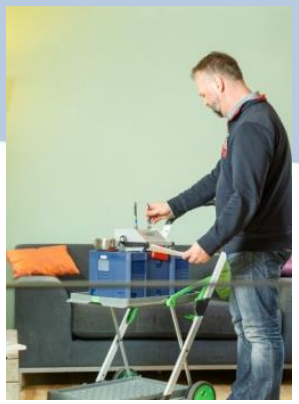
Bremer Umweltinstitut

Gesellschaft für Schadstoffanalytik und Begutachtung mbH

# Current data on the occurance of VOCs in indoor air and emissions from building products: What do we know and what should we know?



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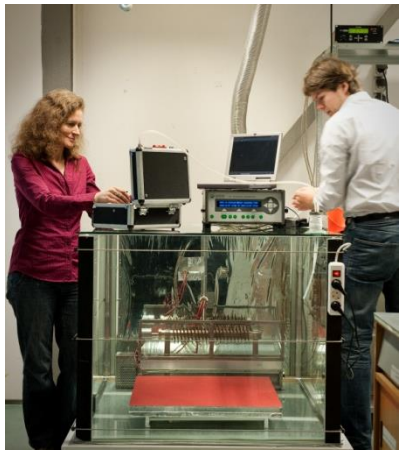
# Bremer Umweltinstitut GmbH


- Approx. 30 employees
- Laboratory fields: Chemical, Microbiological, Fibers (Asbestos/SMF), emission test chambers, sensory testing laboratory
- Sampling and evaluation of indoor pollutants
- Product testing
- Research projects



# Structure

1. Occurrence of VOC in indoor air
2. Indoor air evaluation
3. Emission testing
4. Limitations of test chamber investigations
5. Conclusions

# Occurrence of VOC in indoor air

## AGÖF[1] database projects financed by UBA

- VOC DB 1: Influence of methods and quality management (2002 - 2006)
- VOC DB 2: Energy efficient buildings (2006 – 2012)
- VOC DB 3: Odour complaints (2012 -2018)

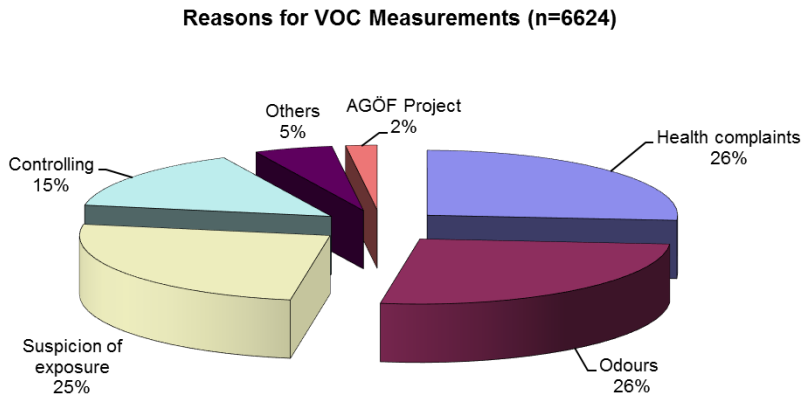
➢ Systematic documentation of VOC concentrations in indoor air and additional information from **occasion related** measurements

[1] Association of ecological research institutes

# Occurrence of VOC in indoor air

## Description of the database

- 7764 data sets with more than 1 005 855 measured values provided by 25 AGÖF institutes
- Information about more than 500 individual substances
- Extensive additional information e.g. on reason, building type, use and sampling

