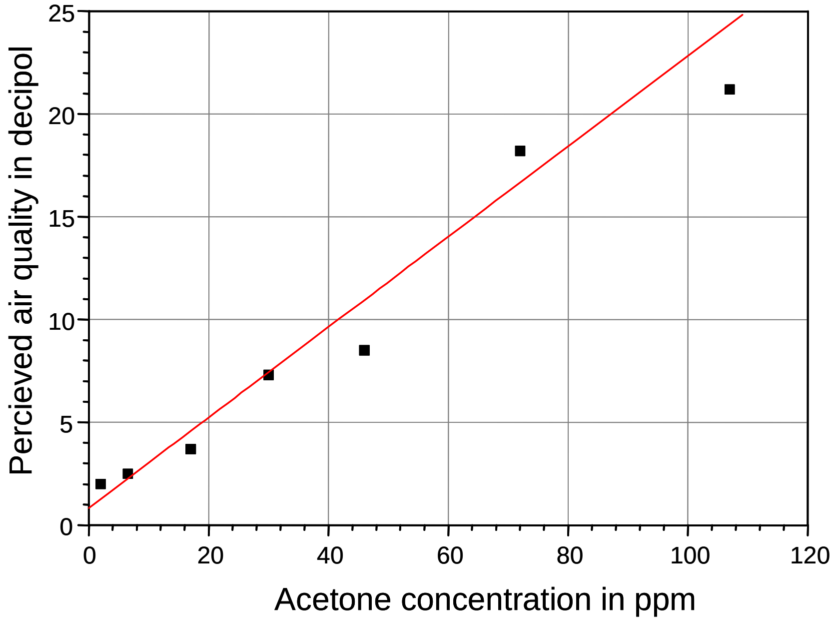


Fig. 21: Schematic illustration of the assessment of an unknown sample



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[25] Bluyssen, P.M.: Air Quality Evaluated by a Trained Panel, PhD Thesis, University of Denmark, 1990

Fig. 22: Relationship between acetone concentration of air and perceived air quality in decipol according to Bluyssen (Bluyssen,1990)

5.1.3 Training of panel members

The training consists of four test days. An overview of the training program is shown in Table 3.

Training day	Topic	Sample content
Day 1	Introduction Training Pre-selection	8 acetone samples
Day 2	Training	6 acetone samples 2 material samples
Day 3	Training	4 acetone samples 4 material samples
Day 4	Final test	8 acetone samples

Table 3: Training schedule to establish a trained panel

On the first training day the purpose of the program and the structure and function of the markers are explained to the test panellists. Eight different acetone concentrations must be determined by each person. The test panellists are told the actual air quality of each individual sample immediately after the test. If the determination of a test person differs greatly from the actual value, the test person has the chance of determining the sample once again knowing the actual value. Thus the possibility is given to the panel to adapt their internal scale to the accurate values in the next determination of a sample.

Panel members who have a very insensitive sense of smell or exhibit a very high error rate are removed from the training programme after the first training day.

On the second and third training day, acetone concentrations and other unknown odours are determined in coincidental order. The comparison of acetone with various unknown odours is an unusual task for the panel members at the beginning of the training. After a few tests the panel members become able to compare smell intensities of the markers with those of the unknown odours.

No values of the actual air quality for the unknown odours are known therefore the supervising person calculates an average value for the panel after the test. The panel is informed of this value, so each person can assess and orient his/her result. However, no influence is exerted on the determination of individual panel members in these tests, since individual differences between each person are natural with different odours.

When unknown odours are determined, the panel members are specially instructed that the supervising persons do not have any control over these tests. This is necessary otherwise the feeling of an examination situation develops in the panel members. The individual determinations are of greater interest in the investigations rather than a result agreed among the test participants.

The actual final test takes place on the fourth and last day. The test consists of the determination of eight unknown acetone concentrations. The markers are available to the panel as a comparison scale. The panel members are not informed about the actual decipol values of the eight samples during the test, thus a comparative determination of the unknown concentrations is not possible.

After training and selection, a short training control for the test person can be performed before each investigation. It is sufficient to repeat this training in intervals of 4 to 6 weeks while regular tests are carried out. Four unknown acetone concentrations must be determined by each participant in the control training. The participants are informed about the results of this test, so that they can see whether their determinations are too high or too low.

Various appraisal methods can be used for the evaluation of the test results to determine the most suitable panel at the end of the training.

Method 1

In the determination of acetone concentrations, the measured values of the test participants are plotted in a diagram, see Fig. 23. The actual value of the acetone sample obtained from Eq. 8 is on the x-axis in decipol. The measured value determined by the test person is indicated on the y-axis. Fig. 23 shows the ranges of tolerance, which must be achieved to successfully pass the final test. With eight unknown acetone concentrations, a maximum of two results may be in the intermediate area and a maximum of one result in the external area. A minimum of five measured values must be in the core area.

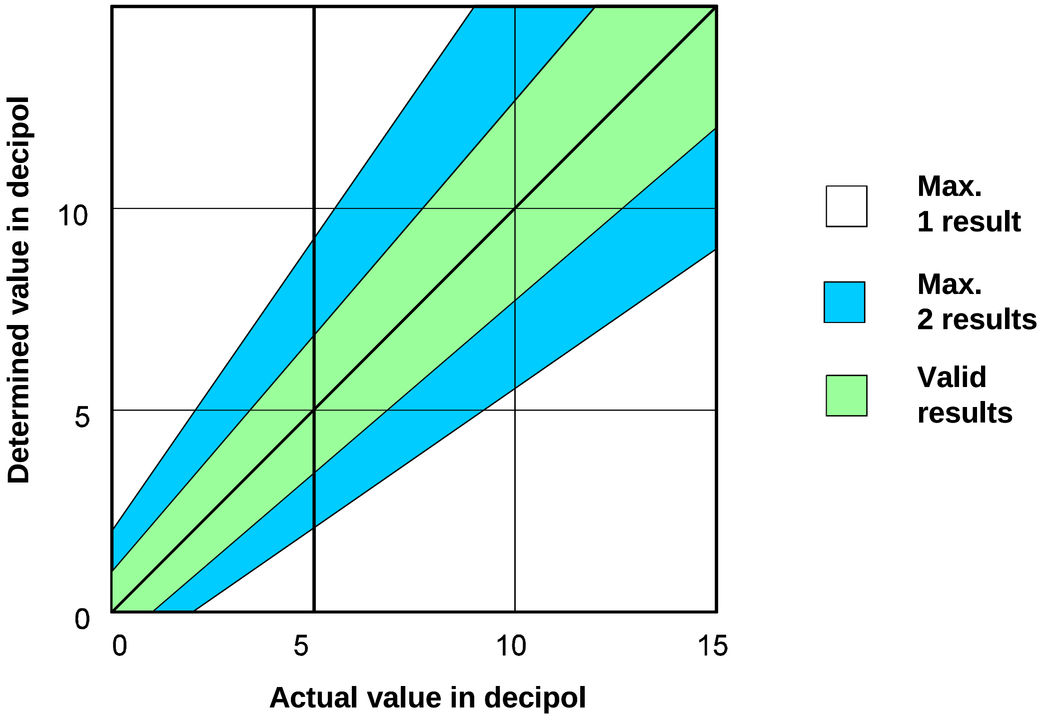

Fig. 23: Ranges of tolerance for the determination of eight unknown samples

This evaluation method provides a quick overview of the performance of each individual test person. Thus this method is very suitable for pre-selection on the first training day, however, in order to determine the best suitable test participants, more exact methods are necessary .

Method 2

Performance factor PF and standard deviation are used as selection criteria. The performance is calculated as:

$$PF = \frac{q_{perc} - q_{act}}{q_{act}} \qquad \text{(Eq. 9)}$$

with PF: performance factor in the determination of an acetone sample

q_{perc}: perceived air quality in decipol (corresponds to the measured value)

q_{act}: actual air quality in decipol.

The performance factor is calculated for each determination of a test person. In order to be able to compare the test participants within the panel, the average value of the performance factors is determined for each test person:

$$\overline{PF} = \frac{1}{n}\sum_{i=1}^{n} PF_i \qquad \text{(Eq. 10)}$$

with $\overline{PF}$: medium performance factor for n acetone samples

PF_i: performance factor for the determination of one acetone sample

n: number of tests.

Since negative and positive performance factors can compensate for each other when calculating the average, a standard deviation for the individual test participants must be used as another criterion. Bluyssen indicates a range from –0.11 to 0.11 as guide values for the performance factor and a limiting value of 0.4 for standard deviation.

In order to increase the expressive strength of the medium performance factor, the absolute value is determined for the individual performance factors:

$$\overline{PF} = \frac{1}{n}\sum_{i=1}^{n} \left|PF_i\right| \qquad \text{(Eq. 11)}$$

with $\overline{PF}$: medium performance factor for n acetone samples

$\left|PF_i\right|$: absolute value of the performance factor for one acetone sample

n: number of tests.

Thus positive and negative values do not compensate for each other in calculating the average value and the calculated average value corresponds to the average result deviation of the test person concerned.

Rank lists are set up for the performance factor (PF) and standard deviation. Panel members with a low performance factor and a small standard deviation are the most suitable. The selected individuals must have a PF less than 0.3 and a standard deviation less than 0.35.

Method 3

Fanger suggests determining an Individual Performance Factor (IPF) for each test person and each sample. This can be calculated as:

$$IPF = \frac{(q_{perc} - q_{act})}{A \cdot q_{act} + B} \qquad \text{(Eq. 12)}$$

with IPF: performance factor for the determination of an acetone sample

q_{perc}: perceived air quality in decipol (test person)

q_{act}: actual air quality in decipol

A, B: correction factors.

The correction factors depend on the air quality to be determined and are defined as follows:

For perceived air quality < 5 decipol:

$A = -3/28$,

$B = +59/28$.

For perceived air quality ≥ 5 decipol:

$A = +4/28$,

$B = +24/28$.

These correction factors enable a larger tolerance in the field of 0 to 5 decipol than using the previous evaluation methods. Thus this method takes into account the circumstance where the test person finds it difficult to differentiate between different acetone concentrations in the range of 0 to 5 decipol.

5.1.4 Determination of unknown odours

Within the framework of a European audit project for the optimisation of air quality indoors and energy expenditure, Clausen et. al (Clausen, 1993)[26] performed evaluations of the perceived air quality in offices. They investigated the standard deviation of the assessments of a trained panel and determined the permissible standard deviations from the results as a function of the medium perceived air quality of the panel. The result of these investigations is shown in

Fig. 24.

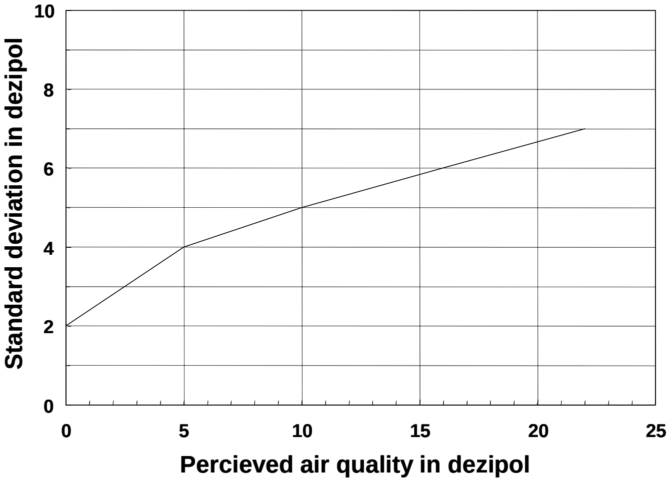

Fig. 24: Permissible standard deviations in the determination of unknown samples

This criterion is applied when training the panels. When an unknown odour is determined, the standard deviation and an average value of the perceived air quality are calculated for the group of test participants. To ensure certain accuracy of the measurement, the standard deviation of the entire group must be below those indicated in

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[26] Clausen, G.; Pejtersen, J.; Bluyssen, P.M.: Final Research Manual of „European Audit Project to Optimize Indoor Air Quality and Energy Consumption in Office Buildings", Technical University of Denmark, TNO-Building and Construction Research, 1993

Fig. 24.

