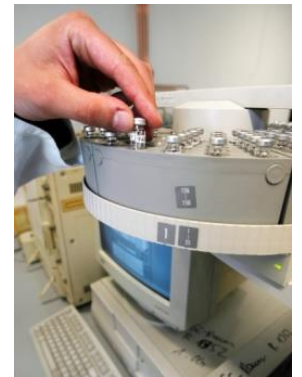
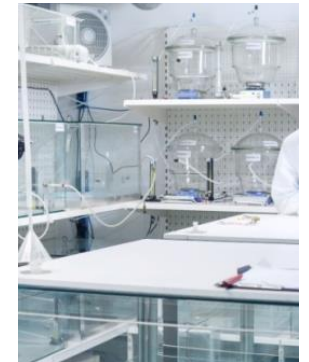
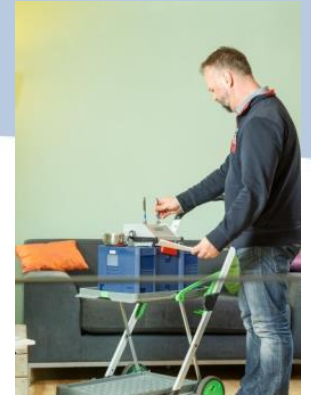


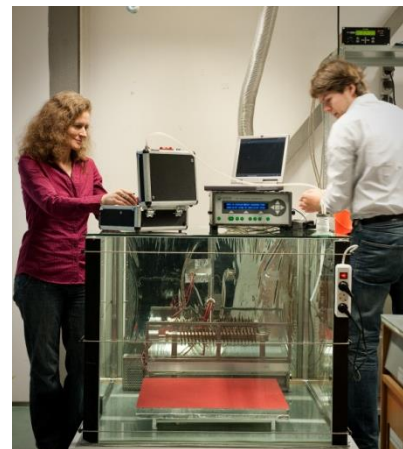
Current data on the occurrence of VOCs in indoor air and emissions from building products: What do we know and what should we know?

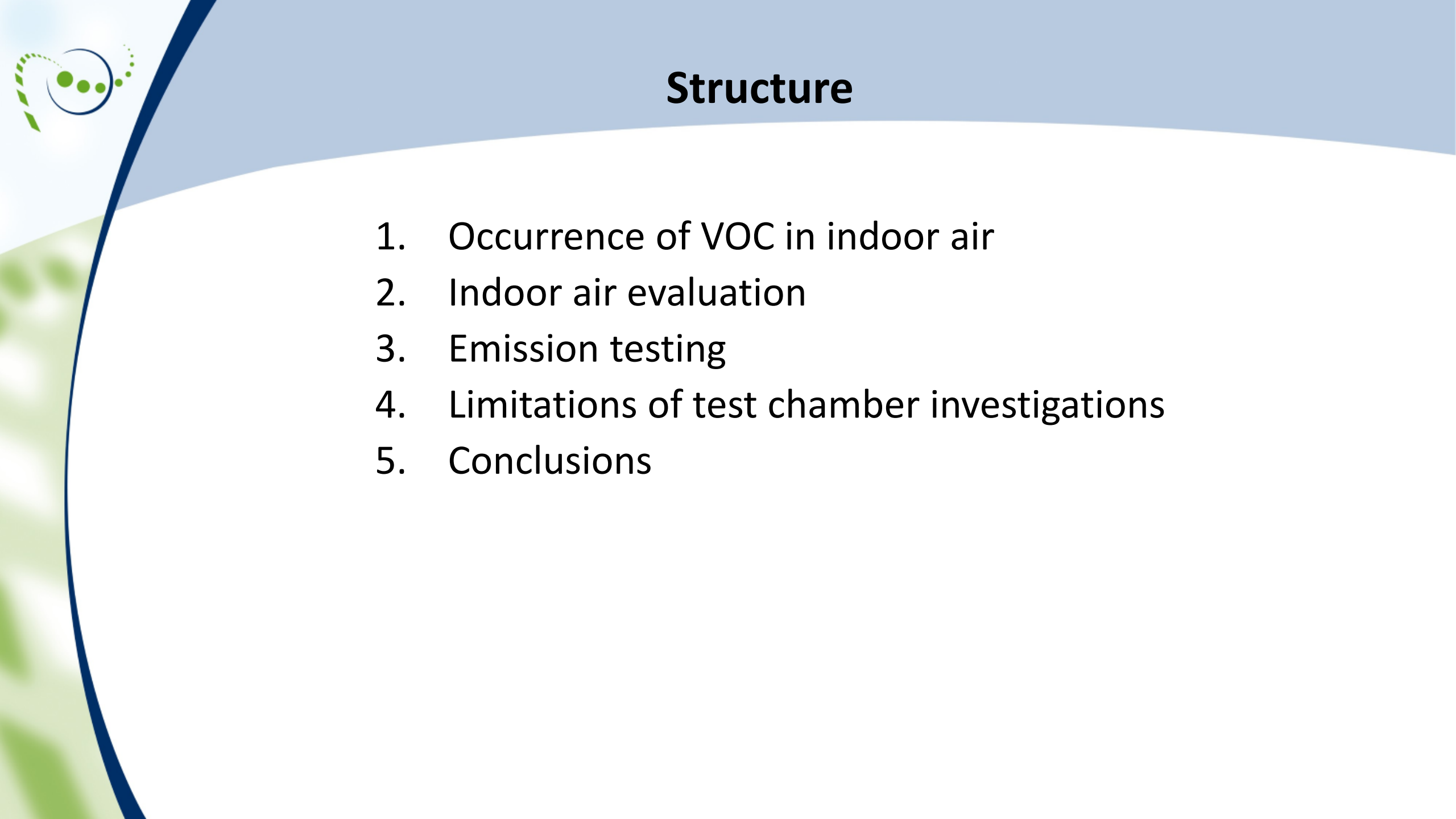
**Dr. Heidrun Hofmann
Bremer Umweltinstitut GmbH**





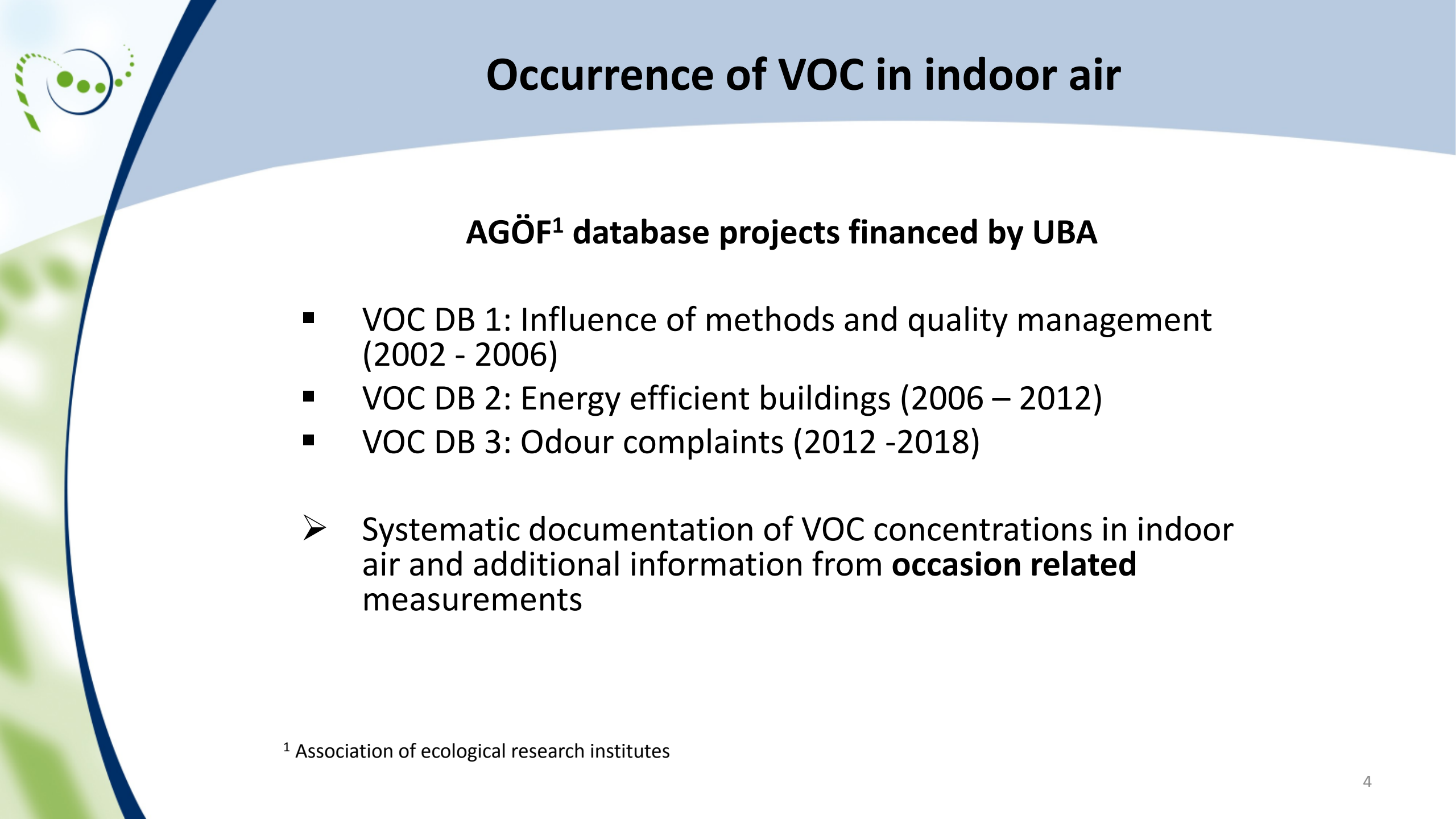
- **Approx. 30 employees**
- **Laboratory fields: Chemical, Microbiological, Fibers (Asbestos/SMF), emission test chambers, sensory testing laboratory**
- **Sampling and evaluation of indoor pollutants**
- **Product testing**
- **Research projects**





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

AGÖF¹ 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

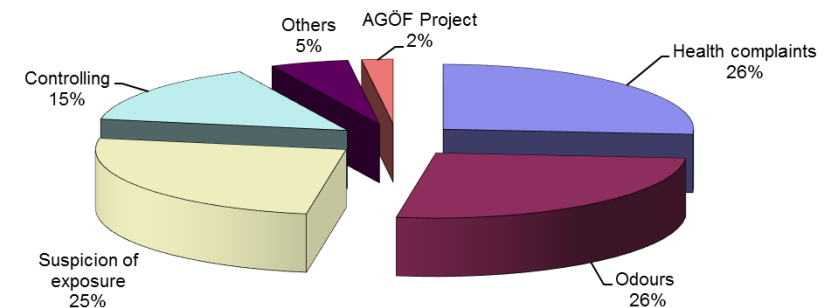
¹ Association of ecological research institutes

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

Reasons for VOC Measurements (n=6624)



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?