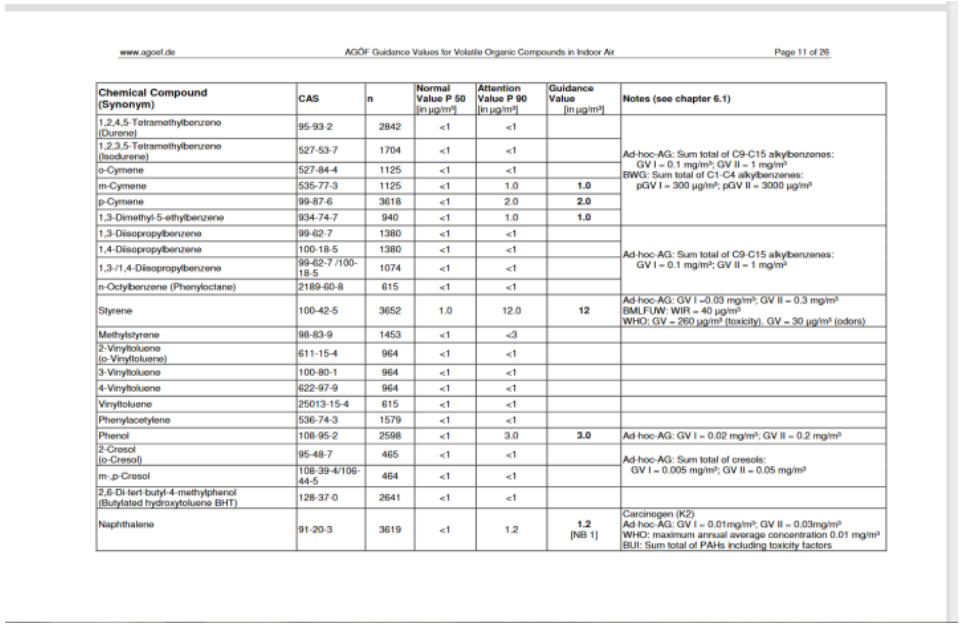


# Occurrence of VOC in indoor air

## Results

- Which substances are most frequently detected indoors and in which concentrations?
- Which trends can be identified?
- What are the main influencing factors?

**AGÖF Guidance Values for VOC**



www.agoef.de AGÖF Guidance Values for Volatile Organic Compounds in Indoor Air Page 11 of 26

| Chemical Compound (Synonym) | CAS | n | Normal Value P 50 [in µg/m³] | Attention Value P 90 [in µg/m³] | Guidance Value [in µg/m³] | Notes (see chapter 6.1) |
|---|---|---|---|---|---|---|
| 1,2,4,5-Tetramethylbenzene (Durene) | 95-93-2 | 2842 | <1 | <1 | | Ad-hoc-AG: Sum total of C9-C15 alkylbenzenes: GV I = 0.1 mg/m³; GV II = 1 mg/m³<br>BWG: Sum total of C1-C4 alkylbenzenes: pGV I = 300 µg/m³; pGV II = 3000 µg/m³ |
| 1,2,3,5-Tetramethylbenzene (Isodurene) | 527-53-7 | 1704 | <1 | <1 | | |
| o-Cymene | 527-84-4 | 1125 | <1 | <1 | | |
| m-Cymene | 535-77-3 | 1125 | <1 | 1.0 | **1.0** | |
| p-Cymene | 99-87-6 | 3618 | <1 | 2.0 | **2.0** | |
| 1,3-Dimethyl-5-ethylbenzene | 934-74-7 | 940 | <1 | 1.0 | **1.0** | |
| 1,3-Diisopropylbenzene | 99-62-7 | 1380 | <1 | <1 | | Ad-hoc-AG: Sum total of C9-C15 alkylbenzenes: GV I = 0.1 mg/m³; GV II = 1 mg/m³ |
| 1,4-Diisopropylbenzene | 100-18-5 | 1380 | <1 | <1 | | |