5.1.5 Evaluation of the training results

The following is an example to illustrate the evaluation of a training which uses the aforementioned method. 21 test participants participate on the first training day. Fig. 25 illustrates the determination of the unknown acetone samples in the first training day for a test person. Since 5 measurement results are in the core area and only one measurement result in the intermediate and/or external area, the test person concerned passed the test. All 21 test participants passed this pre-test and therefore also participated in the further training days.

The results of a final test are evaluated in Table 4 and Table 5. The average value of performance factors PF and IPF and the relevant standard deviations are calculated for each test person. These quantities enable the establishment of a rank for the test participants. The smaller the values of the performance factor (PF and/or IPF) and the standard deviation, the better the placement of a test person.

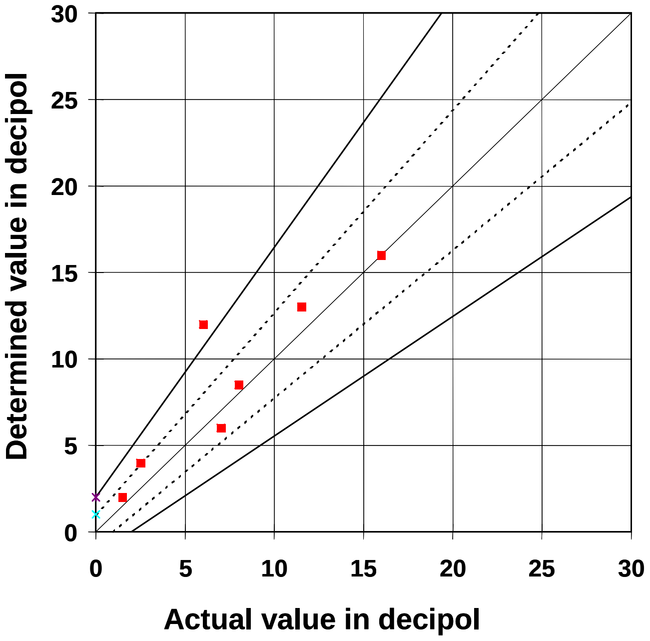

Fig. 25: Example of the test results of a test person on the first training day

Rank	Person	Perfornabce factor PF	Standard deviation
1	C	0.06	0.08
2	E	0.11	0.06
3	A	0.10	0.08
4	F	0.13	0.06
5	P	0.16	0.12
6	D	0.18	0.16
7	J	0.26	0.19
8	K	0.24	0.20
9	O	0.24	0.23
10	H	0.27	0.25
11	I	0.31	0.27
12	S	0.35	0.30
13	R	0.35	0.31
14	Q	0.31	0.37
15	U	0.34	0.41
16	T	0.35	0.48
17	M	0.42	0.44
18	N	0.42	0.49
19	G	0.48	0.61
20	B	0.47	0.69
21	L	0.66	0.58

Table 4: Evaluation of the final test according to Method 2

Rank	Person	Performancer factor IPF	Standard deviation
1	E	0.32	0.19
2	C	0.21	0.31
3	F	0.45	0.28
4	A	0.36	0.38
5	K	0.58	0.25
6	P	0.49	0.44
7	O	0.70	0.52
8	J	0.74	0.48
9	D	0.68	0.79
10	R	0.90	0.73
11	H	0.93	0.70
12	I	0.94	0.69
13	Q	0.89	0.83
14	B	0.98	0.84
15	U	0.94	0.93
16	S	1.12	0.78
17	T	0.85	1.11
18	G	1.12	0.85
19	M	1.18	1.00
20	N	1.14	1.10
21	L	1.62	1.00

Table 5: Evaluation of the final test according to Method 3

The different ranking in the tables results from the different valuation of measurement errors in the range of 0 to 5 decipol as described in Method 3. Test participants with a better ranking in Table 5 have a somewhat larger deviation in the range of 0 to 5 decipol, but this is evaluated somewhat more tolerantly by Evaluation Method 3.

Fig. 26 shows the different behaviour of the two evaluation methods. The medium performance factor (PF and IPF) of the entire panel is indicated on the y-axis. It corresponds to the average value of the individual performance factors of the 21 test participants at a specified acetone concentration. The perceived air qualities determined by the panel are indicated in decipol on the x-axis.

Fig. 26 also shows that the IPF performance factor is constant and independent of the magnitude of the perceived air quality to be evaluated. In contrast, performance factor PF is markedly higher in the range of 0 to 5 decipol than in the range over 5 decipol. The final selection of test participants was made based on the ranking in Table 5.

The fact that the selection of the test participants improves the accuracy of a measurement is shown in Fig. 27. The IPF performance factors of the 14 selected test participants are compared with those of the non selected test participants in the bar chart. The test participants selected at the end of training exhibited better results over the entire training.

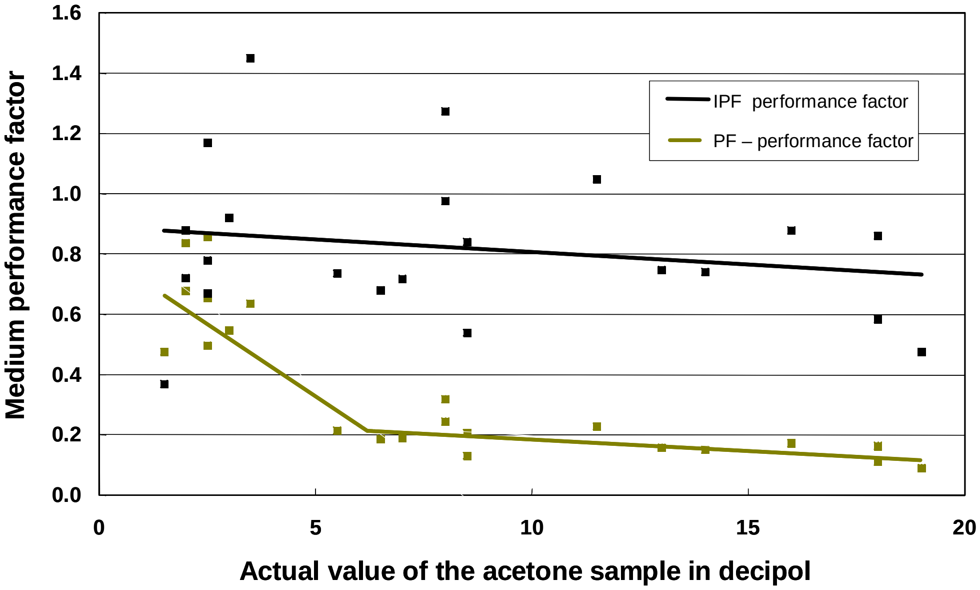

Fig. 26: IPF and PF performance factors as functions of the acetone concentration to be determined

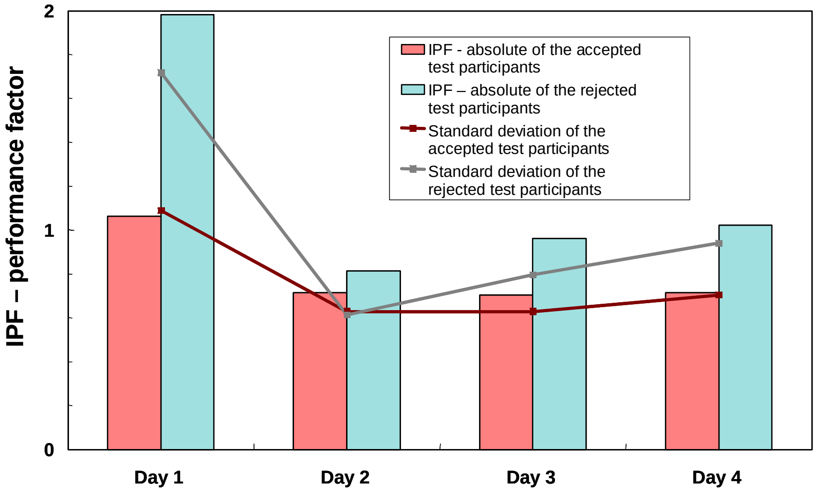

Fig. 27: Performance of the panel

In the determination of unknown odours the panel achieved a standard deviation of 1.1 decipol for a measured value of 4 decipol and 2.8 decipol for a measured value of 12 decipol. The maximum permissible value would be 3.6 decipol for a measured value of 4 decipol and 5.3 decipol for a measured value of 12 decipol.

5.2 Questioning of test participants

In the following section some questions with the associated scales will be exposed and explained.

Question 1: Acceptability/PD (two-point scale)

Imagine, you would have to frequently enter this room during your daily work!

Would you consider the odour in this room as acceptable?

☐ *acceptable* ☐ *not acceptable*

Fig. 28: Question to determine Percentage Dissatisfied (PD)

$$PD = \frac{Number\ of\ answers\ 'not\ acceptable'}{Number\ of\ all\ answers} \qquad \text{(Eq. 13)}$$

In the evaluation of the numbers of answers 'not acceptable' from Question 1 are divided by the number of all answers. This value is called Percentage Dissatisfied (PD).

Question 2: Acceptability (20-point scale)

Please assess the room air additionally on a scale from -10 to +10!

Mark one point on the scale, which corresponds to your estimate!

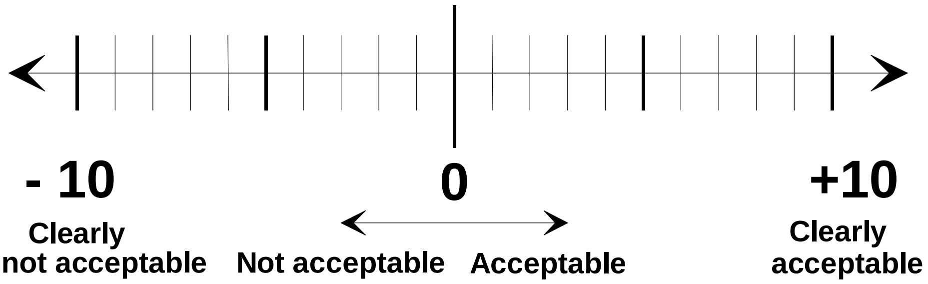

Fig. 29: Question to determine acceptability

$$A_{MV} = Medium\ value\ \ (all\ \ anwsers\ ) \qquad \text{(Eq. 14)}$$

First an average value (A_{MV}) of all answers is calculated from Question 2. This average value is called acceptability.

Question 3: Acceptability (continuous scale)

At the University of Denmark in Copenhagen a continuous scale is used for the acceptability. It is converted into values of +1 (clearly acceptable) to −1 (clearly not acceptable). As in the 20-point scale (Question 2), an average value is calculated from all answers.