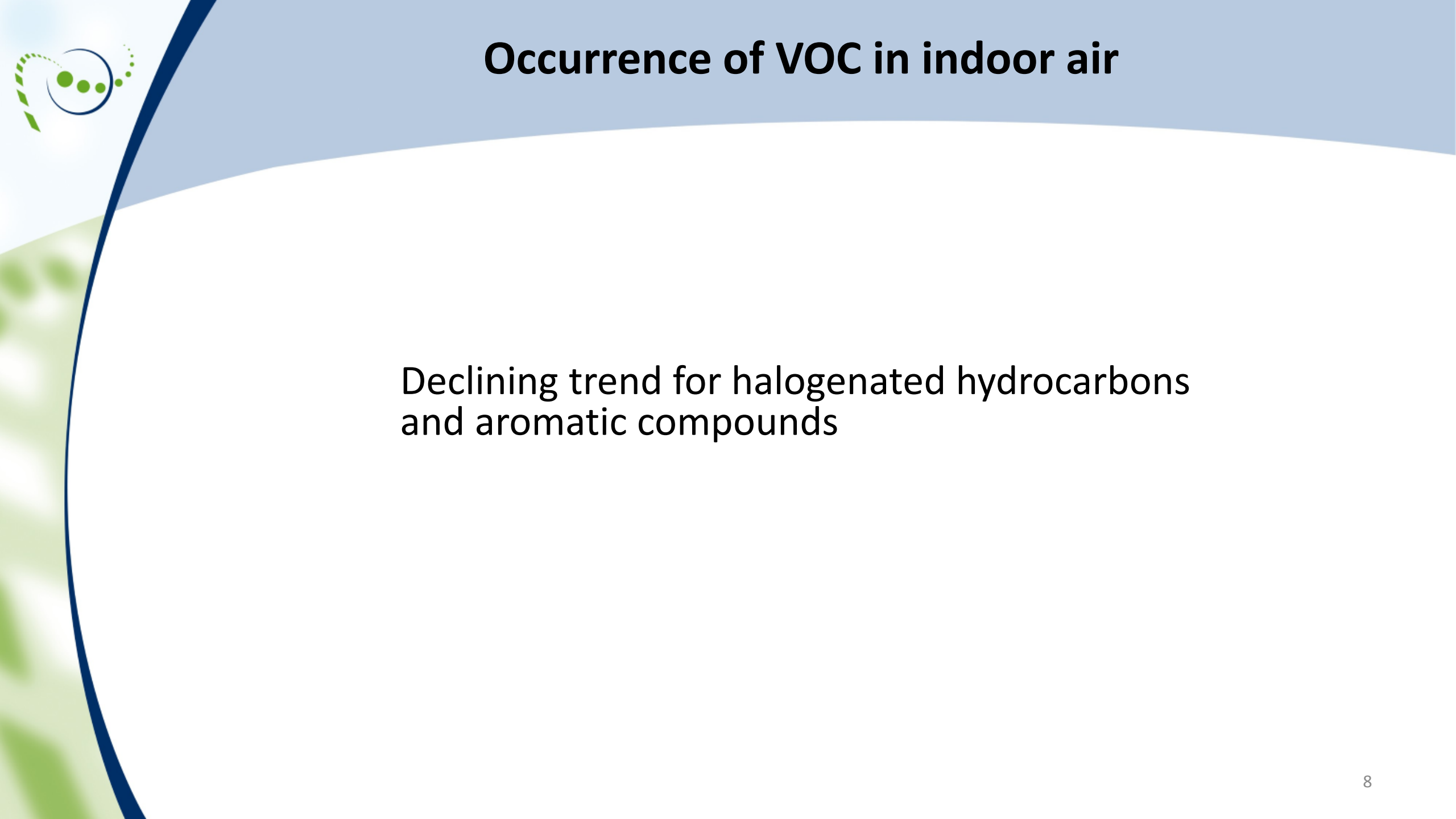
AGÖF Guidance Values for VOC

www.agof.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 5.1)
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 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	Ad-hoc-AG: Sum total of C9-C15 alkylbenzenes: GV I = 0.1 mg/m³; GV II = 1 mg/m³
1,3-Disopropylbenzene	99-62-7	1380	<1	<1		
1,4-Disopropylbenzene	100-19-5	1380	<1	<1		
1,3-/1,4-Disopropylbenzene	99-62-7/100-19-5	1074	<1	<1		
n-Octylbenzene (Phenyltolane)	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 BMLF/LW: WIR = 40 µg/m³ 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	108-39-4/105-44-5	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) Ad-hoc-AG: GV I = 0.01mg/m³; GV II = 0.03mg/m³ WHO: maximum annual average concentration 0.01 mg/m³ BUT: Sum total of PAHs including toxicity factors



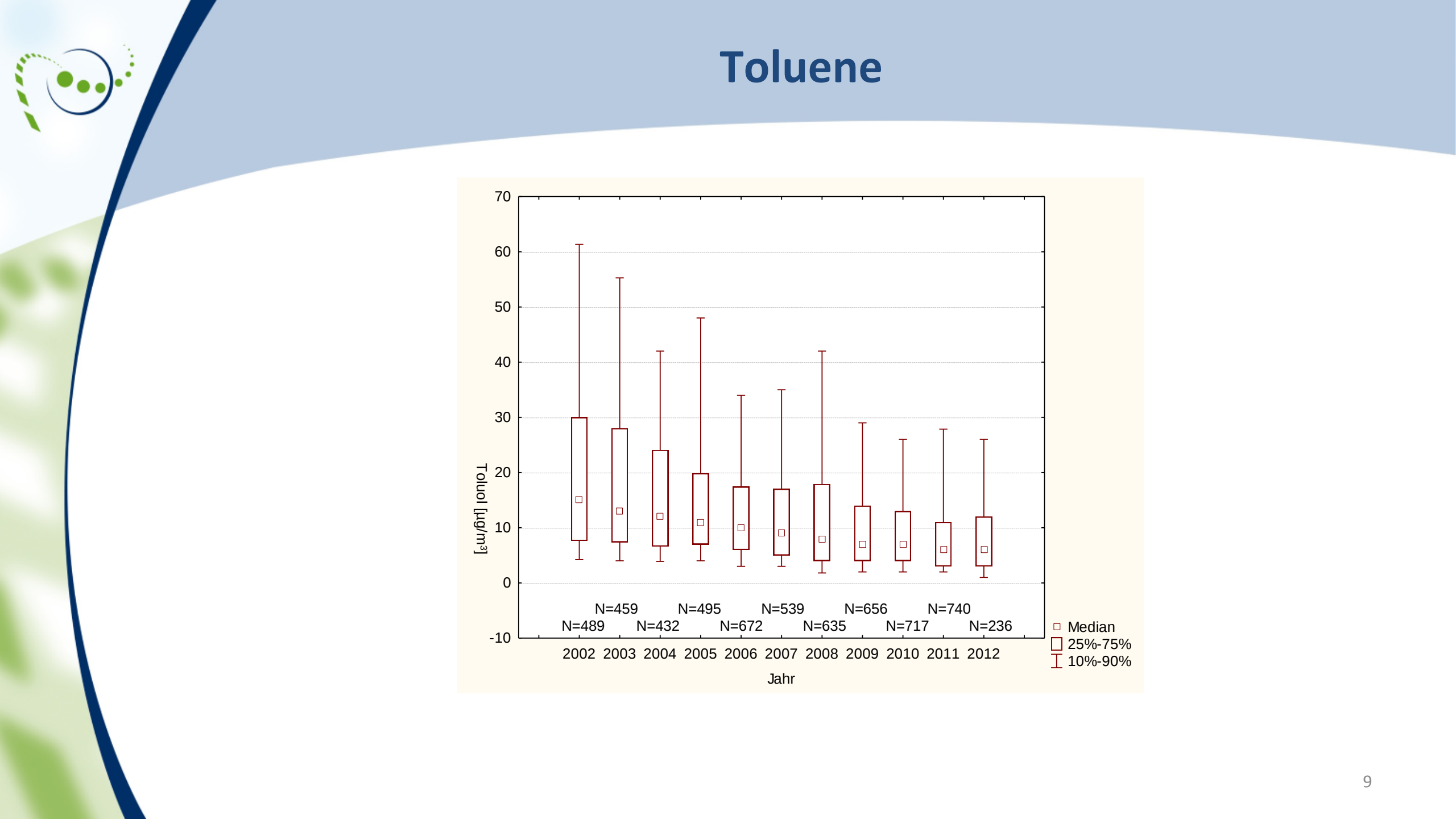
Occurrence of VOC in indoor air

- 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 $1 \mu\text{g}/\text{m}^3$.
- Very high concentrations of several thousand $\mu\text{g}/\text{m}^3$ can occur for solvents like aromatic compounds, esters or alcohols.
- TVOC values range between $25 \mu\text{g}/\text{m}^3$ and $27\,500 \mu\text{g}/\text{m}^3$.