| 1,3-/1,4-Diisopropylbenzene | 99-62-7 /100-18-5 | 1074 | <1 | <1 | | |
| n-Octylbenzene (Phenyloctane) | 2189-60-8 | 615 | <1 | <1 | | |
| Styrene | 100-42-5 | 3652 | 1.0 | 12.0 | **12** | Ad-hoc-AG: GV I =0.03 mg/m³; GV II = 0.3 mg/m³<br>BMLFUW: WIR = 40 µg/m³<br>WHO: GV = 260 µg/m³ (toxicity), GV = 30 µg/m³ (odors) |
| Methylstyrene | 98-83-9 | 1453 | <1 | <3 | | |
| 2-Vinyltoluene (o-Vinyltoluene) | 611-15-4 | 964 | <1 | <1 | | |
| 3-Vinyltoluene | 100-80-1 | 964 | <1 | <1 | | |
| 4-Vinyltoluene | 622-97-9 | 964 | <1 | <1 | | |
| Vinyltoluene | 25013-15-4 | 615 | <1 | <1 | | |
| Phenylacetylene | 536-74-3 | 1579 | <1 | <1 | | |
| Phenol | 108-95-2 | 2598 | <1 | 3.0 | **3.0** | Ad-hoc-AG: GV I = 0.02 mg/m³; GV II = 0.2 mg/m³ |
| 2-Cresol (o-Cresol) | 95-48-7 | 465 | <1 | <1 | | Ad-hoc-AG: Sum total of cresols: GV I = 0.005 mg/m³; GV II = 0.05 mg/m³ |
| m-,p-Cresol | 108-39-4/106-44-5 | 464 | <1 | <1 | | |
| 2,6-Di-tert-butyl-4-methylphenol (Butylated hydroxytoluene BHT) | 128-37-0 | 2641 | <1 | <1 | | |
| Naphthalene | 91-20-3 | 3619 | <1 | 1.2 | **1.2** [NB 1] | Carcinogen (K2)<br>Ad-hoc-AG: GV I = 0.01mg/m³; GV II = 0.03mg/m³<br>WHO: maximum annual average concentration 0.01 mg/m³<br>BUI: Sum total of PAHs including toxicity factors |