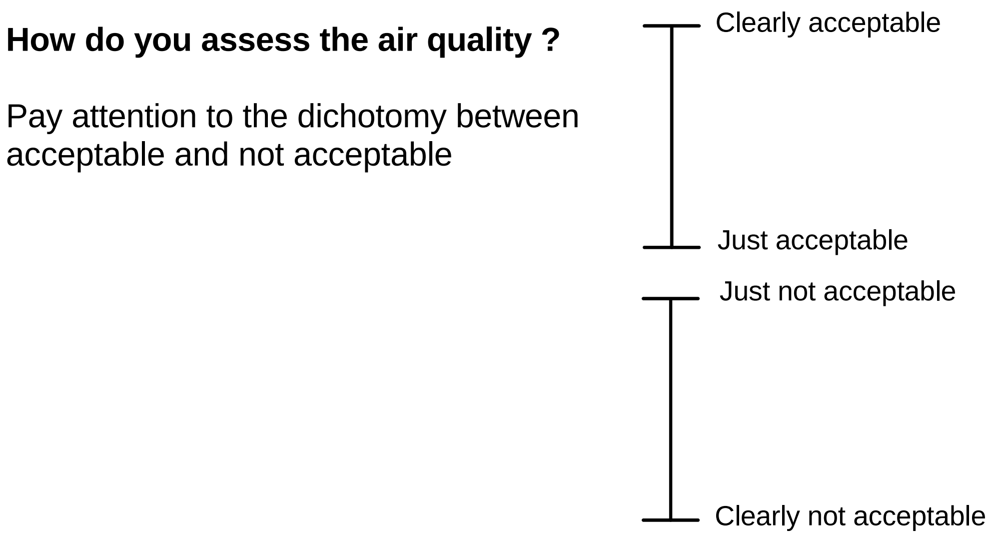

Fig. 30: Question to determine acceptability using a continuous scale, used at the Technical University of Denmark

Question 4: Intensity (6-point scale)

At the University of Denmark, in addition to acceptability, a second question about odour intensity is also asked. Here the odour is to be classified using a 6-point scale from odourless (no odour) to very strong (overpowering).

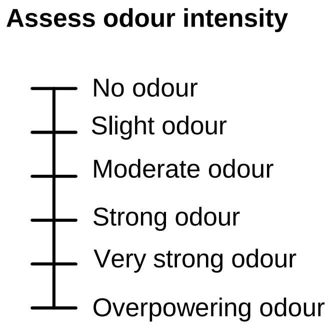

Fig. 31: Scale to determine odour intensity

5.3 Execution of a direct room assessment

The panel is ushered from one room to the next. Each person goes into the rooms one by one and assesses the perceived air quality directly after entering. Assessment is made after the first impression, before an adaptation to the odour can take place and smell perception is reduced. The trained panel members assess the air quality directly in decipol units. The panel members are also asked to take an acceptability assessment (yes/no), whether they can imagine working in this air quality for eight hours and find it acceptable.

In addition to this assessment the panel members are asked about the type of odour, and whether they can identify it and associate it with anything. On certain measuring days, special characteristics resulting from the room use, such as perfume smell, coffee smell or cleaning agent odour can be recognised and included in the evaluation of the assessments.

During the assessment the supervisor records whether the windows and doors are opened and the rooms are ventilated and how many persons are there in the room. Thus differences can be identified in the contamination loads and ventilation of the rooms.

Fig. 32 shows a questionnaire which is filled out by the panel members in an assessment task. The first column indicates the designation of the investigated room. The panel members put their assessment of perceived air quality in decipol in the second column. Column 3 indicates whether they regard the air quality as acceptable. If the panel member is in a position to identify the odour, he/she can make a note about his/her odour impression in the last column. The questionnaire shows the first two room assessments by a panel member.

	Perceived air quality	Acceptable (yes/no)	What does it smell like?
Outdoor air	1 – 2	yes	fresh
In front of HL 10 corridor	2	yes	
HL 2	7	yes	coffee
HL 3	9	yes	linoleum
HL 4			
HL 14, workshop			

Fig. 32: Questionnaire for the assessment of perceived air quality in rooms

5.4 Two-stage assessment method

Different measuring methods are available in the literature to determine odour intensity, perceived air quality, acceptability or hedonics of odours. A conversion of the different measurands is only partly possible, thus results of different studies are difficult to compare. This problem made the practical application of the measurand "perceived air quality" rather difficult. Currently, work is going on in Hermann Rietschel Institute to develop a new system for the determination of air quality. Another important aspect is the addition of odours.

"olf" as a universal source strength

The definition of the source strength "olf" puts all odorous substances on an equal footing. This assumption could not be confirmed by recent investigations in Hermann Rietschel Institute.

In addition to a direct assessment by a trained panel, a method of dynamic olfactometry was also used according to DIN EN 13725 within the context of investigating emissions from building materials. In this method the odour threshold of a sample is taken as an assessment standard of source strength. Odour threshold is reached when the odour concentration causes 50% of the panel members to detect the smell. The odour unit GE is derived from this: 1 GE is the quantity of odour carriers distributed in 1 m³ of neutral air that triggers an odour response.

In addition to acetone (300 mg/m³), the emissions from an adhesive and chip board were first assessed in decipol by an olfactometer and then by a trained panel.

Sample	Perceived air quality in decipol	Odour threshold in GE
Acetone	30	15
Adhesive	29	70
Wood	17	32

Table 6: Assessment of the samples in decipol and determination of the odour threshold in GE

The test results show that acetone and adhesive were almost identically assessed by the trained panel (29 and 30 decipol). However, smell threshold results deviated strongly from each other. While the odour threshold of acetone is reached at a fifteen-fold dilution, the emissions from the adhesive must be diluted 70-fold. This relationship is plotted in Fig. 33.

The samples show very different dilution behaviour in comparison to the initial concentrations of odour-generating substances. The definition of a substance-independent source strength (olf) is not suitable to represent this behaviour.

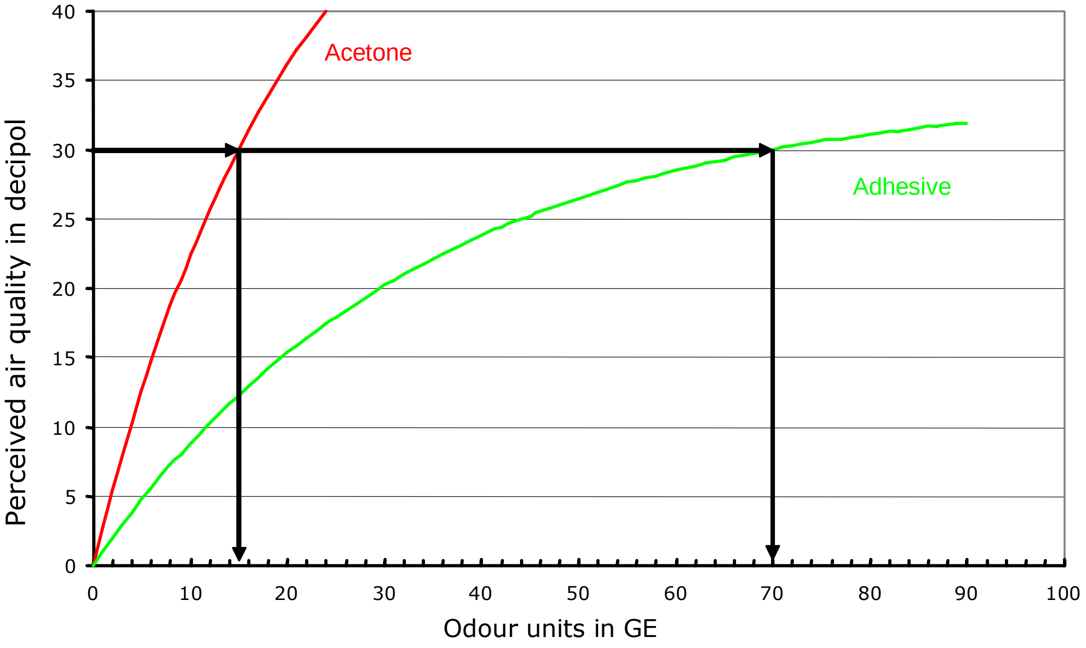

Fig. 33: Schematic relationship of perceived air quality in decipol and smell units in GE

Untrained and trained panels

Conversion functions used so far to transfer assessments of untrained and trained panels assume that the assessments are independent of external influences.

Untrained panels however, show a different reaction to changes in the thermal conditions of air than trained ones. According to the investigations of Fang[27] and Böttcher[28] the acceptability of air with a constant contamination load decreases with an untrained panel as the specific enthalpy rises, see Fig. 34. Whether the change of specific enthalpy was caused by a variation of temperature or humidity had no influence on this test result.

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[27] L. Fang; „Impact of Temperature and Humidity on Perceived Indoor Air Quality"; Ph. D. Thesis; Technical University of Denmark; 1997

[28] O. Böttcher: "Experimentelle Untersuchung zur Berechnung der empfundenen Luftqualität (Experimental investigation for calculation of perceived air quality); Thesis; Technical University Berlin, 2003

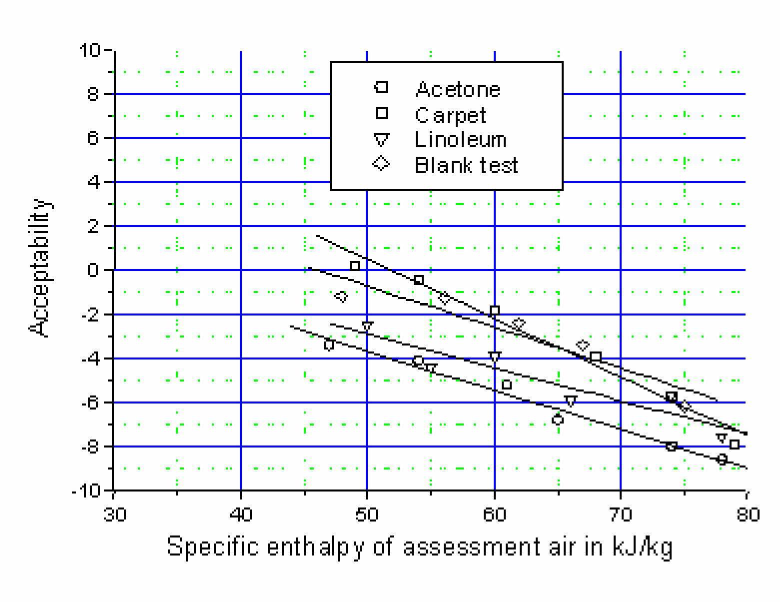

Fig. 34: Relationship between the specific enthalpy and perceived air quality by an untrained panel

A trained panel however showed no uniform behaviour in the assessment of air samples with different specific enthalpy. Böttcher's test results for the odorant acetone are shown in Fig. 35.

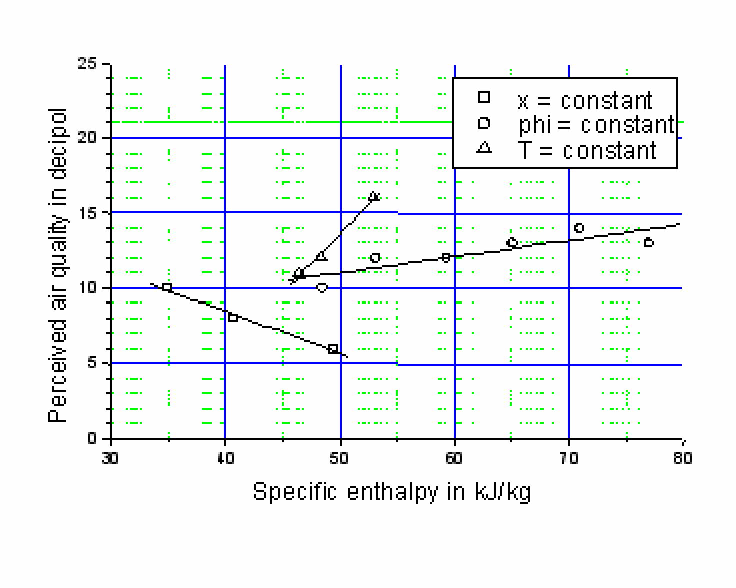

Fig. 35: Influence of a change of the specific enthalpy on the assessment that perceived air quality by a trained panel

Temperature T and absolute humidity x have an opposite effect on the assessment of perceived air quality by a trained panel. If the relative humidity remains unchanged during the tests, there is no or only a very small correlation between the specific enthalpy and perceived intensity of an odour. This test result indicates that untrained and trained panels do not determine the same measurand. This statement explains difficulties experienced so far with the conversion of measurement results by untrained and trained panels.