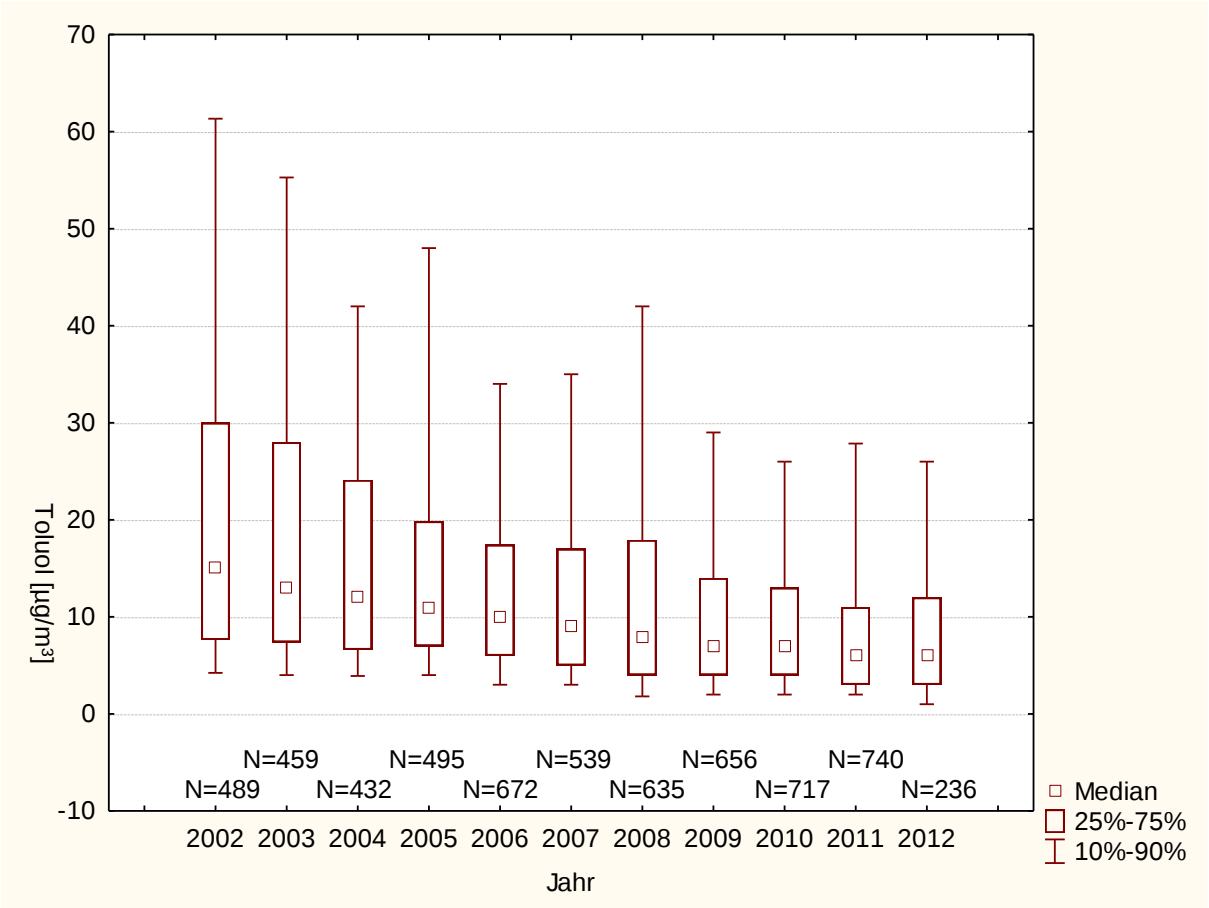


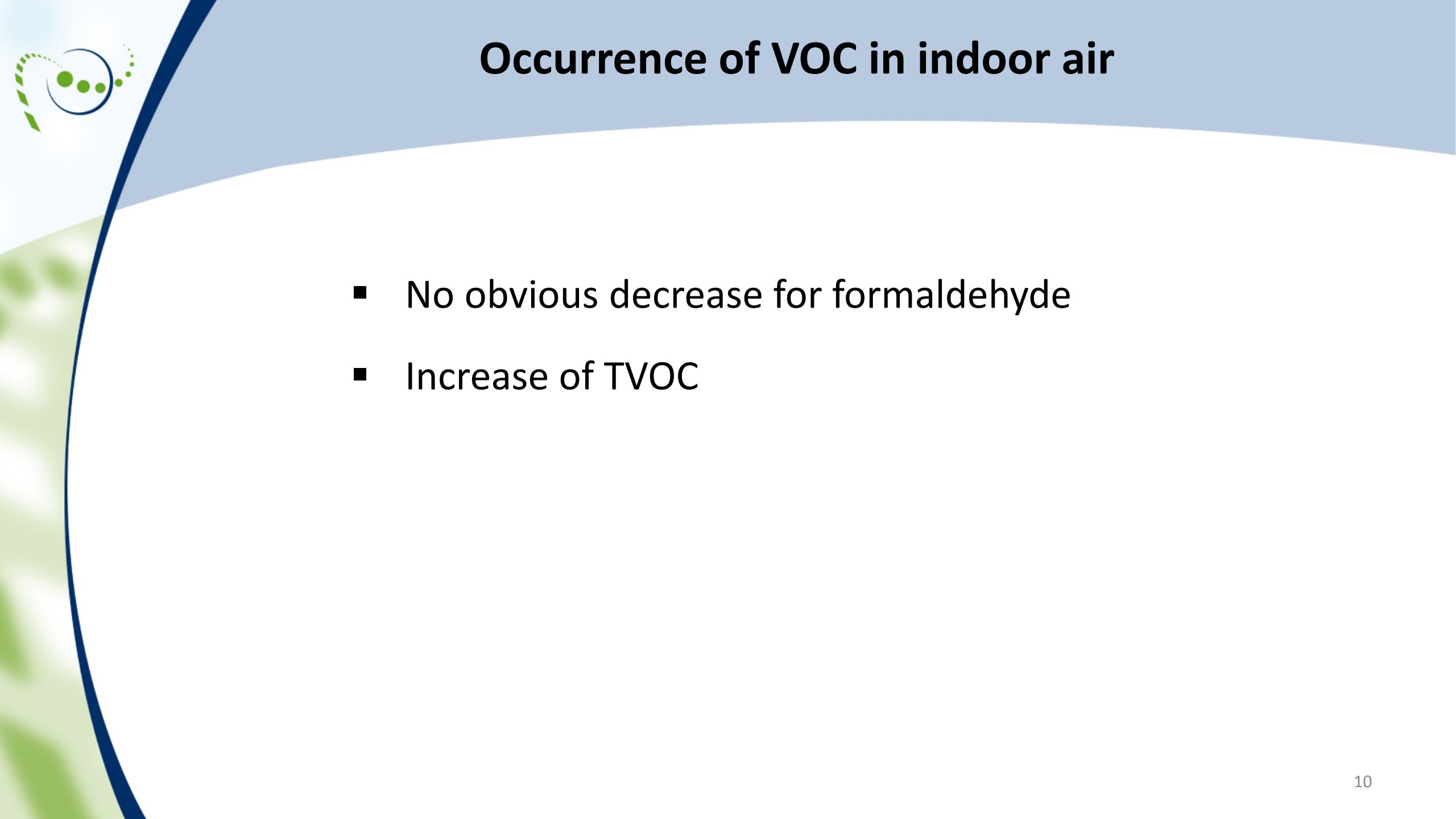
Occurrence of VOC in indoor air

Declining trend for halogenated hydrocarbons
and aromatic compounds



Toluene

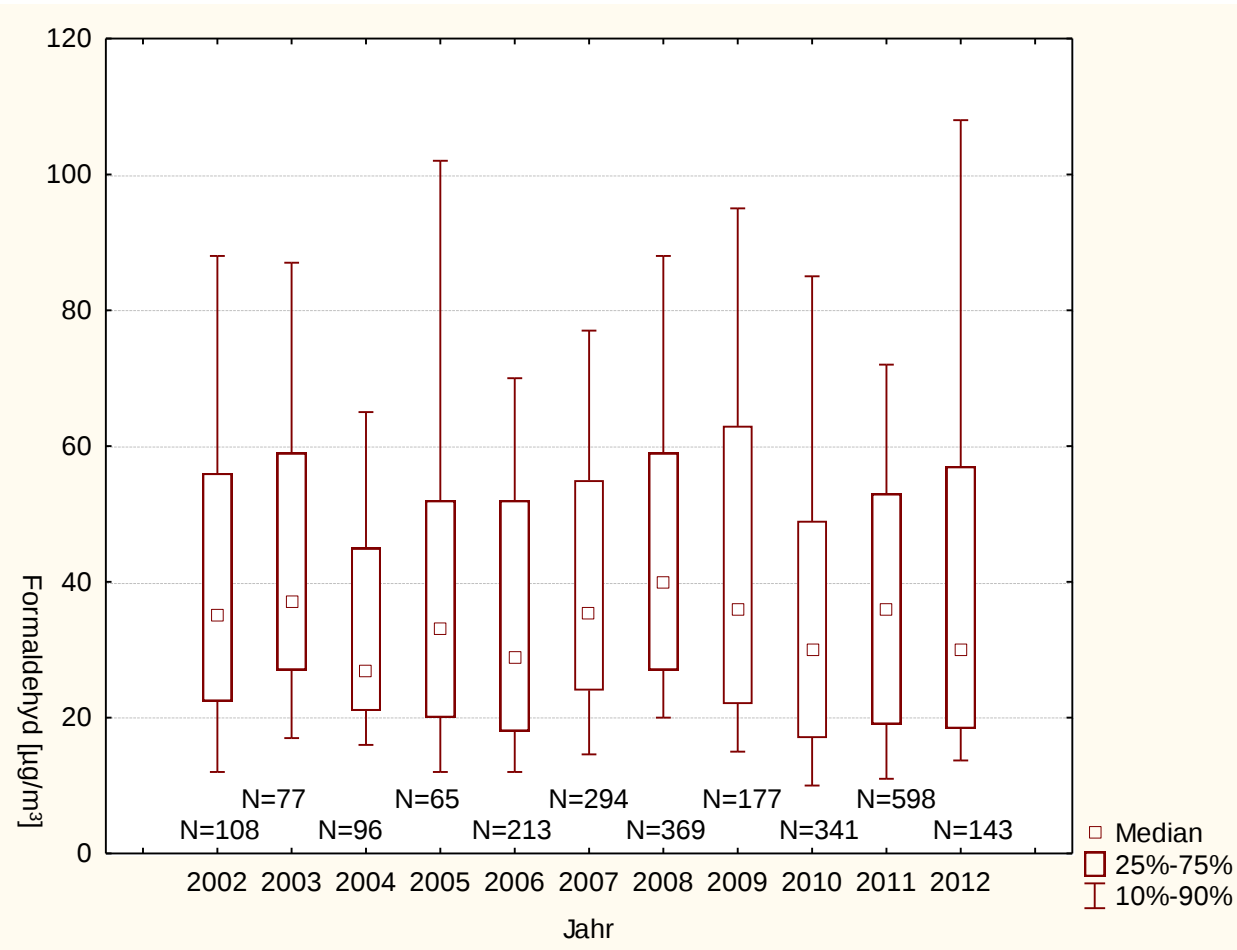




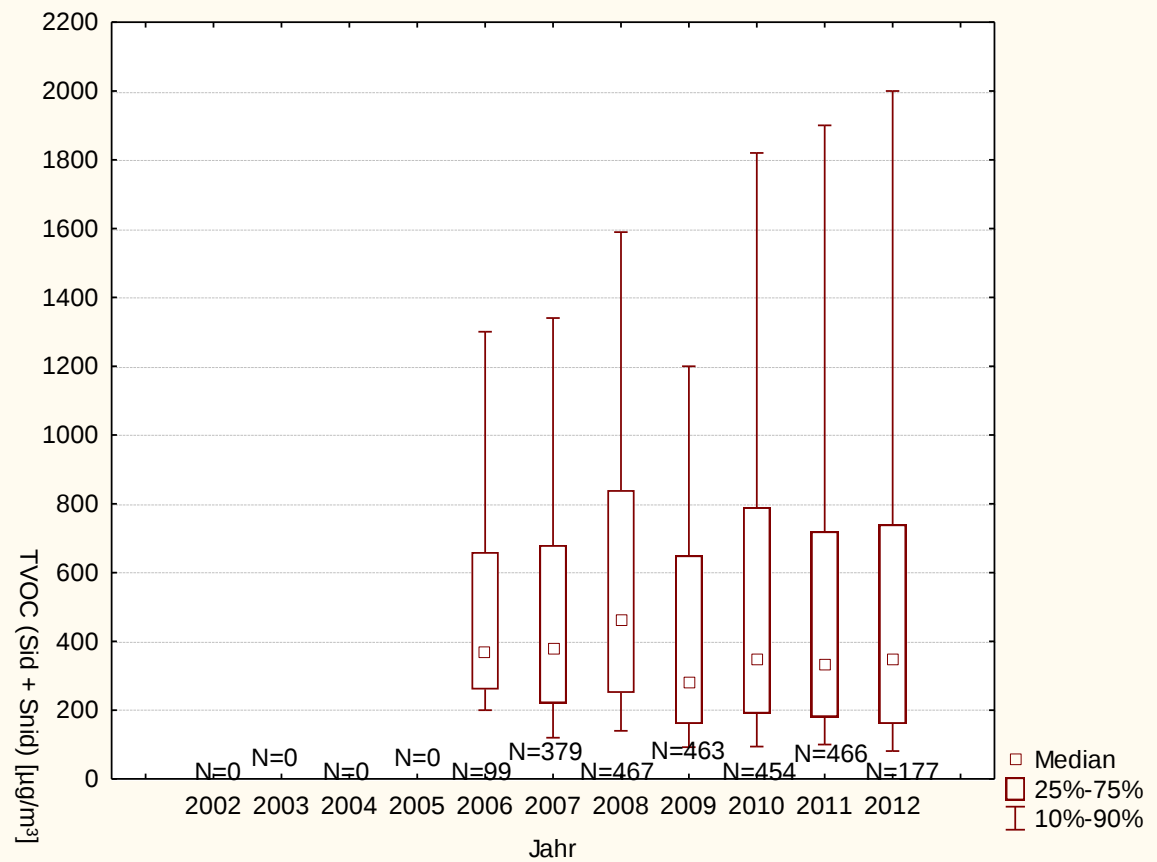
Occurrence of VOC in indoor air

- No obvious decrease for formaldehyde
- Increase of TVOC

Formaldehyde



TVOC





Occurrence of VOC in indoor air