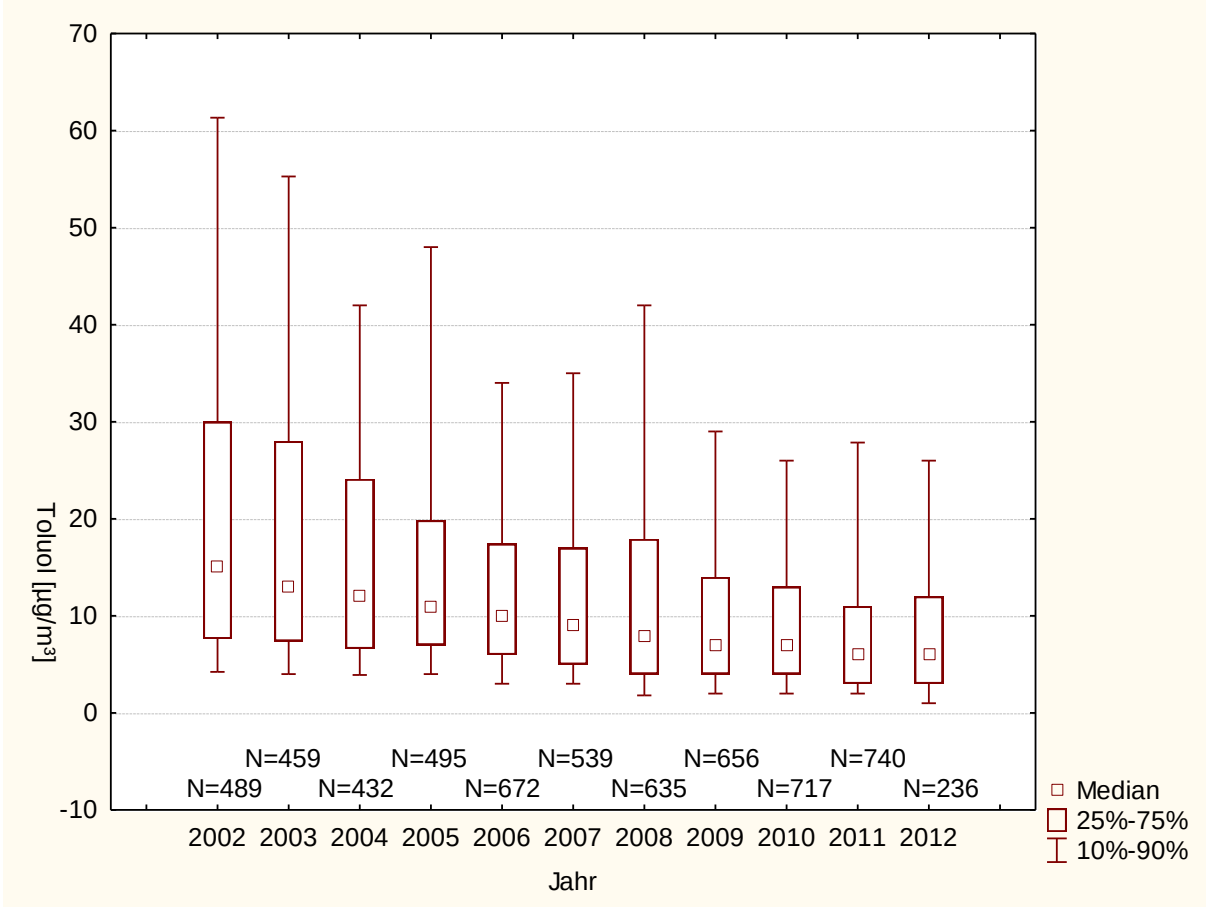
# Occurrence of VOC in indoor air

- Over 500 compounds can be detected in indoor air.
  Some compounds were detected in almost all samples: Acetaldehyde, formaldehyde, toluene and n-hexanal (> 95 % of cases).
  66 % of the measured values are below the detection limit of 1 µg/m³.
- Very high concentrations of several thousand µg/m³ can occur for solvents like aromatic compounds, esters or alcohols.
- TVOC values range between 25 µg/m³ and 27 500 µg/m³.