5.4.1 Structure of the two-stage assessment method

Based on the results mentioned, a two-stage model for the determination of perceived air quality has been developed. The model takes into account the differences between untrained and trained panels.

Any material delivers various chemical substances to the ambient air. In the first assessment stage the nose as a sensor detects the odour-generating substances emitted by the material. The different sensitivity of the nose to different odour-generating substances results in perceived intensity Π of the odorants contained in air by the panel members. The relative humidity of air affects the mass transfer at the moist "sensor surface" of the nose and affects the intensity impression of an odour. Trained panels, who work with a comparative scale, try to arrange the intensity of the smell of a sample using the scale reference samples. The acceptability of the odour impression is secondary and not queried by this assessment.

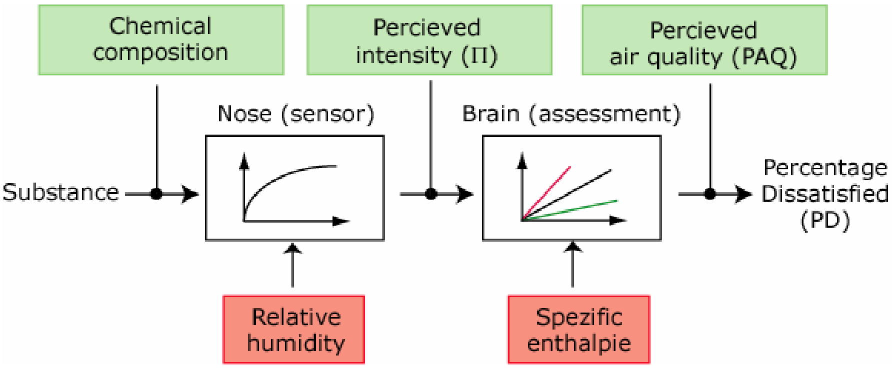

Fig. 36: Two-stage assessments of air quality by a panel member

In the second stage of the smelling procedure, the brain assesses the signals sent by the nose. In addition to the intensity, the hedonics of the smell determines its effect on the panel member. The untrained panel is asked about the acceptability of air as a daily work ambient. No scale is available for the determination of odour intensity. The untrained panel member is not forced to concentrate on the intensity of the odour impression, thus the percentage dissatisfied is directly determined from the question about acceptability, which is used to determine the perceived air quality. The increase of the specific enthalpy negatively affects the perceived air quality. In addition to the relative humidity, temperature also has an influence on the measurement result in the hedonic assessment, although the intensity of the perceived odour does not change.

5.4.2 Introduction of perceived intensity

The perceived intensity Π can only be determined with trained panels using a comparative scale. The unit of Π is pi. The comparative scale at Hermann Rietschel Institute consists of acetone-air mixtures. The gradation is linear with regard to acetone concentration. Currently, however, work is taking place on a linear intensity scale which can be used independently of the base odorant for a comparative scale. A later conversion of the results is feasible.

The comparative scale of intensity is defined at Hermann Rietschel Institute by the following points:

- 0 pi = 20 mg acetone/m$^3_{air}$. 50% of the panel can notice an odour at 20 mg acetone/m$^3_{air}$. It is the odour threshold for acetone. This acetone concentration corresponds approximately to 2 decipol.
- Concentrations for 1 to n pi follow a linear gradation of the acetone concentrations. The objective of further development is a linear scale with regard to perceived intensity.

Assessments below $\Pi = 0$ pi are not reasonable, since only very few panel members can detect this small odour intensity.

5.4.3 Logarithmic characteristics for perceived intensity

A logarithmic scale is assumed for the relationship between the intensity of an odorous substance and concentration analogous to Weber-Fechner's law[29], which worked satisfactorily for other sensory perceptions. All odorants possess a logarithmic characteristic as a function of concentration. Since a certain substance can only be attributed to an odour impression of a material sample in exceptional cases, in most other cases the determination of concentration C is not possible. The indication of an area-specific air flow rate q_A or the newly introduced flow rate-specific load per unit area A_q is reasonable.

The area-specific air flow rate q_A is a usual measure for emission measurement in test chambers (Draft DIN EN 13419-1). It expresses the ratio of flow rate $\dot{V}$ to the free surface A_{eff} of a material.

$$q_A = \frac{\dot{V}}{A_{eff}} \qquad \text{(Eq. 15)}$$

The inverted value leads to the flow rate-specific load per unit area A_q. This quantity enables the simulation in an emission chamber of the surface of a building material related to the ventilation rate in a room. Thus the results of single-material investigations in an emission chamber can be transferred to the odour load caused by this material in a ventilated room.

$$A_q = \frac{A_{eff}}{\dot{V}} \qquad \text{(Eq. 16)}$$

$$\Pi = a \cdot \log_{10}\left({}^{C}\!/\!{}_{C_0} \right) = a \cdot \log_{10}\left({}^{q_{A,0}}\!/\!{}_{q_A} \right) = a \cdot \log_{10}\left({}^{A_q}\!/\!{}_{A_{q,0}} \right) \qquad \text{(Eq. 17)}$$

A minimum of two concentrations or area-specific air flow rates must be measured for the determination of the logarithmic profile of odour intensity for each odour-generating substance or an equivalent for each odour-relevant building material with a free surface in the room. A larger number of measuring points with a following compensation calculation is recommended, so that fluctuations of individual values can be compensated for. Parameter a

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[29] Fechner, G. T.: „Elemente der Psychophysik"(Elements of Psychophysics), Vol. 2, Breitkopf and Härtel Leipzig, 1860

determined in such a way is a measure of the rise of the perception intensity with the concentration or area-specific air flow rate. Since the odour threshold is at $\Pi = 0$ pi, the value C_0 provides the relevant odour threshold concentration and $A_{q,0}$ gives the necessary emitting material surface to reach the odour threshold for a single substance or substance combinations.

$$\Pi = 0 = a \cdot \log_{10}\left(C \big/ C_0 \right) = a \cdot \log_{10}\left(A_q \big/ A_{q,0} \right) \quad \rightarrow \quad \frac{C}{C_0} = 1\,; \quad \frac{A_q}{A_{q,0}} = 1 \qquad \text{(Eq. 18)}$$

Different building materials show clear differences in characteristics of perceived intensity. The use of a uniform source strength for the assessment of air quality is therefore not possible (also see Chapter 3.1).

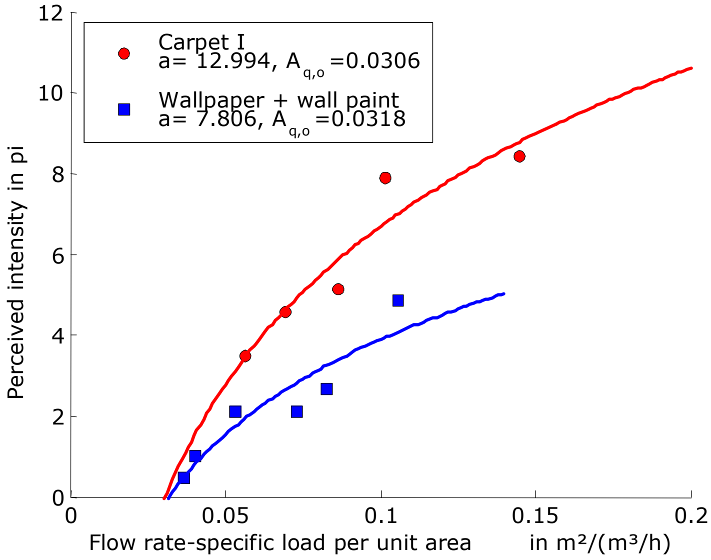

Fig. 37: Logarithmic characteristics of perceived intensity of two odorants

The calculation values of the perceived intensity Π can be negative, although measurement of these values is not possible. Data about perceived intensity Π are defined only in the positive range through the described measurement method.

5.4.4 Addition of odour intensities

Suitable rules for the addition of odorants from different materials must be determined for the forecast of air quality in a room with known odour sources, e.g. building materials. Böttcher showed that a logarithmic function can be used for the description of the relationship between perception and source strength for the sense of smell, similar to the sense of hearing. Thus it appears obvious that the known addition rule for sound intensities can be applied to the addition of odour intensities. The following formula shows the calculation of sound level L_i of an acoustic source in decibel unit [dB].

$$L_i = 10 \cdot \log_{10}\left(I \big/ I_0 \right) \qquad \text{(Eq. 19)}$$

The factor in front of the logarithm is constant and thus independent of the acoustic source. This factor, in the following denoted by a, depends on the substance tested in the odour perception investigations. Based on the assumed analogy between the senses of hearing and smell, the arithmetic average of the individual factors is calculated for the resulting factor a_{res} of several odour sources. Table 7 shows the analogy for the addition of stimuli between the senses of hearing and smell.

Sense of hearing	Sense of smell
$L_1 = 10 \cdot \log_{10}\left(I/I_0\right)$	$\Pi_1 = a \cdot \log_{10}\left(C/C_0\right)$
$L_{res} = 10 \cdot \log_{10}\left(\sum_{i=1}^{n} 10^{L_i/10}\right)$	$\Pi_{res} = a_{res} \cdot \log_{10}\left(\sum_{i=1}^{n} 10^{\Pi_i/a_i}\right)$ $\Pi_{res} = \frac{\sum_{i=1}^{n} a_i}{n} \cdot \log_{10}\left(\sum_{i=1}^{n} 10^{\Pi_i/a_i}\right)$

Table 7: Assumed analogy for the addition of stimuli between the senses of hearing and smell

If the specific parameters a_i of the tested substances are equal, the calculation of the perceived air quality of the odorant combination from the single material characteristics is completely similar to level addition in acoustics.

Böttcher showed in tests on two-substance combinations that the perceived odour intensity of a superimposition of odorants can be calculated approximately similarly to the resulting sound level of several acoustic sources. Material samples were placed in two emission chambers of an experimental rig, see Fig. 38. The flow passed through the chambers successively, thus the emissions from the materials were superimposed.