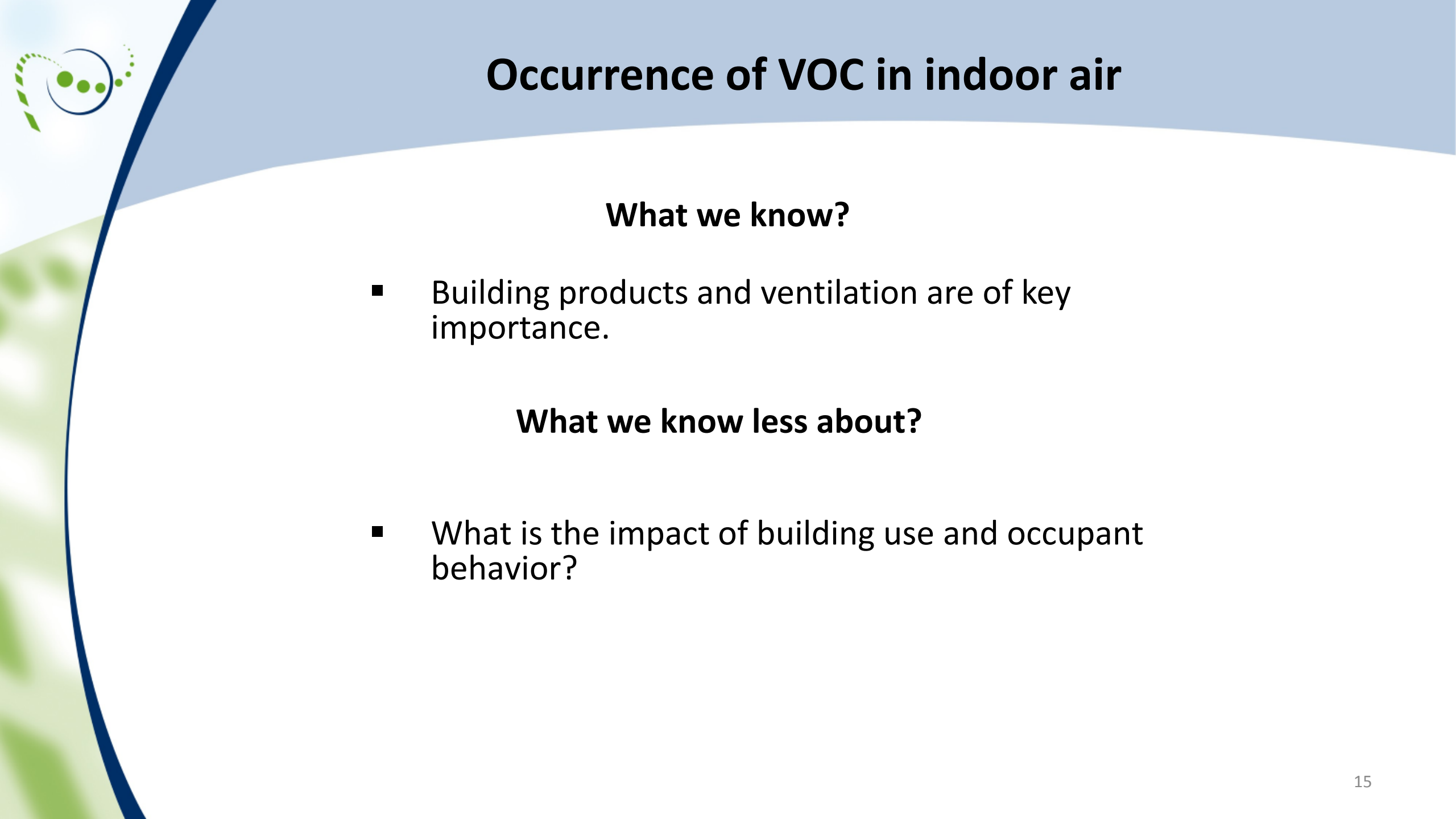
- No decrease of total VOC pollution
- Number of individual substances increases, the substance variety is expanding



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 occurrence (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.



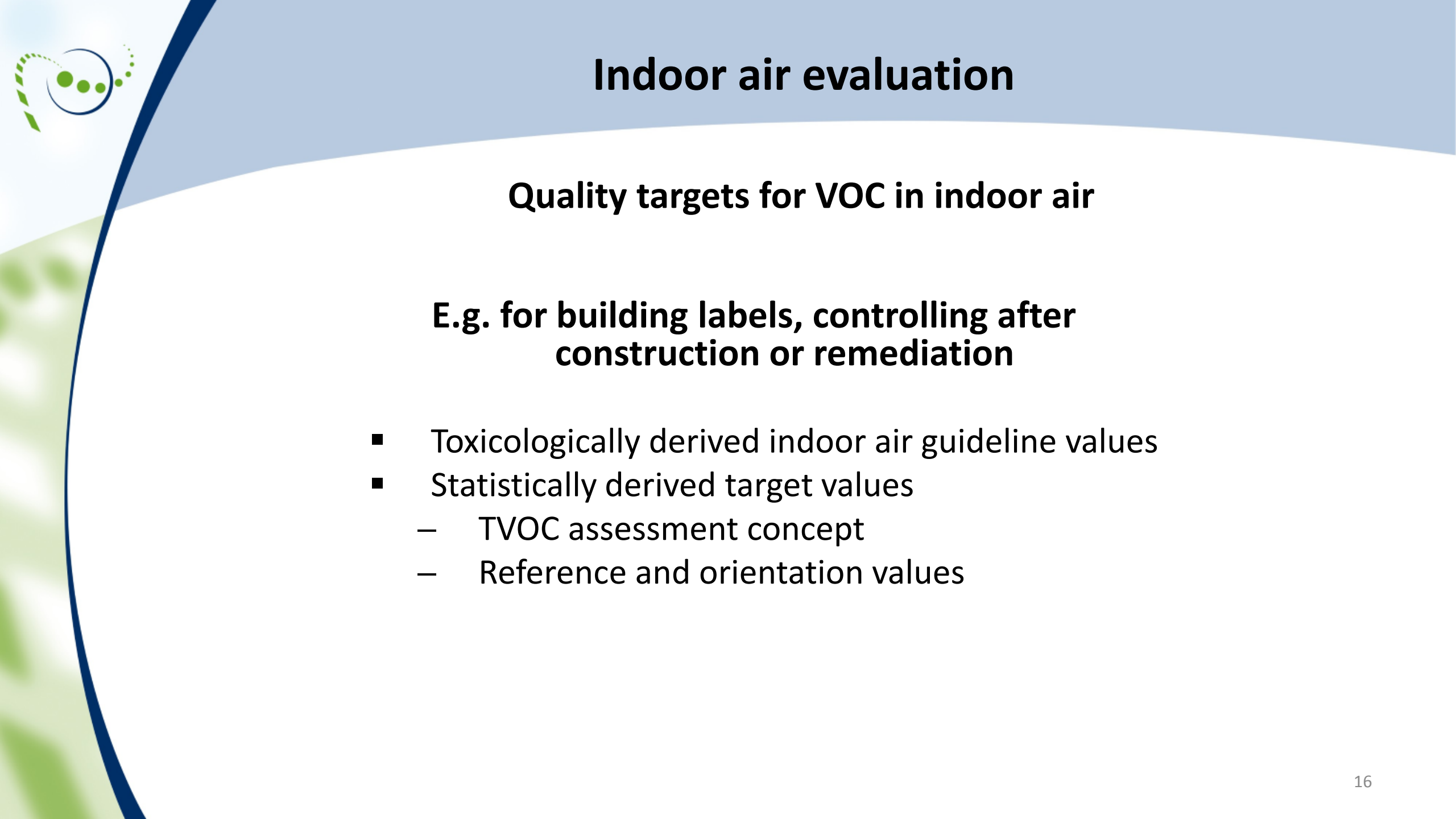
Occurrence of VOC in indoor air

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?