# Occurrence of VOC in indoor air

Declining trend for halogenated hydrocarbons and aromatic compounds

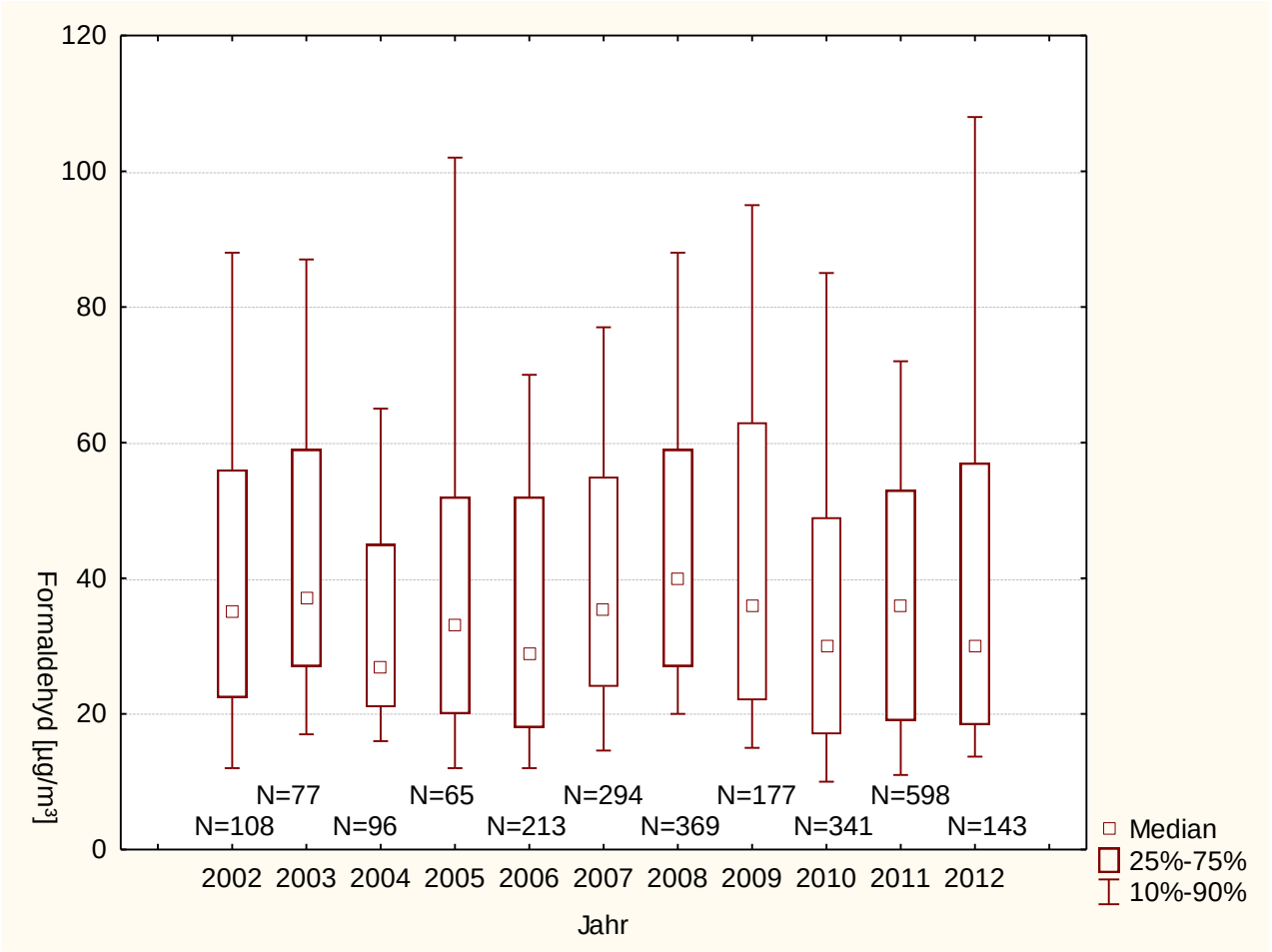
# Toluene


70
60
50
40
30
20
10
0
-10
Toluol [µg/m³]
N=459
N=495
N=539
N=656
N=740
N=489
N=432
N=672
N=635
N=717
N=236
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Jahr
Median
25%-75%
10%-90%