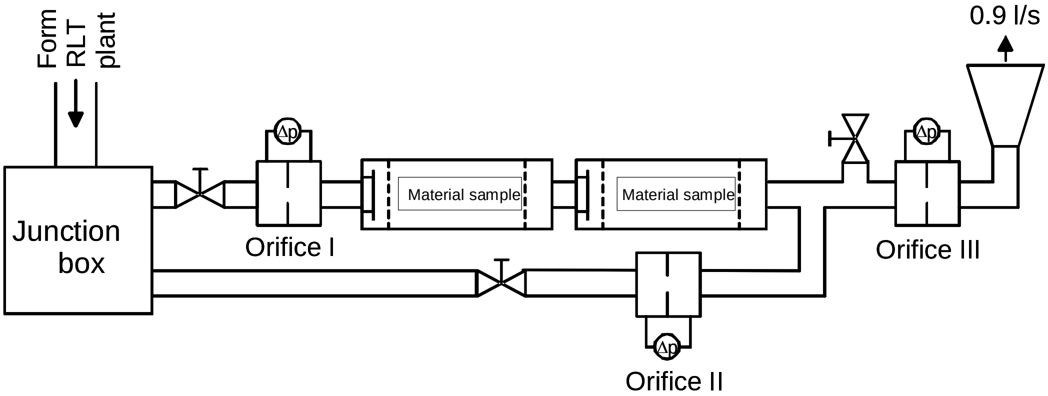

Fig. 38: Experimental set-up for testing the addition rules for perceived intensity of odorants

Subsequently, contaminated air from the chambers was diluted with non-contaminated air from the RLT equipment of the air quality laboratory. The flow rate through the emission chambers and the flow rate at the assessment funnel for the provision of samples can be kept constant in this experimental setup.

Fig. 39 and Fig. 40 illustrate the results of the addition tests. First the dilution curve was determined for each odorant. Subsequently, materials were placed into both emission chambers, so that an addition of odorants could be obtained.

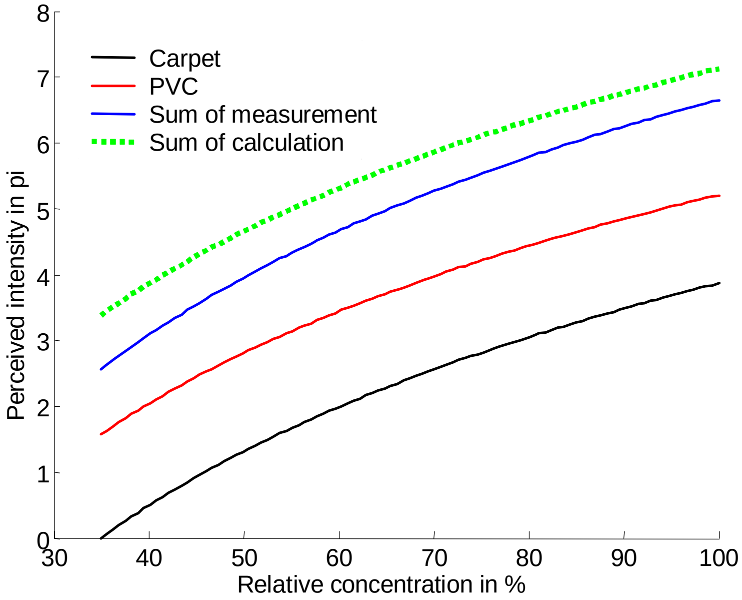

Fig. 39: Comparison of measured and calculated perceived intensity using the level addition method for a carpet and a PVC floor covering

The tests on a carpet material and a PVC floor covering show a satisfactory agreement between measured and calculated values for perceived intensity using the above analogy with acoustics engineering.

The addition of acetone and a PVC floor covering, see Fig. 40, provides a markedly better agreement between experiment and calculation. Since the flow passes through both emission chambers successively in the experimental setup shown, that the measurement result of the second material sample is influenced by adsorption of an odorant from the first material sample cannot be excluded. Adsorption could not be proved instrumentally by gas chromatography and mass spectrometry, an influence on the olfactory assessments is however very probable. Thus it is possible to explain the different quality of the agreement between measurement and calculation in the two investigations. In future tests the emission chambers will be arranged in parallel to excluded adsorption effects on the investigated material surfaces.

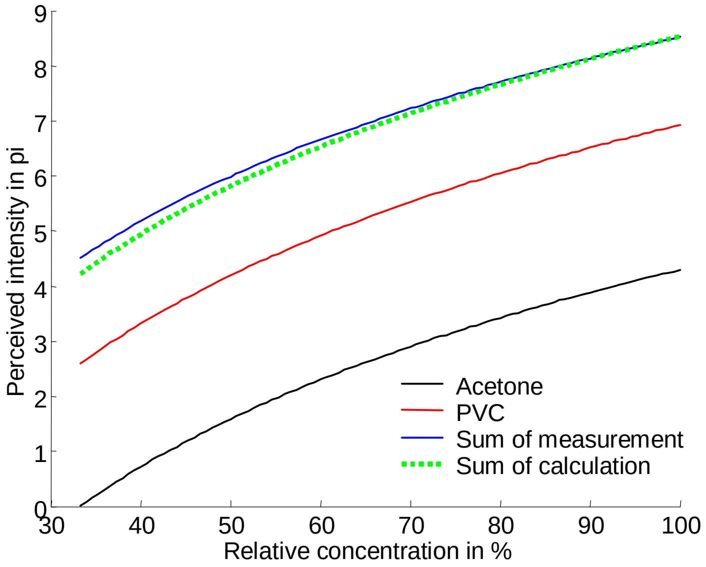

Fig. 40: Comparison of measured and calculated perceived intensity using the level addition method for acetone and a PVC floor covering

5.4.5 The second stage of the assessment method

The missing component in the two-stage assessment system is the transfer function between perceived intensity and perceived air quality. A similar method can be devised using basic odours for odour perception analogous to light, whose colours can be arranged in a chromatic circle, , e.g. the odour classes suggested by Amoore, see Table 8.

Table 8: Characterisation of odour classes (Amoore et al. in Schmidt[30])

Odour class	Chemical substance
Flowery	Phenylethyl-methyl-ethyl-carbinol
Ether-like	Ethylene dichloride
Musk deer-like	ω-hydroxy pentadecane acid lacton
Camphor-like	Camphor
Sweaty	Butyric acid
Putrid	Butyl mercaptan
Minty	Menthone

Chemical substances can be directly attributed to these basic odours, which simplify the experimental investigations of these odorants. If the transfer functions are known and can be superimposed, perceived intensity and attribution of the odorant to the basic odours enables a determination of perceived air quality.

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[30] R. F. Schmidt, H.-G. Schaible; „Neuro- und Sinnesphysiologie" (Neuro and Sense Physiology); Springer Publishing House, Berlin Heidelberg New York London Paris Tokyo; 2001; p. 379

5.5 VDI method

Since the beginning of the 1970s, scientists have dealt intensively with the possibility of making odours in outdoor air measurable. The result was the VDI 3881-3883 guidelines "Olfactometry – odour threshold determination", which has meanwhile been integrated into the DIN EN 13725 European standard.

The VDI method uses odour threshold of a sample as a basic unit for the determination of outdoor air quality. Using a dilution system, the concentration of a sample is increased until the odour threshold is reached. Odour threshold is defined as the concentration of odour carriers, at which 50% of the defined population perceives an odour impression. In addition to odour threshold, two other quantities have to be determined in the VDI method. With an increasing concentration the odour intensity can be determined by an increasing odour impression from 'not detectable' to 'extremely strong' (see Fig. 41), and the hedonic effect by a change of odour impression from 'very pleasant' to 'very unpleasant'.

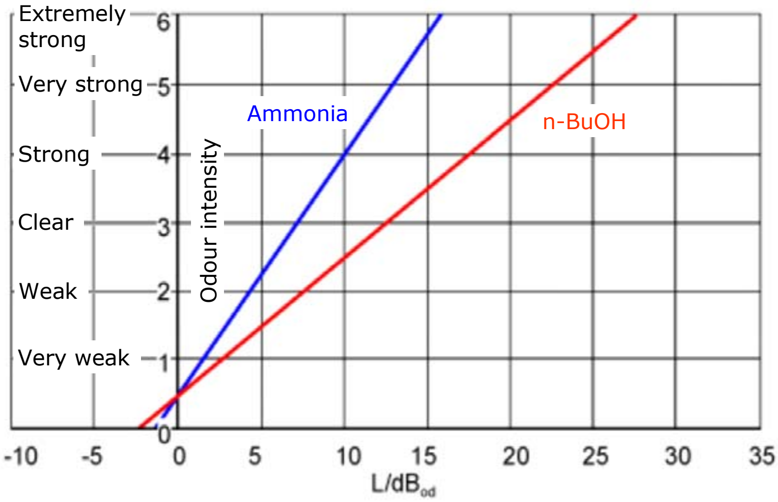

Fig. 41: Odour level and odour intensity

While the odour of coffee in low concentrations is perceived as pleasant, it becomes unpleasant at high concentrations. Other materials such as ammonia or butanol do not exhibit this characteristic and smell unpleasant even at low concentrations, see Fig. 42.

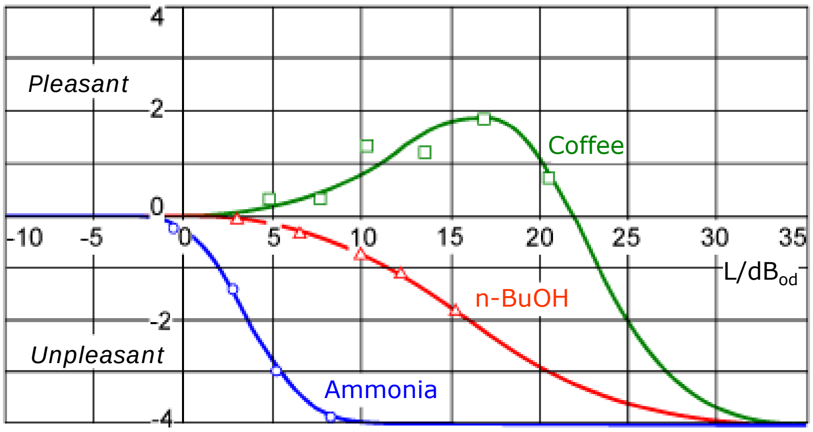

Fig. 42: Odour level and hedonics

Air quality determination methods described in VDI 3881-3883 can be divided into odour threshold determination, odour intensity determination, determination of hedonic odour effect and psychometric determination of odour nuisance.

Some instructions refer to problems, which emerge only in open air, such as temporal fluctuations of odour nuisance due to changing wind influences.

Of general importance are the instructions concerning the selection of the panellists, measurement accuracy, site conditions, sampling, assessment methods and introduction of basic terms:

Odour threshold
The concentration of odour carriers at the odour threshold leads to an odour impression in 50% of the defined population.

Odor unit *[GE]*
1 GE is the quantity of odour carriers distributed in 1 m³ neutral air that triggers an odour impression.

Odorant concentration $[C_{G,P}]$
The odour threshold is determined by diluting a gas sample. The numerical value of the odorant concentration of the gas sample is obtained from the flow rates of the sample and neutral air [GE/m³].

Determination limit $[C_{G,84}]$
Concentrations statistically above the odour threshold

The TO7 Olfactometer of the Mannebeck company is used in the Hermann Rietschel Institute for investigations according to the VDI method, see Fig. 43. It enables the simultaneous use of up to four panel members and requires a test manager.