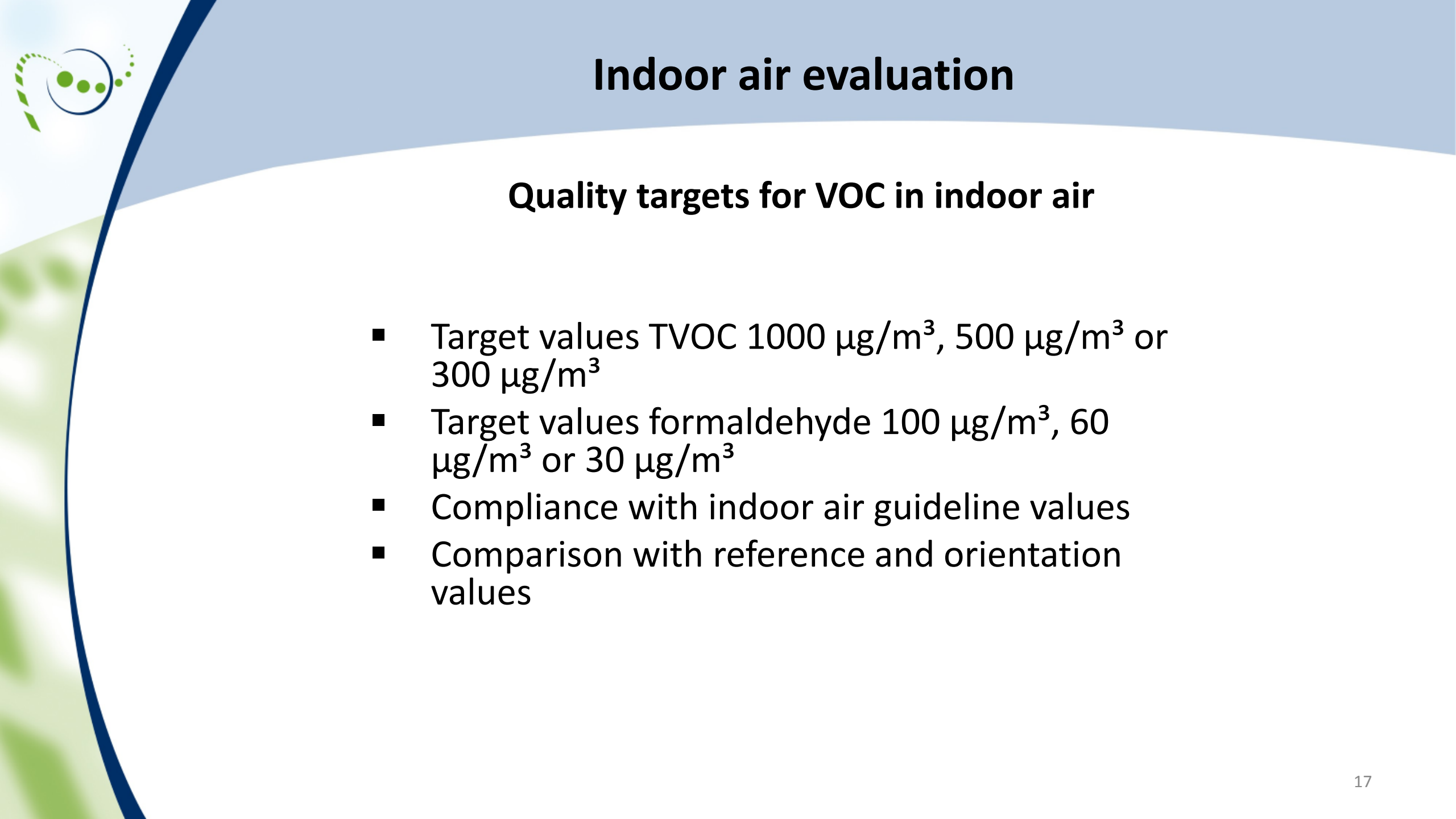


Indoor air evaluation

Quality targets for VOC in indoor air

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

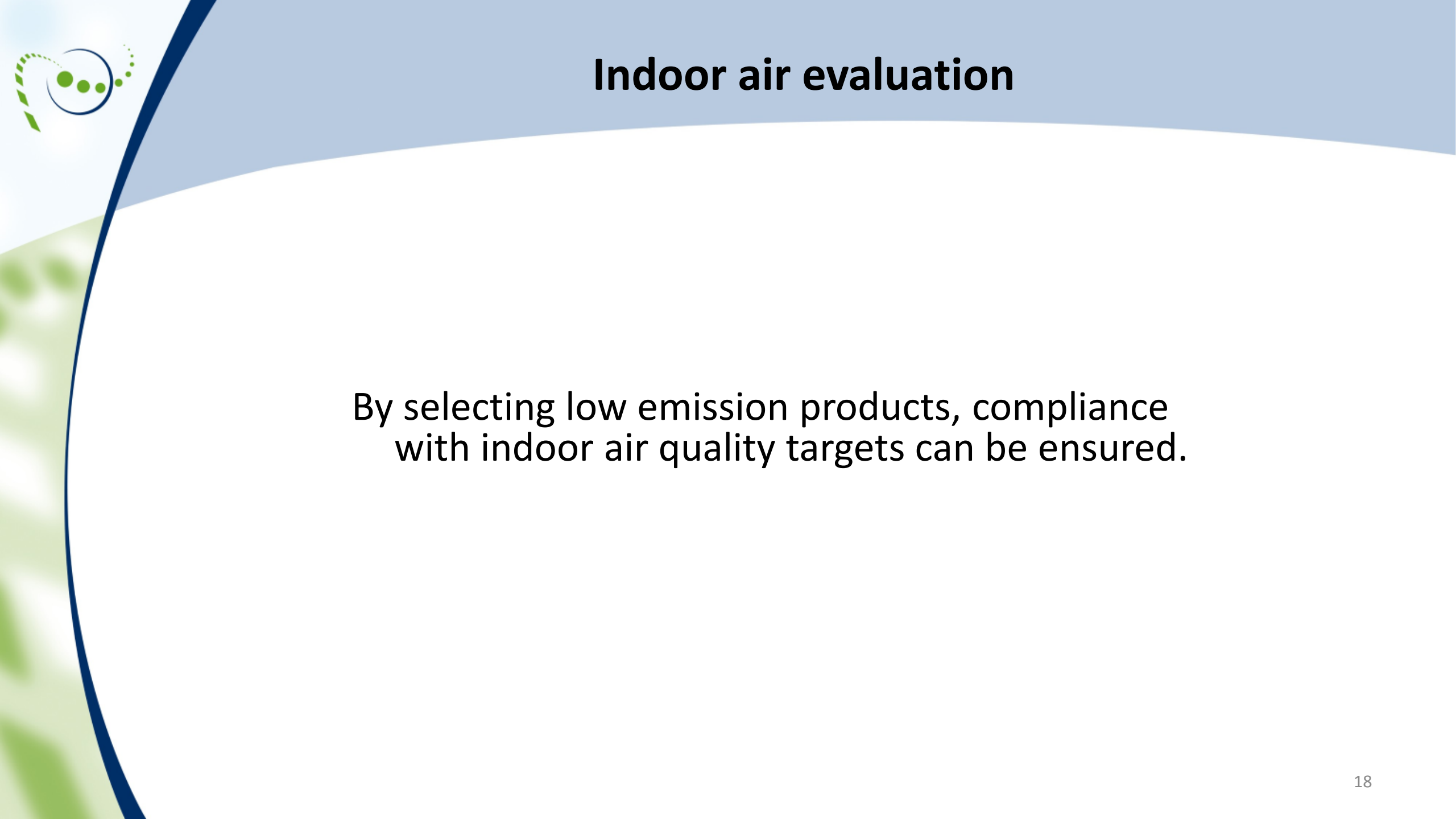
- Toxicologically derived indoor air guideline values
- Statistically derived target values
 - TVOC assessment concept
 - Reference and orientation values



Indoor air evaluation

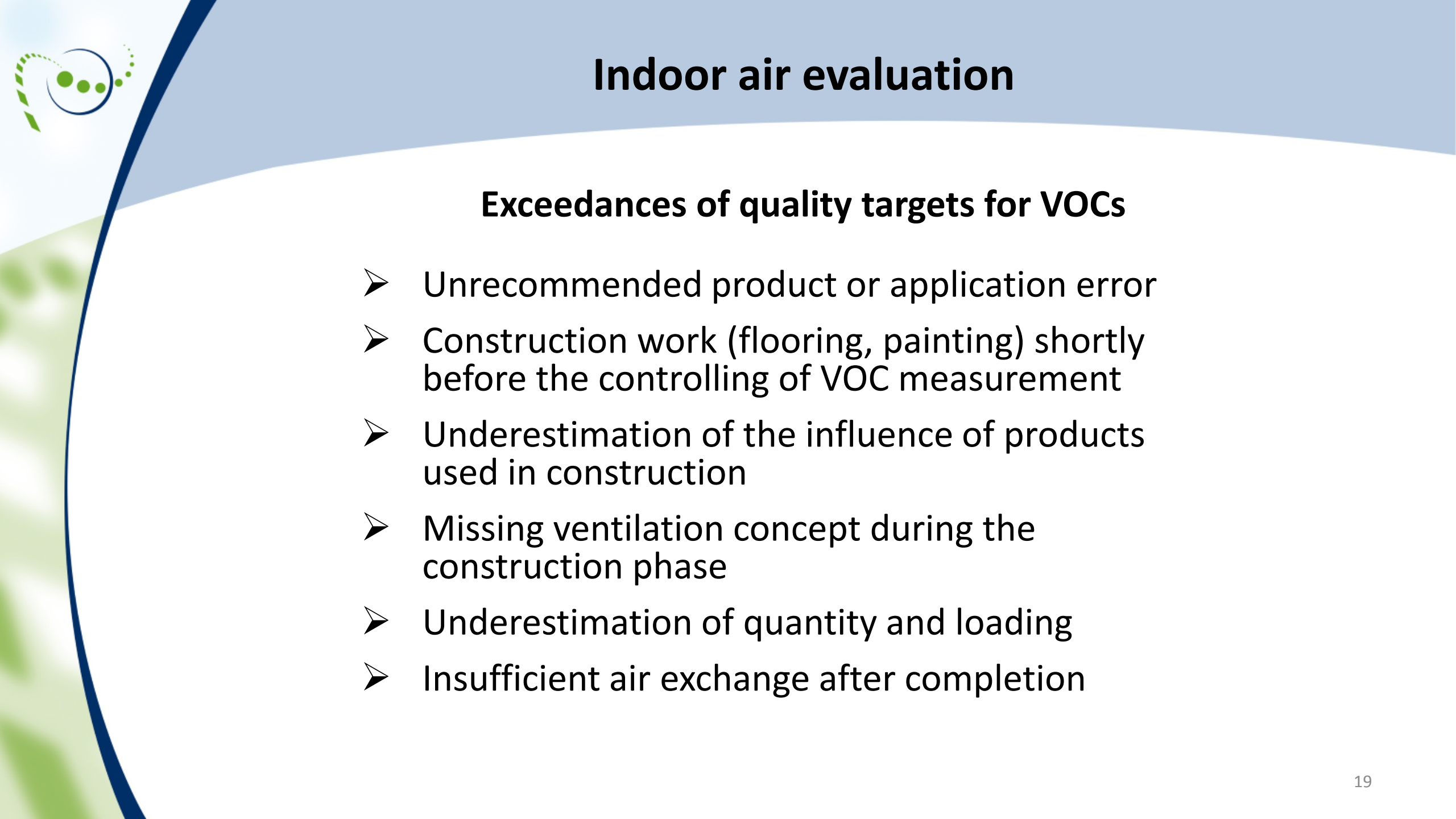
Quality targets for VOC in indoor air

- Target values TVOC 1000 $\mu\text{g}/\text{m}^3$, 500 $\mu\text{g}/\text{m}^3$ or 300 $\mu\text{g}/\text{m}^3$
- Target values formaldehyde 100 $\mu\text{g}/\text{m}^3$, 60 $\mu\text{g}/\text{m}^3$ or 30 $\mu\text{g}/\text{m}^3$
- Compliance with indoor air guideline values
- Comparison with reference and orientation values