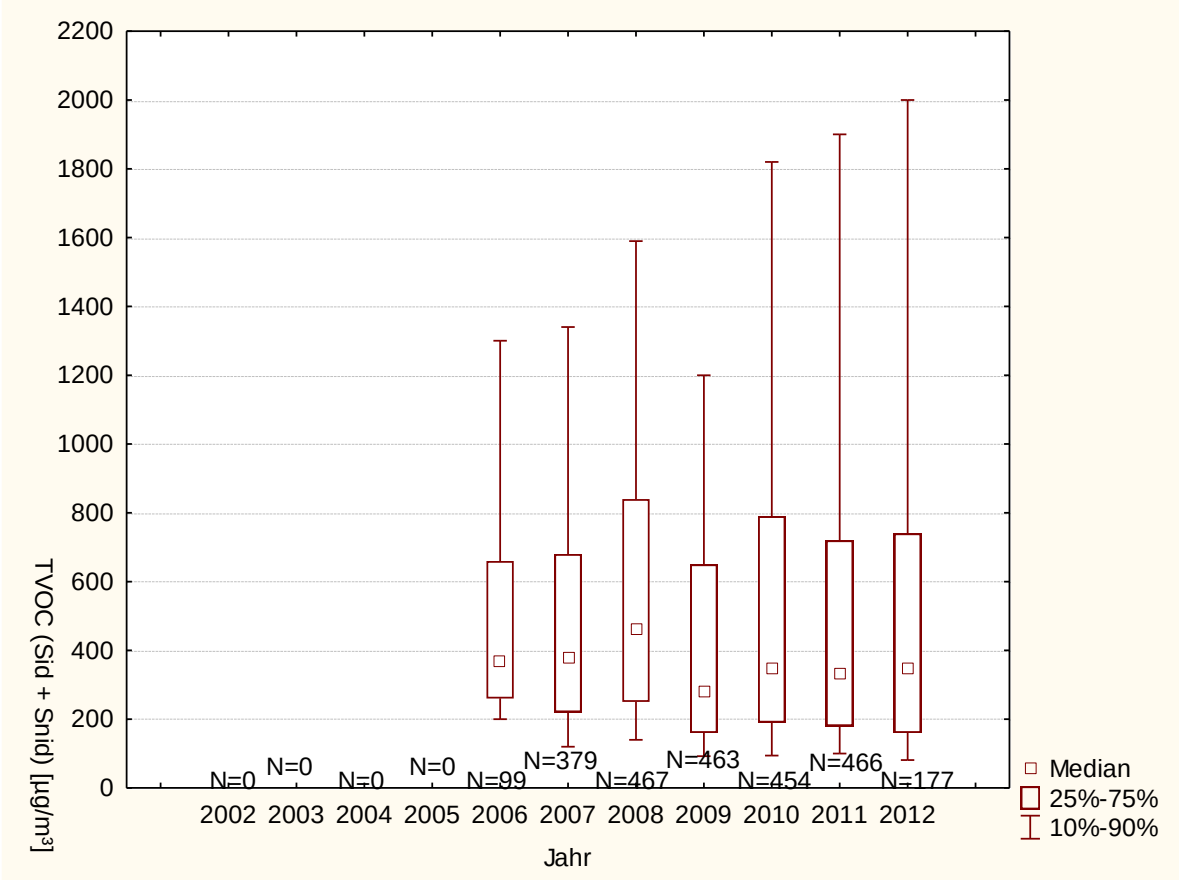
# Occurrence of VOC in indoor air

- No obvious decrease for formaldehyde
- Increase of TVOC

# Formaldehyde



# TVOC


2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
TVOC (Sid + Snid) [µg/m³]
N=0
N=0
N=0
N=0
N=99
N=379
N=467
N=463
N=454
N=466
N=177
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Jahr
Median
25%-75%
10%-90%

# Occurrence of VOC in indoor air

- No decrease of total VOC pollution
- Number of individual substances increases, the substance variety is expanding

# Occurrence of VOC in indoor air

## Influencing factors

- Time passed after renovation or construction was the main factor.
- In rooms with manual ventilation, air exchange rates are lower and higher VOC concentrations can occur.
- The use and type of building affect VOC occurence (e.g. school vs. office or housing; lightweight wood vs. massive construction).
- In cases of odour complaints the VOC source was often the floor construction.

# Occurrence of VOC in indoor air

**What we know?**

- Building products and ventilation are of key importance.

**What we know less about?**

- What is the impact of building use and occupant behavior?

# Indoor air evaluation

## Quality targets for VOC in indoor air

## E.g. for building labels, controlling after construction or remediation

- Toxicologically derived indoor air guideline values
- Statistically derived target values
  - TVOC assessment concept
  - Reference and orientation values

# Indoor air evaluation

## Quality targets for VOC in indoor air

- Target values TVOC 1000 µg/m³, 500 µg/m³ or 300 µg/m³
- Target values formaldehyde 100 µg/m³, 60 µg/m³ or 30 µg/m³
- Compliance with indoor air guideline values
- Comparison with reference and orientation values

# Indoor air evaluation

By selecting low emission products, compliance with indoor air quality targets can be ensured.

# Indoor air evaluation

## Exceedances of quality targets for VOCs

- Unrecommended product or application error
- Construction work (flooring, painting) shortly before the controlling of VOC measurement
- Underestimation of the influence of products used in construction
- Missing ventilation concept during the construction phase
- Underestimation of quantity and loading
- Insufficient air exchange after completion

# Emission testing

**Methodological standards:**

DIN EN ISO 16000:9, 10, 11, DIN EN 16516:2018-01

DIN ISO 16000-3, DIN ISO 16000-6, DIN ISO 16000-28

**Evaluation systems:**

AgBB / MVV TB: Annex 8 (ABG), Belgian VOC regulation, Blue Angel, Natureplus, emicode etc.