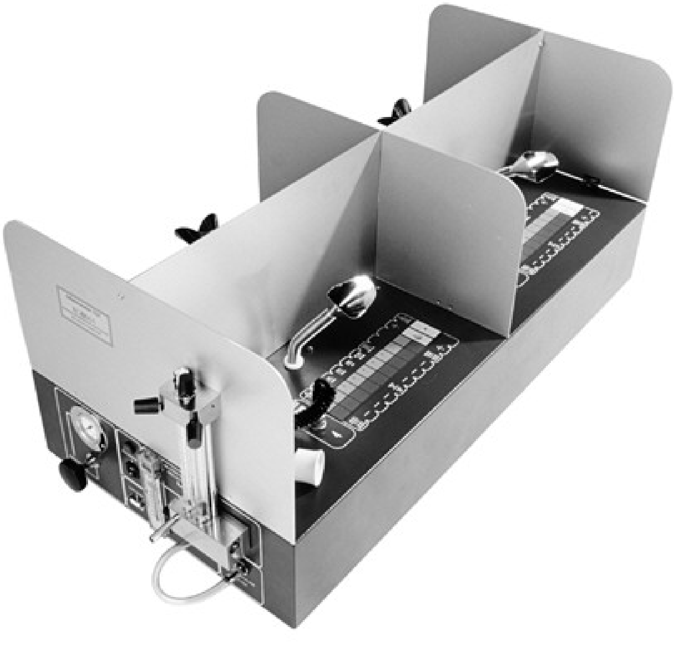

Fig. 43: TO7 Olfactometer

The device is operated with synthetic air from steel cylinders. A gas pump is operated by this clean air; sample air is sucked directly from the sample bag or through the pre-mixing system. The flow rate of sample air is adjusted by needle valves and a variable-area flowmeter using computer control. Dilution ratios can be selected from 1:2.5 to 1:64,000. With the help of a stepping motor-steered rotary valve, pure air is replaced with mixed air at the smelling masks between two breaths of the test person and a very small rinse air flow rate is adjusted during the exhaling phase. Thus the system uses a minimum amount of sample air of less than eight litres per minute. An optical breath rate scheduler synchronises these steps for all four panel members working on the equipment. The system is controlled by a notebook computer, but the test manager manually adjusts the dilution of sample air at the mixing system relying on the specifications of the control program. The measured data are showed on the display with a complete statistic evaluation immediately after measurement.

Due to their design, olfactometers are suitable at the above dilution ratios for the high odorant concentrations, usually occurring in outdoor areas.

Application of the VDI method contributed to the limit method becoming generally accepted, in which alternating sample air and neutral air is supplied through a dilution system to the panel members at the smelling masks. First a high amount of synthetic neutral odourless air is mixed with sample air. The concentration of sample air is increased by reducing the neutral air content in specified steps, until all panel members perceive an odour impression, see Fig. 44.

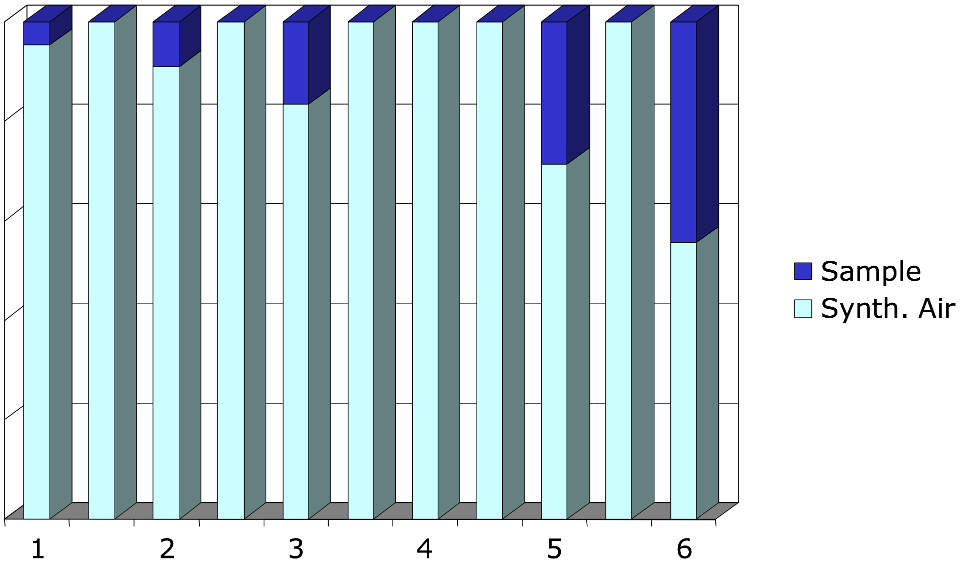

Fig. 44: Limit method

The odour threshold can be determined by a specified assessment method. In order to obtain statistically secured results, the sample air must be recognised at least twice consecutively without any doubt. Hence it follows that all panel members must have recognised an odour impression in the sample air at a dilution of 1:5 to be able to evaluate a measurement series.

Odour nuisances occur indoors in low concentrations, often around the odour threshold. Notwithstanding, constant odours may represent a nuisance even within this range, since they are detected by 50% of the population and may be perceived as unpleasant (Oberthür, 1998)[31].

The dilution of such low odour concentrations by a ratio of 1:5 may reduce them to such an extent that they fall short of the odour threshold in the sample and cannot be evaluated by the VDI method.

Direct assessment of sources of odorants may provide a field of application for the olfactometer. If the emission behaviour of building materials for example is investigated under laboratory conditions, values assessed by trained panels may exceed 30 decipol many times. To be able to assess and compare such high concentrations, the use of an olfactometer is reasonable if an odorant concentration exceeding 15 GE/m³ is expected.

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[31] Oberthür, R.: Vergleich der olfaktorischen Geruchsmessverfahren für Innenraum- und Außenluft (Comparison of olfactory odour measurement methods for indoor and outdoor air), in: VDI Berichte 1373 Kommission Reinhaltung der Luft, Gerüche in der Umwelt (Commission of clean air and odours in the environment), VDI Publishing House, 1998

6 Technical measurement methods

6.1 Chemical analyses

Numerous measuring procedures are available for chemical analyses of sample air, but most measuring instruments can only detect one or a few materials. A comprehensive analysis of the composition of the contaminants in the sample air can be performed by gas chromatography.

6.1.1 Description of a gas chromatographic system

Gas chromatography (GC), like all other chromatographic methods, is a separation method. The key components of gas chromatographic systems are, as illustrated in Fig. 45, an injector, a separation column and a detector. The injector's task is sample introduction and evaporation. The way as the sample is introduced into the injector depends entirely from the investigated substances and samples.

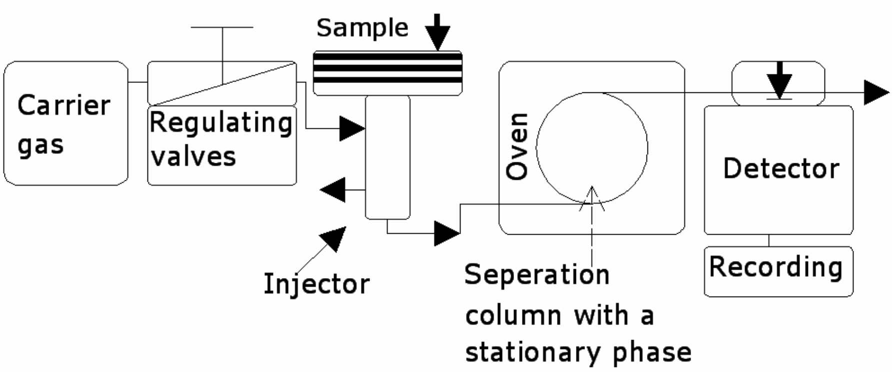

Fig. 45: Schematic set-up of a gas chromatograph according to Schram (Schram, 1995)[32]

The evaporated sample passes through the stationary phase of the separation column. The mobile phase, i.e. the carrier gas flows through the separation column. This gas transports the components of the mixture to be separated. The separation column is in an oven, where the sample is separated in an isotherm or (more often) temperature-programmed way, see Fig. 47. The detector has the task of recording the separated materials as a function of time and providing an electrical signal, to enable quantification and identification depending on the detector system. Many and various devices are used as detectors. A coupling with high-performance mass spectroscopy is increasingly becoming standard, which, in addition to quantification, supplies valuable information for substance identification.

6.1.2 Evaluation of gas chromatograms

The chromatogram provides important information about the composition of a sample (Schomburg, 1987)[33]. An electrical signal (abundance, y-axis) is

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[32] Schram, J.: Analytik luftgetragener Schadstoffe, Skript, Fachhochschule Niederrhein, Fachbereich Chemie, Krefeld, 1995

continuously recorded as a function of time (x-axis), which is proportional to the concentration of the separated substance. As long as only the carrier gas flows from the column to the detector, the so-called base line is recorded, see Fig. 46. As soon as one of the separated components leaves the column with the carrier gas and arrives at the detector, the signal increases according to the concentration up to a maximum and drops back to the base line. Thus a "peak" results for each separated component. Similar retention times (the time at which the component is separated and the peak has its maximum) of different components may produce superimposed peaks, which makes the evaluation more difficult. The area under the peak provides information on the concentration of the separated substance. If one or more standard substances are used, a comparison of the area of the unknown peak with the peak area of the standard can provide an estimate for the concentration. The injected quantity (usually 1 µl) of the standard is always known.

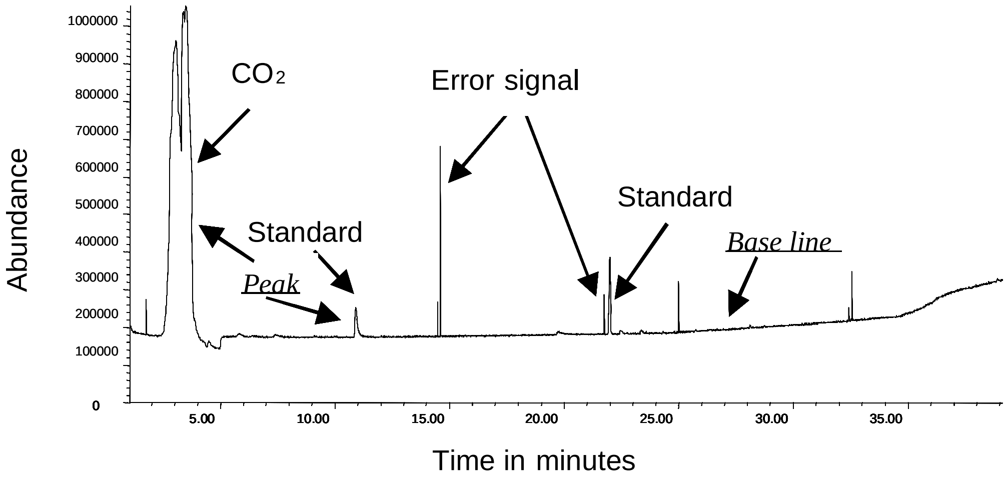

Fig. 46: Gas chromatogram

Error signals are generated due to electronic noise. Error signals are lines in a chromatogram which do not create areas, see Fig. 46.

6.1.3 Thermodesorption and cold feeder

Volatile components of a material or volatile components bound at an adsorbent sever their connection at high temperatures. This principle is used in thermodesorption.

In thermodesorption (TDS system) a carrier gas flows through adsorption tubes in a furnace at a high temperature and in so doing anneals them. Substances adsorbed during air sampling leave the adsorber the same way as they enter. That is, the sample air arrives from a specified direction onto the adsorber and

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[33] Schomburg, G.: Gaschromatograhy bases, practice, capillary technology, 2. Edition, VCH Publishing House Company, 1987

the substances contained in the sample air leave it with the carrier gas the same way.