Indoor air evaluation

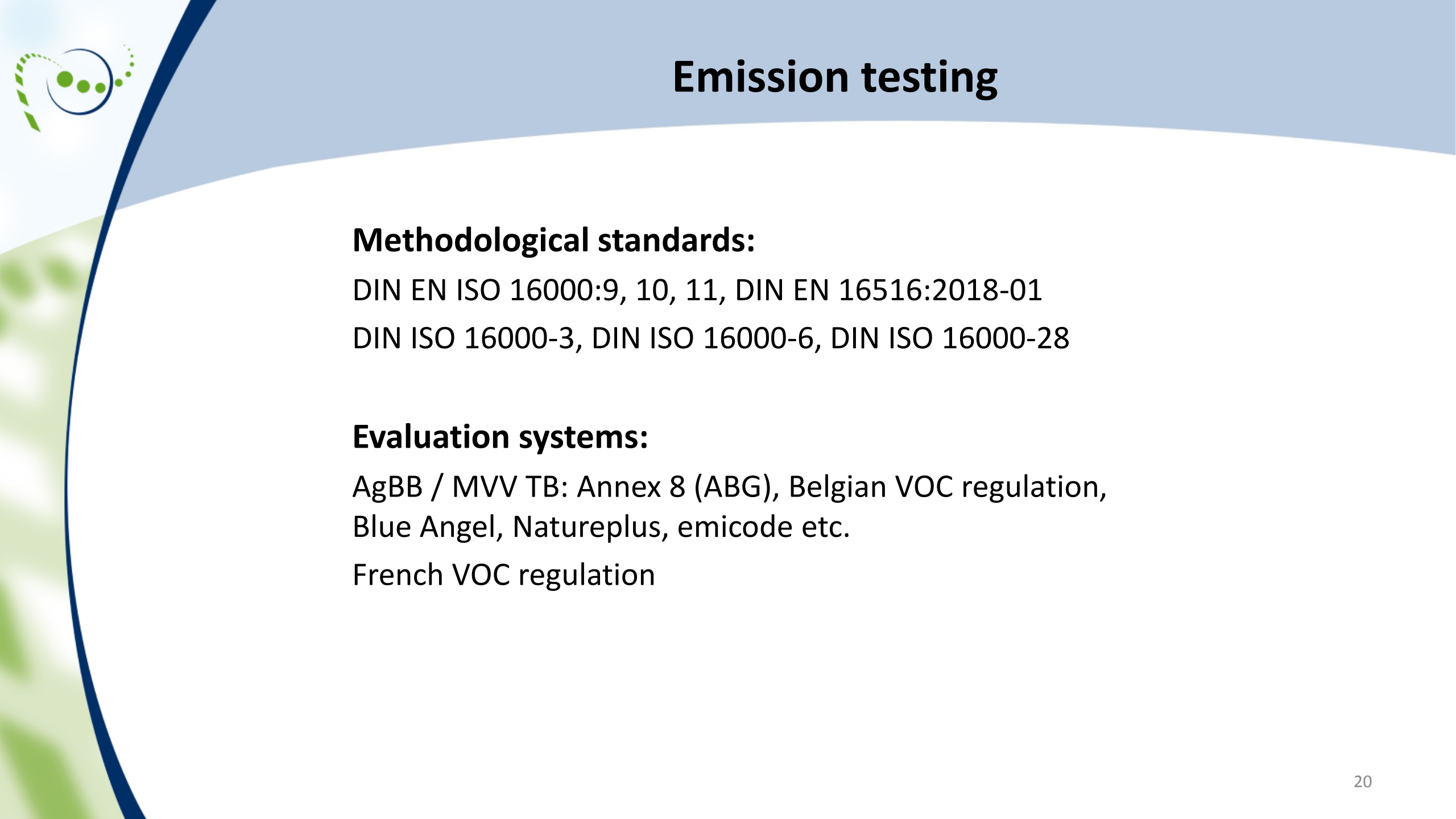
By selecting low emission products, compliance with indoor air quality targets can be ensured.



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:

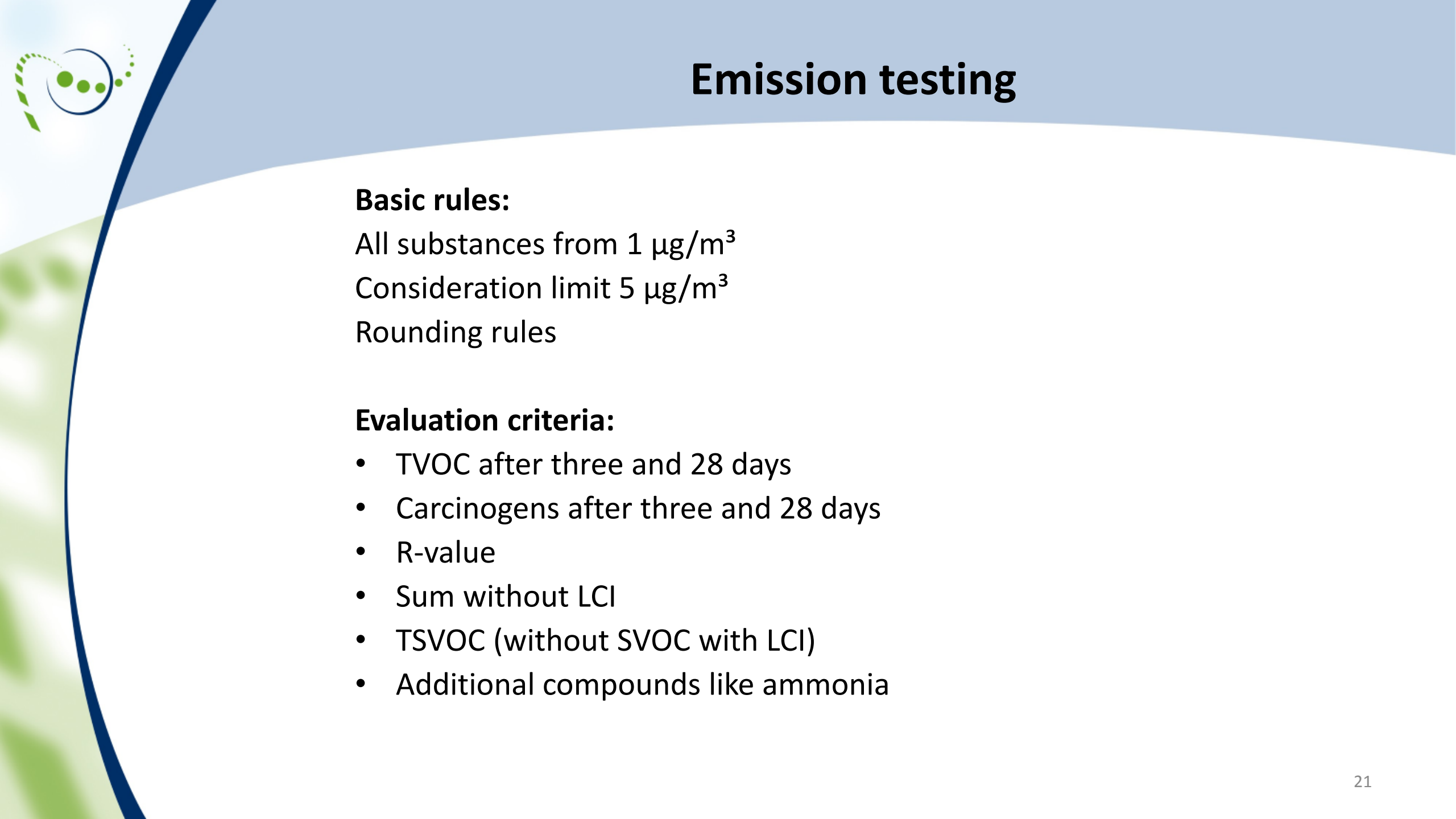
DIN EN ISO 16000:9, 10, 11, DIN EN 16516:2018-01

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:

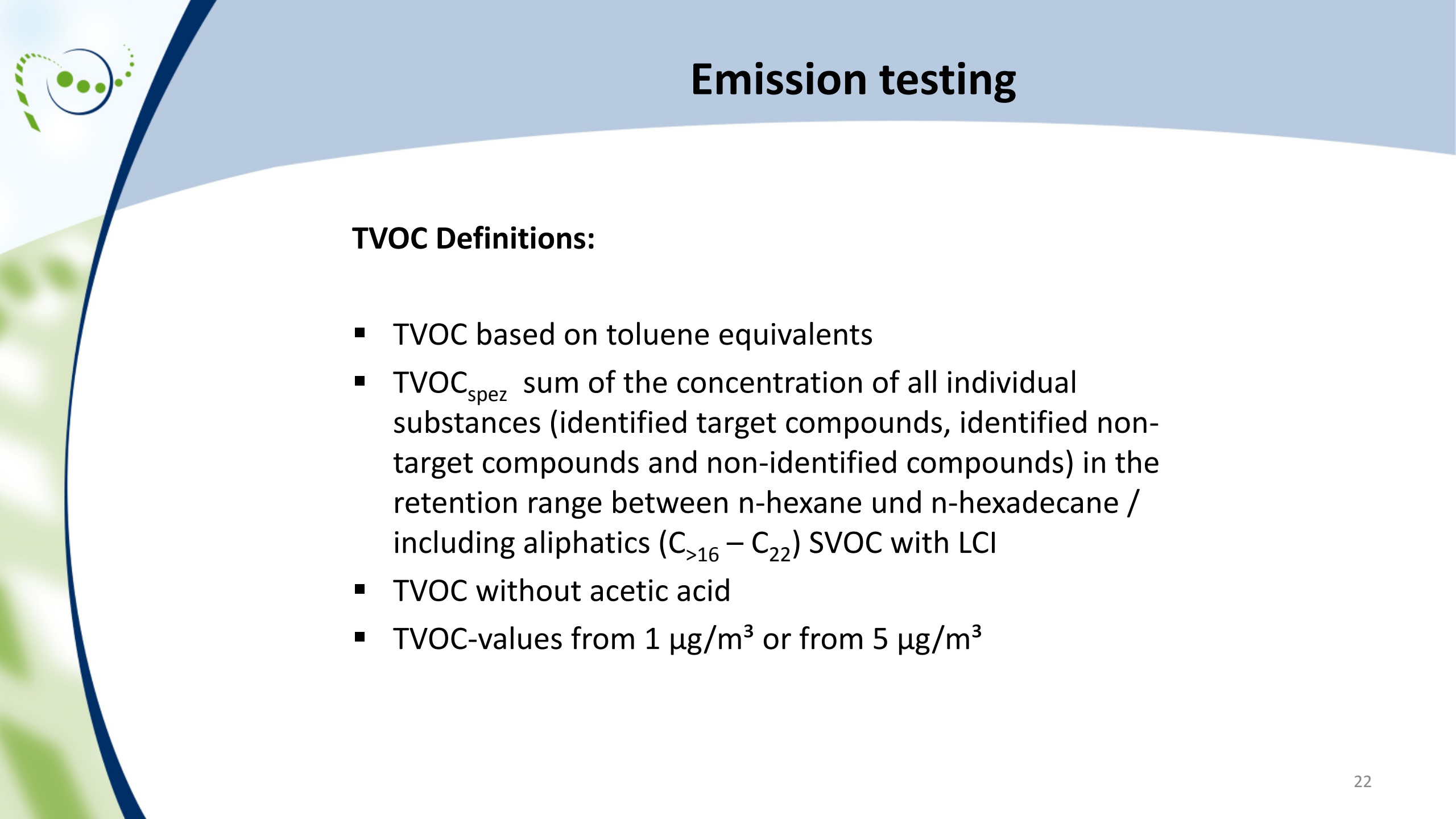
All substances from 1 $\mu\text{g}/\text{m}^3$

Consideration limit 5 $\mu\text{g}/\text{m}^3$

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
- $\text{TVOC}_{\text{spez}}$ 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 ($\text{C}_{>16} - \text{C}_{22}$) SVOC with LCI
- TVOC without acetic acid
- TVOC-values from $1 \mu\text{g}/\text{m}^3$ or from $5 \mu\text{g}/\text{m}^3$



Emission testing

Results:

Wide variability

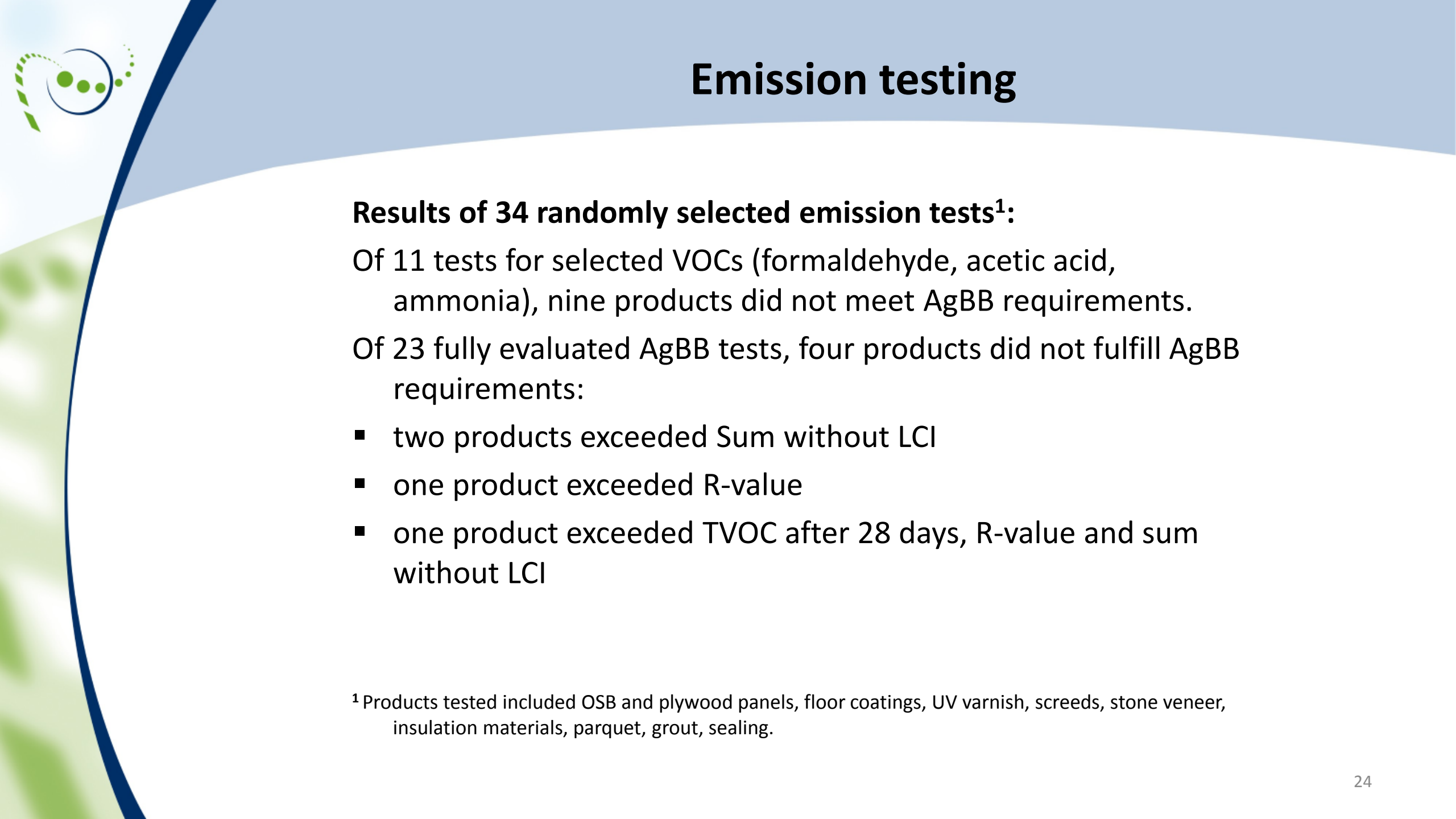
Changes in the material composition of tested products over the years

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

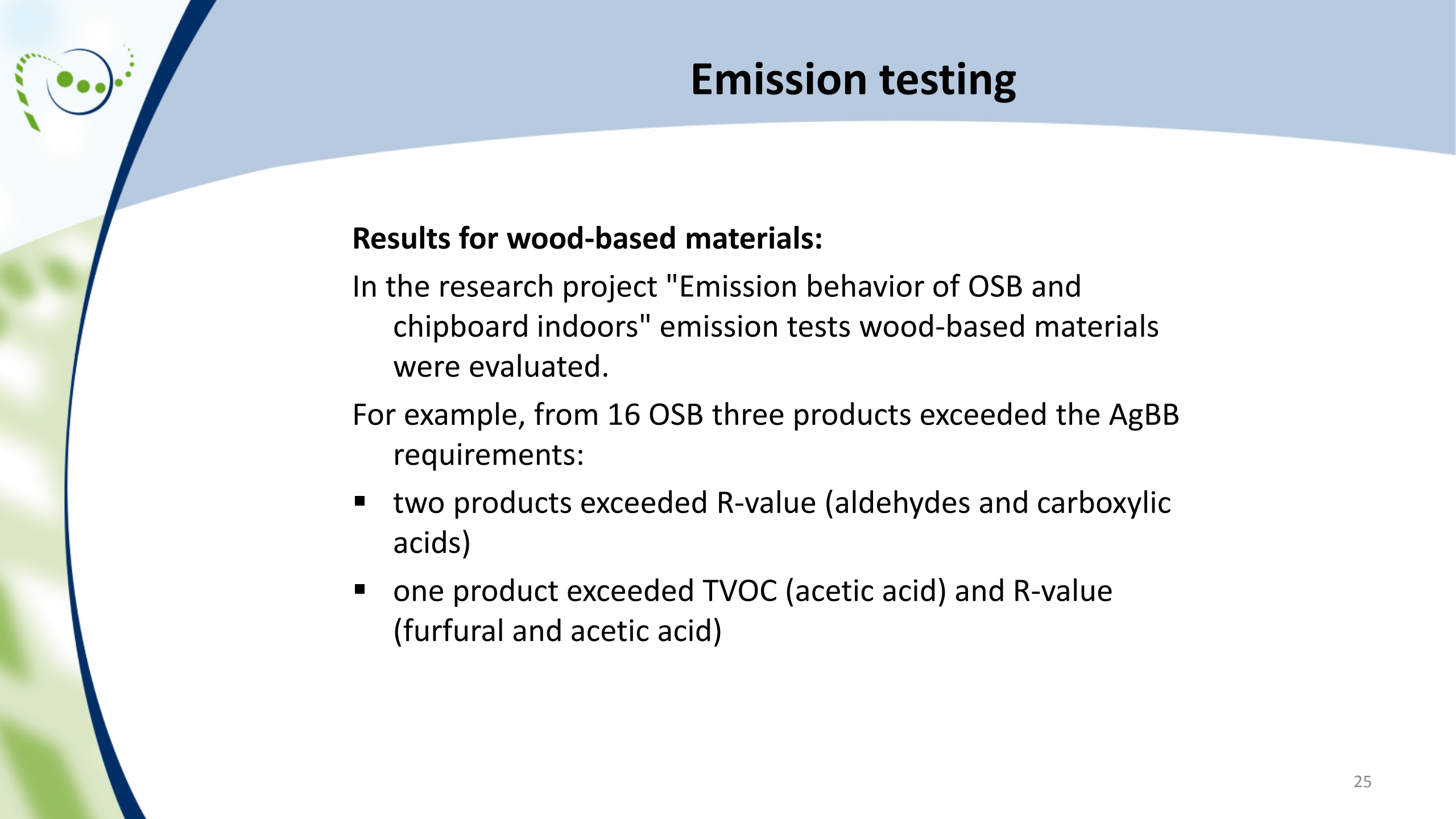
Results of 34 randomly selected emission tests¹:

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.