French VOC regulation

# Emission testing

**Basic rules:**

All substances from 1 µg/m³

Consideration limit 5 µg/m³

Rounding rules

**Evaluation criteria:**

- TVOC after three and 28 days
- Carcinogens after three and 28 days
- R-value
- Sum without LCI
- TSVOC (without SVOC with LCI)
- Additional compounds like ammonia

# Emission testing

**TVOC Definitions:**

- TVOC based on toluene equivalents
- $TVOC_{spez}$ sum of the concentration of all individual substances (identified target compounds, identified non-target compounds and non-identified compounds) in the retention range between n-hexane und n-hexadecane / including aliphatics ($C_{>16}$ – $C_{22}$) SVOC with LCI
- TVOC without acetic acid
- TVOC-values from 1 µg/m³ or from 5 µg/m³

# Emission testing

**Results:**

Wide variability

Changes in the material composition of tested products over the years

Formerly more frequent:

Very high solvent concentrations in coatings (e.g. wood preservatives, fire protection coatings, parquet coatings).

Product-specific emissions, e.g. phenol in PVC, alcohols or dicarboxylic acid esters in resin-bonded screeds.

- **Reduction of product emissions**

# Emission testing

**Results of 34 randomly selected emission tests[1]:**

Of 11 tests for selected VOCs (formaldehyde, acetic acid, ammonia), nine products did not meet AgBB requirements.

Of 23 fully evaluated AgBB tests, four products did not fulfill AgBB requirements:

- two products exceeded Sum without LCI
- one product exceeded R-value
- one product exceeded TVOC after 28 days, R-value and sum without LCI

[1] Products tested included OSB and plywood panels, floor coatings, UV varnish, screeds, stone veneer, insulation materials, parquet, grout, sealing.

# Emission testing

**Results for wood-based materials:**

In the research project "Emission behavior of OSB and chipboard indoors" emission tests wood-based materials were evaluated.

For example, from 16 OSB three products exceeded the AgBB requirements:

- two products exceeded R-value (aldehydes and carboxylic acids)
- one product exceeded TVOC (acetic acid) and R-value (furfural and acetic acid)

# Emission testing

**What we are  able to do?**

- Selection and improvement
- Identification of sources for VOC immissions

**What we are unable to do?**

- Transferring emission results to specific indoor air situations to predict indoor air concentrations

# Limitations of test chamber investigations

The substance spectrum is methodically defined and not complete.

The time limit of 28 days is well suited for decay processes (e.g. solvents). Reaction processes or emissions from multilayer structures are less well representable.

The influence of typical indoor factors such as heat, humidity, radiation or ozone is not considered.

The continuous ventilation in the test chamber influences the course of the emissions. In reality, the air exchange rate varies.

Interactions between different products, superstructures and the formation of sinks are not considered.

# Limitations of test chamber investigations

Compared to the test chamber scenario, reality is much more complex.

Emission data provide a basis. Further parameters must be taken into account for the suitability of a product.

# Conclusions

## Importance of TVOC

**Indoor air / Construction products**

- Orientation / overview

Sum parameters for assessable, non-assessable and unidentified substances

- Hygienic evaluation

Increase of complaints at higher TVOC values (additive effect of substances with same effect endpoints)

➢ **TVOC-Assessment always in combination with toxicologically derived assessment parameters**

# Conclusions

- Consumers are not experts in evaluating emission test results even architects and planners fail.
- We need reliable requirements for safe handling of (building) products.
- Evaluation of emissions cannot be reduced to a few parameters.
- We need a comprehensive evaluation concept based on the AgBB scheme with continuous expansion and revision.

# Conclusions

Emission tests and the specification of VOC classes are an important first step. Further steps are necessary:

- **Binding requirements**

Selection according to VOC emissions can lead to disadvantages for sustainable products.

- **We also need parameters for $CO_2$ emissions, resource consumption and reusability.**

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und Begutachtung mbH

Thank you
for listening