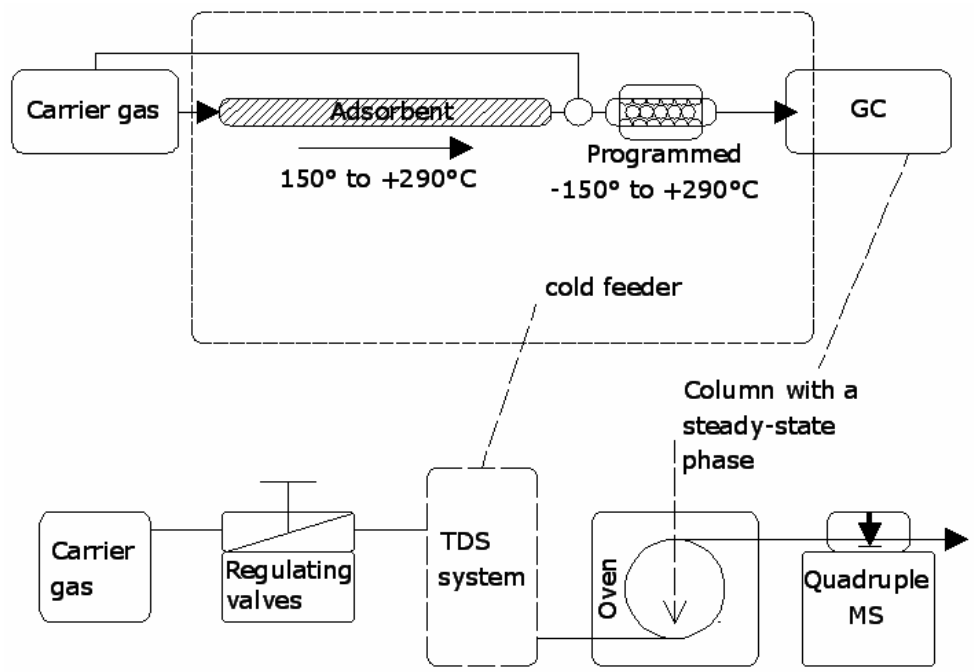

Fig. 47: Schematic set-up of the system used with thermodesorption and a cold feeder and a mass spectrometer

If the desorption temperature for a material is reached or exceeded, it is desorbed from the adsorbent and carried along by the carrier gas (helium, nitrogen). The materials are released at different times during the heating phase depending upon their desorption temperature. The desorption oven is heated at a constant heating rate of 40 °K/min to a temperature of 290 °C. This final temperature is kept for 5 minutes to achieve a complete desorption. The entire heating procedure takes 13 minutes.

The desorbed materials are cryofocussed (collected) in a cold feeder (cold trap). The system is cooled by liquid nitrogen to -150 °C, and the desorbed substances are cooled far below their boiling point and condensed. A rapid heating of the cold feeder system from -150 °C to 290 °C (injection) at a heating rate of 10 °K/s makes all substances evaporate and they condense on the separation column, where they enter into interaction with the steady-state phase of the column. An adsorption and desorption process takes place at the separation column, proceeding at a different speed for each substance. At the end of the capillary column, the components enter the detector separately, at different times.

If the material to be tested is placed directly into the glass tube without an adsorbent (e.g. TENAX®), the method is called direct thermodesorption. In the direct thermodesorption a different heating program is applied for each material.

6.1.4 Mass spectrometer

The individually occurring substances of the sample mixture appearing from the gas chromatograph are introduced into the ionisation chamber of the mass spectrometer under a vacuum and are ionised there. Subsequently, the ions are deflected to various extents in a magnetic field using Lorenz's force as a function of their weight. In the detector, i.e. a secondary-electron multiplier, signals are produced, which are made visible in the gas chromatogram. Thus a mass spectrometer consists of three parts: an "ion source", i.e. a device producing ions, an "analyzer", i.e. a separating device and a "secondary-electron multiplier", i.e. the target for recording the ions.

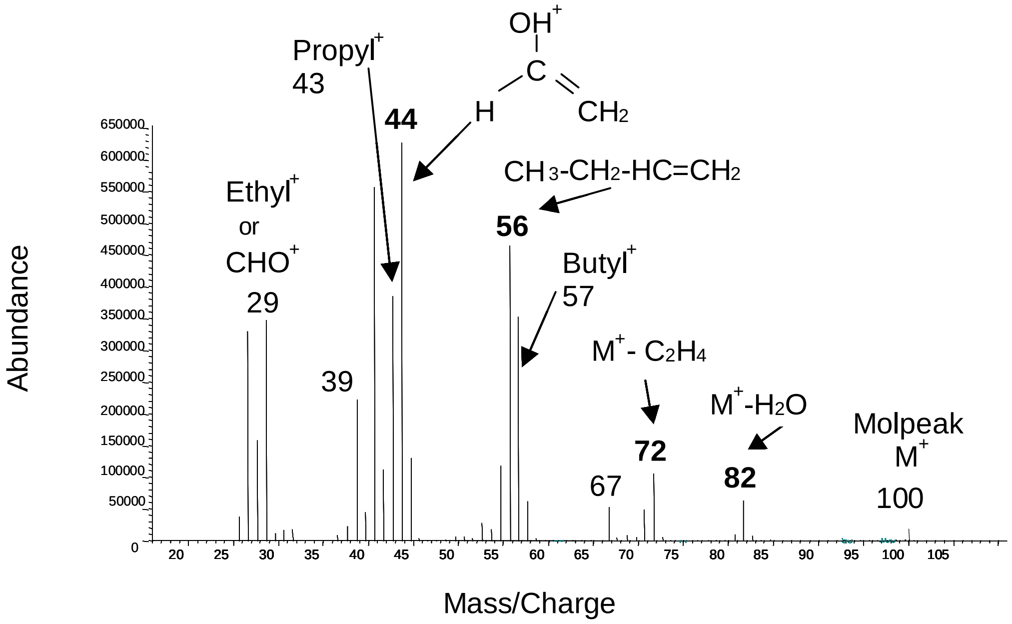

Fig. 48: Mass spectrum of hexanal

The general advantage of mass spectrometry to other chromatography detectors is that, in addition to the pure measuring signal which produces the peak in the chromatogram, a mass spectrum is also determined. This mass spectrum, if it is determined under specified boundary conditions (Standard Spectra Auto Tune), can be considered as a finger print for each compound. A comparison of this specified mass spectrum with a data base provides valuable information for substance identification. An experienced analyst obtains information from the mass spectrum interpretation greatly surpassing the search possibilities in libraries. Thus a mass spectrometer is clearly superior to most other chromatography detectors.

Fig. 48 shows the mass spectrum of hexanal: the signal size (abundance) is plotted against the mass/charge ratio. The molecule is divided into molecule fragments on entering the ioniser and positive ions of different masses are produced. Mass-charge numbers characteristic of the material are shown in the diagram. The target–masses for hexanal (56, 72 and 82) are highlighted in bold-faced font. Target–masses are those masses which primarily characterise the material. Mass spectra are consulted for the analysis of air samples.

6.2 Multi-gas sensor systems

6.2.1 Operational principle of a multi-gas sensor

Multi-gas sensor systems or so-called "electronic noses" are combinations of several sensors for the measurement of volatile organic components in the gaseous phase. The presence of substances in the room air is mostly detected by measuring electrical quantities. These sensor systems work by the subsequent processing of raw data. The electronic nose can only be used as a measuring instrument for the assessment of pollution or odour load in air samples when data acquisition by the sensors is combined with the respective evaluation algorithms.

The sensors do not have a high selectivity, responding to several substances. The electronic nose is based on the principle that a set of sensors with different sensitivity and selectivity produce a signal pattern that characterises a substance or a substance mixture. The exact composition of a gas cannot be determined only with difficulty or at all, since all sensors respond to several substances. The electronic nose incorporates a method which enables the determination of the characteristic cumulative parameters of a gas mixture.

Multi-gas sensor systems can be built from different types of gas sensors, which differ in the type of detection and measurand. Commercially available systems chiefly employ metal oxides, conducting organic polymers, piezoelectric quartz and surface acoustic wave ducts as sensors.

Metal oxide sensors are, in addition to the most frequently used tin oxide (SnO_2), manufactured from other metal oxides, such as ZnO, Fe_2O_3 and WO_3. In these detectors the electrical resistance of the sensor is measured. It serves as a measure for the substances adhering to the sensor surface. Metal oxide sensors work only in an oxygen-containing atmosphere. The oxygen bonds with the surface of the sensors and takes up electrons from the conduction band of the metal oxides. This leads to an increase in the electrical resistance of the sensor. A dynamic equilibrium develops between the oxygen species (O^-, CO_2^-, CO_2^-, OH^-) adsorbed on the surface. If air samples with volatile substances flow over the sensor surface, another equilibrium develops and the resistance of the sensor changes.

A potential relationship ($R = A\,[c]^n$) exists for a wide concentration range between the concentration of a volatile substance in sample air and the electrical resistance of the metal oxide sensor.

Different sensitivity and selectivity of the sensors are reached by adding different catalyst materials (platinum and palladium) in different concentrations to the metal oxide. The conductivity of the sensors can also be influenced by the temperature to which the sensors are heated by a hot wire. Depending upon the metal oxide of the sensor the optimum operating temperatures are between 200 and 500 °C. The recommended temperatures for SnO_2 sensors are around 300 °C.

It has to be noted that the measured values of the sensors depend upon humidity. This dependence is less pronounced in metal oxide sensors than in other sensor types such as piezoelectric quartz sensors and conducting polymers.

Piezoelectric quartz sensors (BAW – Bulk Acoustic Wave or QMC – Quartz Micro Balance) are mass-sensitive sensors. In this instance the oscillation frequency is the electrical measurand. Piezoelectric materials, i.e. quartz, possess the characteristic that they transform electricity into mechanical energy and vice versa.

The sensors consisting of a thin quartz disk are provided with vacuum-evaporated gold electrodes on the front and back. If an alternating voltage is applied to the electrodes, the quartz starts oscillating due to the piezoelectric effect at their basic frequency.

The sensitive element of the sensor consists of coating the quartz with different polymers of different sorption characteristics. Due to the deposition of substances from sample air on the polymer layer, mass and thus oscillation frequency of the quartz change. Frequency changes due to substance accumulation are very small compared with the basic oscillation frequency of quartz (some Hertz compared to about 10 MHz), thus high measuring accuracy is required.

Conducting polymers: as in metal oxide sensors, conductivity (or electrical resistance) is the measurand in these sensors. They exhibit reversible changes of conductivity when chemical substances are adsorbed or desorbed on the surface. Polymers work at room temperature and lower temperatures in the range of 20 to 100 °C and do not need any expensive heating system, thus their energy consumption is low. The sensors are more selective than metal oxides and possess high sensitivity to volatile organic substances. However, the signals of these sensors are affected much more by humidity than signals of metal oxide sensors.

Surface acoustic wave ducts (SAW - Surface Acoustic Wave) are mass-sensitive similar to piezoelectric quartz sensors, a frequency change is also detected in these sensors. This sensor type works with surface acoustic waves (SAW).

6.2.2 Sensor systems in Hermann Rietschel Institute

Currently two systems are used at the Hermann Rietschel Institute: Moses II and Kamina.

Moses II is an electronic nose, which was developed at the University of Tübingen. The name MOSES stands for **mo**dular **se**nsor **s**ystem. It consists of a computer casing (with power unit and measured value transmission), in which different sensor modules can be integrated and interconnected. The sensor modules consist of a measuring chamber with a sensor array and control and evaluation electronics. In addition to the sensor modules, there is an input module which accommodates the flow control for the air sample flow rate using three interchangeable sample entry points and temperature and moisture measurement.

The MOSES nose at the Hermann Rietschel Institute, see consists of an input module, a quartz sensor module and a metal oxide sensor module. The quartz module consists of 8 mass-sensitive and very moisture-sensitive piezoelectric quartz sensors. Investigations carried out so far showed that these sensors are less suitable for the measurement of room air quality. The second module consists of 8 metal oxide sensors which are held at a temperature of approx. 300 °C by an electrical heating.

Fig. 49: MOSES II sensor system

Fig. 50: Kamina sensor system

The second system, Kamina, was developed by the Karlsruhe Research Center. The name Kamina stands for **Ka**rlsruhe **mi**cro **Na**se (nose). It is an electronic nose of small size, which needs an external pump for transporting sample air. It can be equipped with a measurement head and fan for measuring the ambient air as shown in Fig. 49. Contrary to MOSES, Kamina has no modular structure and can only be operated as a single unit.

The nose consists of a steering control and evaluation unit and a measuring head with a sensor chip. The measurement data can be transmitted through a RS232 interface to a PC. The data are evaluated by the MC Shell software. The software also enables adjustment of the operational parameters and control of measurement processes of the nose.

Kamina possesses 38 metal oxide sensors, which are arranged on a chip. In addition to the gas sensors, temperature sensors are mounted on both sides of the chip (in the gas flow direction). Four different heating elements enable adjustment of a temperature distribution over the chip. Fig. 50 shows the Kamina sensor system.

6.2.3 Evaluation of measurement signals

The use of multi-gas sensor systems requires subsequent processing of the sensor measurement data. Depending on the task, qualitative, classifying methods or quantitative methods can be applied. Due to the main fields of application of the systems for quality control of products, most systems are delivered with software, which contains the most common classifying and pattern-recognition methods. They are the Principal Component Analysis (PCA) and the Linear Discriminant Analysis (LDA).

A calibration is necessary for the quantitative determination of the odour or the pollution. For this purpose, regression methods such as Multiple Linear Regression (MLR) and Principal Component Regression are used (a combination of Principal Component Analysis with MLR) and the method of the partial least error quadrates. A further possibility is the application of biologically inspired methods such as artificial neural networks (ANN). Some of the methods will be briefly discussed below.

Principal Component Analysis reduces the large amount of sensor data to a few factors, the principal components, relying on a high cross-sensitivity of the sensors. The method describes a coordinate transformation of the input data on to the eigenvectors of the sensor data matrix.

The sensor data are summarised in a matrix for this purpose. They can be expressed by a linear combination of the eigenvectors.

If the data are reduced to a few principal components, some information is lost through this transformation. Having two to three principal components, 94 % to 99% of the information can be recovered. This results from the high cross-sensitivity of the sensors.

In the case of two principal components, a characteristic plane is obtained. If the data are plotted on a plane, similar samples are close to each other. Samples that differ greatly are in different ranges of the plane. This method only enables a comparison between the samples. No direct conclusions about the gas composition can be drawn from the determined data.

Principal Component Regression uses an optimisation of the measuring data matrix by a PCA as the basis for a multiple linear regression. The regression functions are determined by a set of training data, for which the intended output quantity, for example odour intensity, is known and can be attributed.

Another method is **the Linear Discriminant Analysis**. This routine has not yet been applied at the Hermann Rietschel Institute for investigations using electronic noses., A comparison of the data between different measurements is only possible, analogous to PCA. The data are also imaged by a transformation on to a new data space. Unlike PCA, the principal components are not used as transformation axes and the axes need not be orthogonal to each other. Training data are needed for the transformation. The data are divided in classes on the basis of the intended output quantity. The transformation of the data space is performed by a suitable algorithm in such a way that the following two conditions are optimised: the classes should be as compact as possible (i.e. the measured values within a class should lie close to each other) and separated clearly from each other.

Artificial neural networks perform information-processing processes, inspired by the biological nervous system. They consist of a high number of process units, the neurons, linked with each other to solve a specific problem as a whole entity. The configuration of the net is carried out by learning, as in biological systems. In the learning process an adjustment of the links of the neurons takes place.

Neural nets have the advantage that they are able to image processes whose individual steps are not known. However, reasonable results can only be obtained if a suitable structure is selected and sufficient amounts of data are available to adjust the net parameters. The net can only be used for the solution of certain tasks if training has been performed. The training enables a clear value to be attributed to the measurement data. A measurement can be evaluated even without further comparative measurements.

6.2.4 Use of multi-gas sensor systems in air conditioning

Multi-gas sensor systems have not yet been used in air conditioning. The objective of the research at the Hermann Rietschel Institute is the employment of electronic noses for monitoring, measurement and regulation of odour intensity in indoor air.

Quality assurance of products and monitoring of manufacturing processes in food and perfume industry is the key field of application for multi-gas sensor systems. The sensor measurement values of sample air are compared with measured values from measurements on products of required quality. If the measured values lie within the permissible range of tolerance, quality is adhered to. The research is aimed at testing and further developing the systems for many potential fields of use, such as diagnosis of illnesses in medical technology, dangerous material analysis, detection of leaks (gas pipelines), application as warning sensors and ventilation flap control in automobiles.

6.3 Combined measuring method

For the development of new building materials a combined analysis of chemical composition and olfactory assessment of emissions are necessary, since this method enables the recognition and substitution of odour-relevant components of a material.

6.3.1 Sniffer / Olfactory Detector Port (ODP)

The olfactory detector port (ODP) enables the coupling of chemical analysis by a gas chromatograph and odour assessment by humans. Components of olfactory interest can be identified in a chromatogram with the help of the ODP, if the odorant can be determined clearly using this analysis technology.

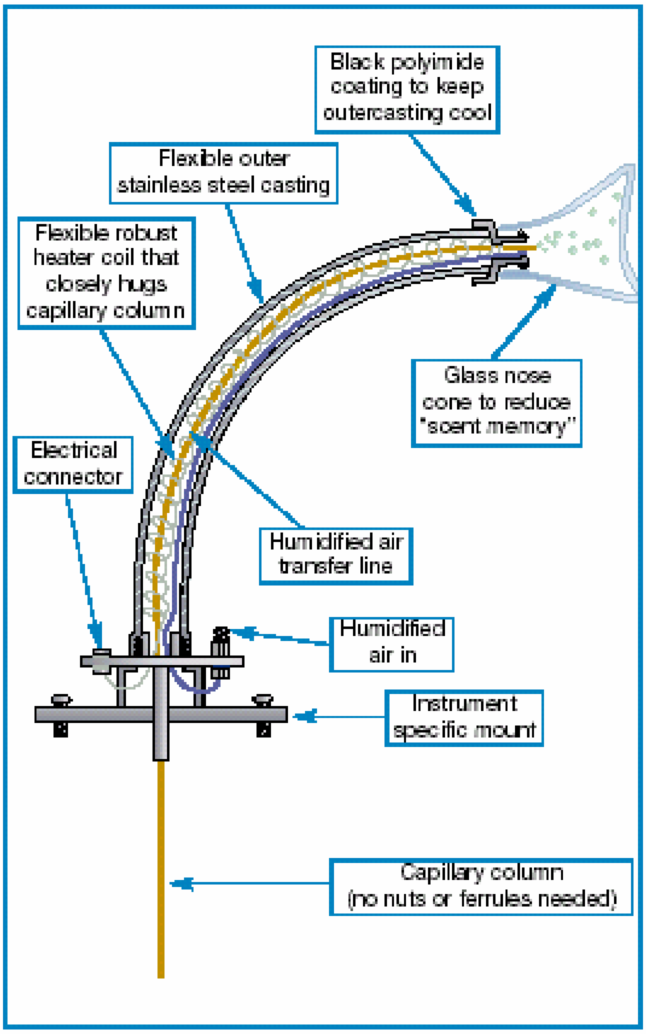

Fig. 51: Example of a sniffer port (ODO II olfactory detection outlet of the SGE firm)

A part of the gas flow (eluate), coming from the gas chromatograph, is rerouted to the so-called olfactory detector port or sniffer, another part is led through an analytic detector (mass spectrometer, flame ionisation detector). This ODP enables persons to evaluate directly olfactorily the gas flow coming from the gas chromatograph. The test person stands at the outlet of the sniffer port, has a signal transmitter in the hand and gives a signal when he/she smells an odour. The time is recorded electronically and can be compared with the gas chromatogram. So the individual substances of a gas mixture can be found out about, whose odours can be perceived by persons.

7 Standards and guidelines

7.1 DIN 1949 Part 2

Air conditioning – health engineering requirements

Air quality assessment according to Fanger has been integrated in German standardisation. DIN 1946-2 "Air conditioning – health engineering requirements" of January 1994 defines three air quality classes from high to low.

Air quality class	Percentage Dissatisfied [%]	Perceived air quality [decipol]
High	≤ 10	0.7
Medium	≤ 20	1.4
Low	≤ 30	2.5

Table 9: DIN 1946-2 „Air conditioning – health engineering requirements"

The values of perceived air quality can be obtained from a conversion of the limiting values for Percentage Dissatisfied to decipol using Fanger's equation.

7.2 VDI 3881 – VDI 3883

Olfactometry

The VDI 3881 guideline was replaced by the DIN EN 13725 standard in July 2003. VDI 3882 describes the determination of odour intensity and the hedonic effect of odour samples. VDI 3883 deals with the effect and assessment of odours (psychometric determinations of odour nuisance, questionnaire technique and determination of nuisance parameters by questioning).

7.3 DIN EN 13725

Determination of odorant concentration using dynamic olfactometry

The standard was published in 07/2003 and replaced the VDI 3881 guideline which was valid until then. It specifies a method for the determination of odorant concentration of a gaseous sample by applying dynamic olfactometry with persons as analysts. It describes the determination of the emission flow of odorants from punctual and area sources, with and without specified flow rates.

The European odour unit per cubic meter [GE_E/m^3] is introduced as a measure and corresponds by definition to the odorant concentration at the detection threshold. The determination of the odorant concentration of the sample takes place by dilution up to the detection threshold and is expressed by a multiple of this threshold.

7.4 ASHRAE Standard 62-2001

Ventilation for Acceptable Indoor Air Quality

Acceptable indoor air quality: air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

Similarly to DIN 1946 Part 2, the guideline indicates necessary exterior air flow rates depending upon building type and use.

7.5 CEN report CR 1752

German version: DIN specialist report 79

Ventilation of buildings – Design criteria for interiors

The report presents formulae, separated according to requirements for health and comfort, for the calculation of the necessary exterior air flow rates.

When health-endangering substances are there, the air flow rate required for health reasons must be determined from the contamination load of the substance in µg/m³.

The report contains further table values with necessary air flow rates for rooms in different types of building (requirements for comfort). For the calculation of the expected contamination, data are presented on sensory contamination loads caused by persons and buildings (including furniture, carpets and air conditioning devices).

7.6 DIN EN 13419-1

Determination of emission of volatile organic compounds (Part 1: Emission test chamber method)

This standard describes the tests of emissions from building materials: test principle, test device, test piece including test method and test report. Only the test of the VOC emissions from the material is performed without any assessment of perceived air quality.

7.7 M1 Emission Classification of Building Materials

Protocol for Chemical and Sensory Testing of Building Materials

The Building Information Foundation RTS, Finland

This Finnish guideline describes the tests of emissions of building materials from sampling, sample storage up to actual testing. Tests of VOC emissions from the material and testing of the odour delivery by CLIMPAQs are described in this guideline. The guideline refers in the procedure of the sensory tests with CLIMPAQs to the north test method NT BUILD 482.

7.8 Nordtest Method NT BUILD 482

Nordtest, Espoo, Finnland

The method describes the execution of both chemical and sensory measurements of building materials in CLIMPAQ test chambers. This method is also used in Denmark.

7.9 Nordtest Method NT BUILD 484

Nordtest, Espoo, Finnland

The measurement using Field and Laboratory Emission Cell (FLEC) is described.