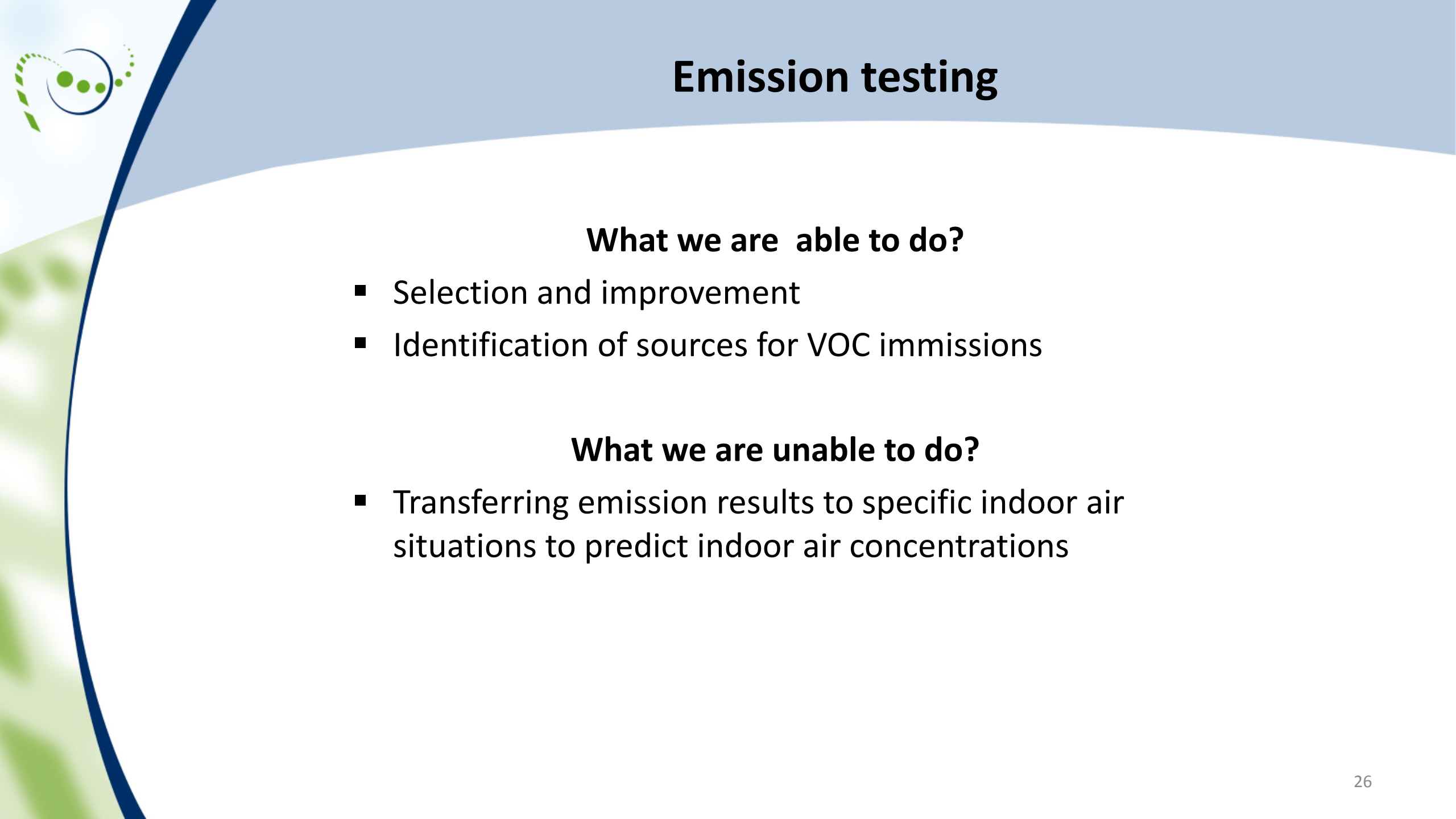
Emission testing

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



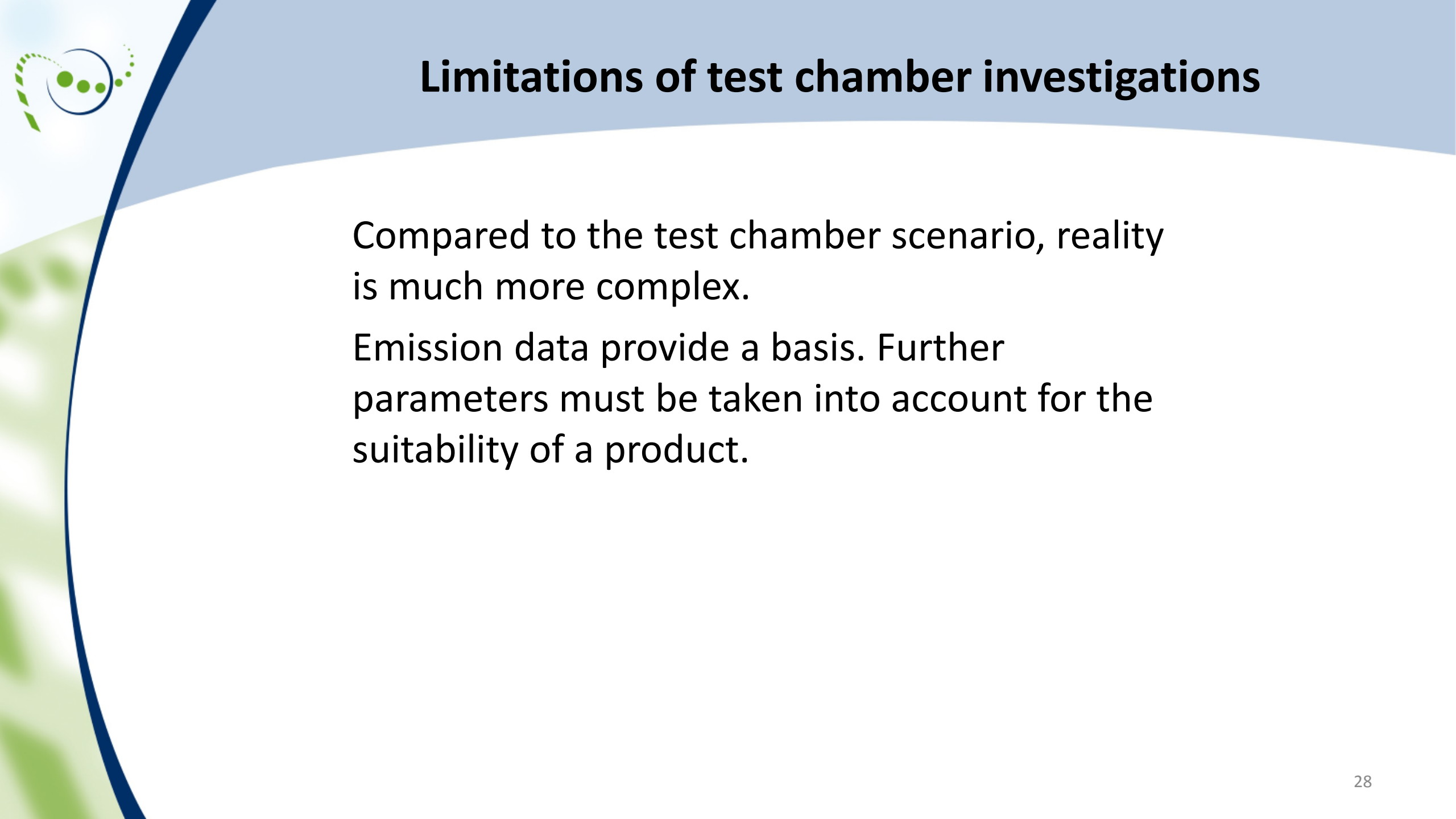
Limitations of test chamber investigations

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.

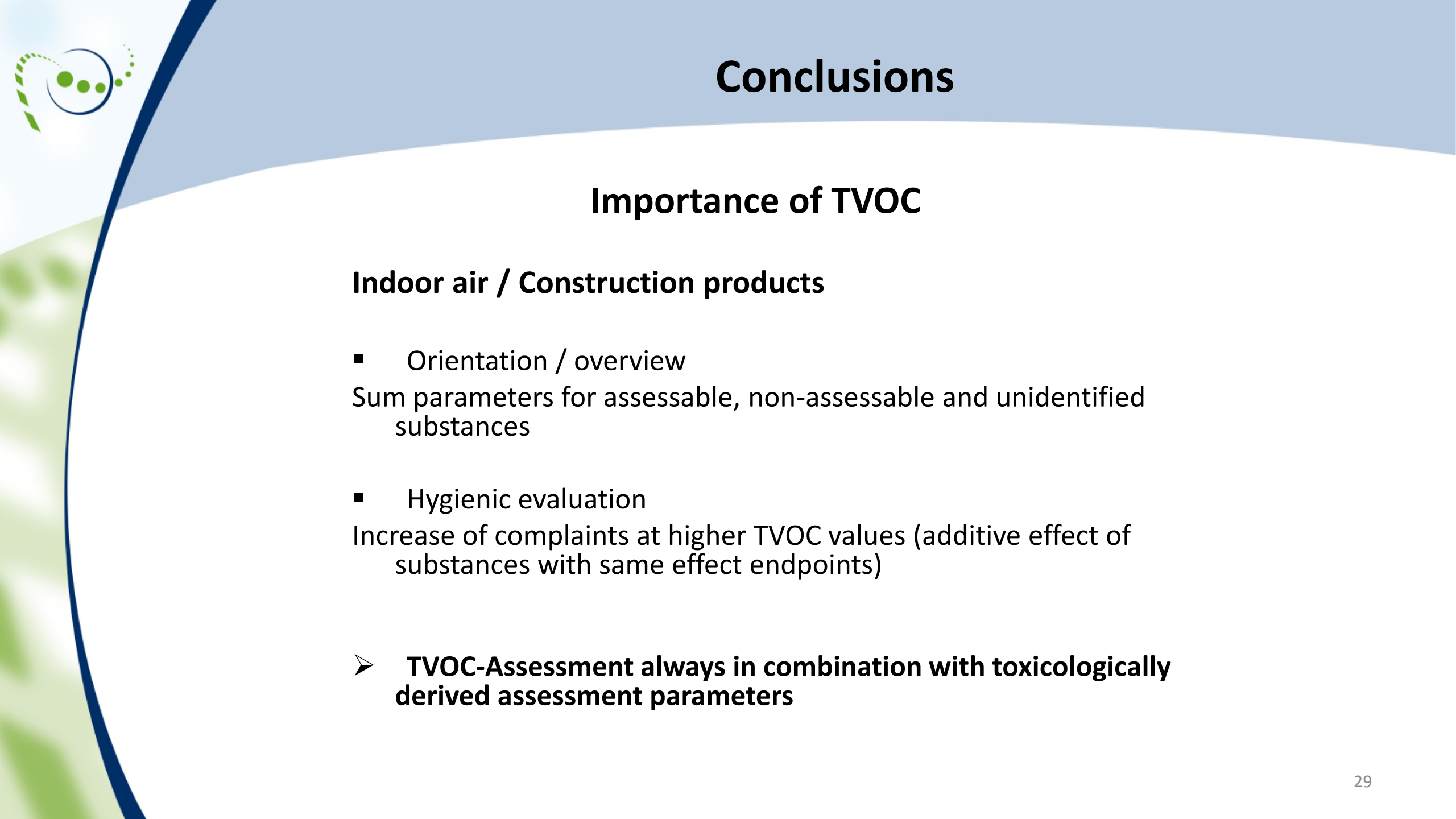
The continuous ventilation in the test chamber influences the course of the emissions. In reality, the air exchange rate varies. Interactions between different products, superstructures and the formation of sinks are not considered.



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.

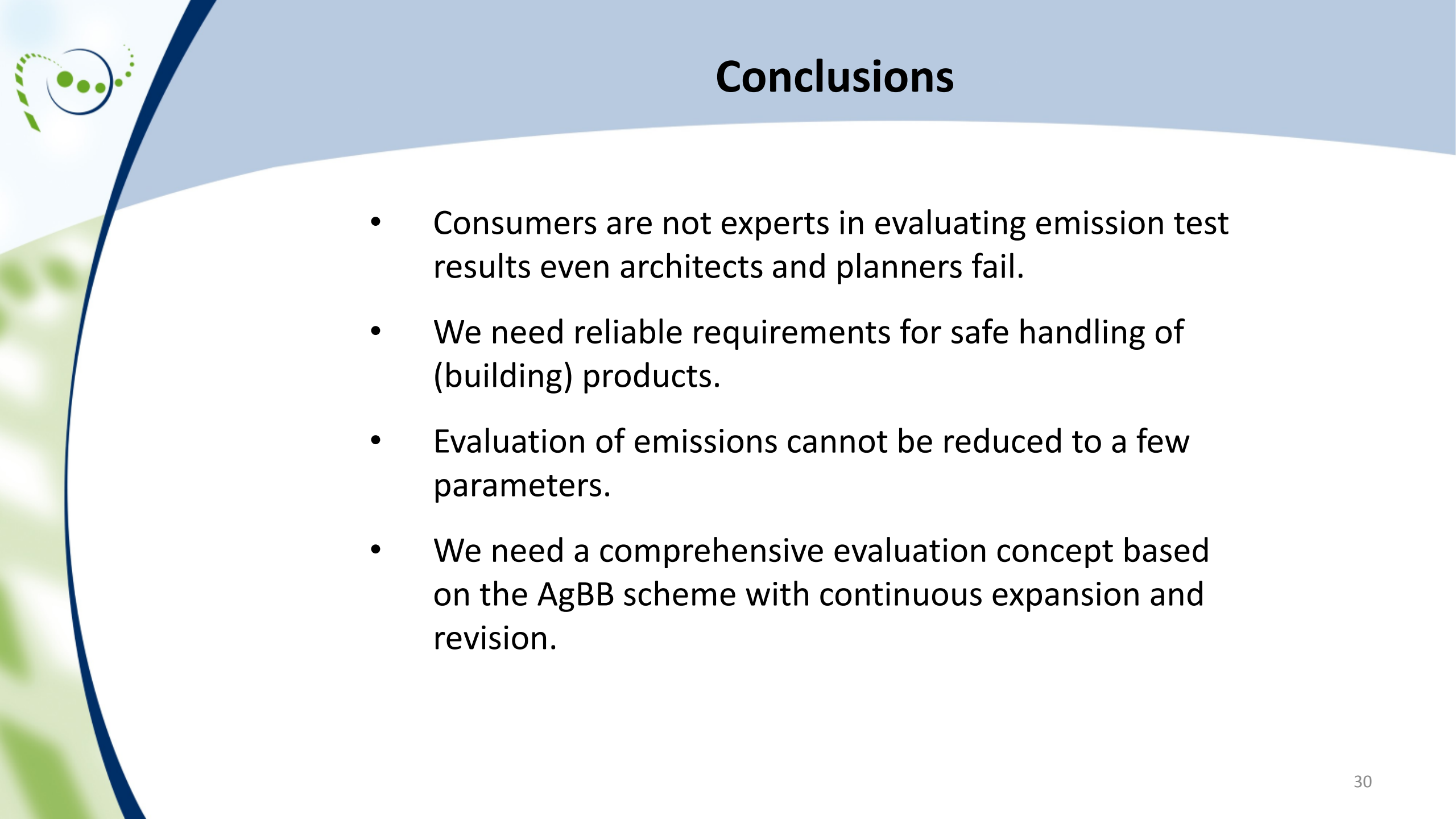


Conclusions

Importance of TVOC

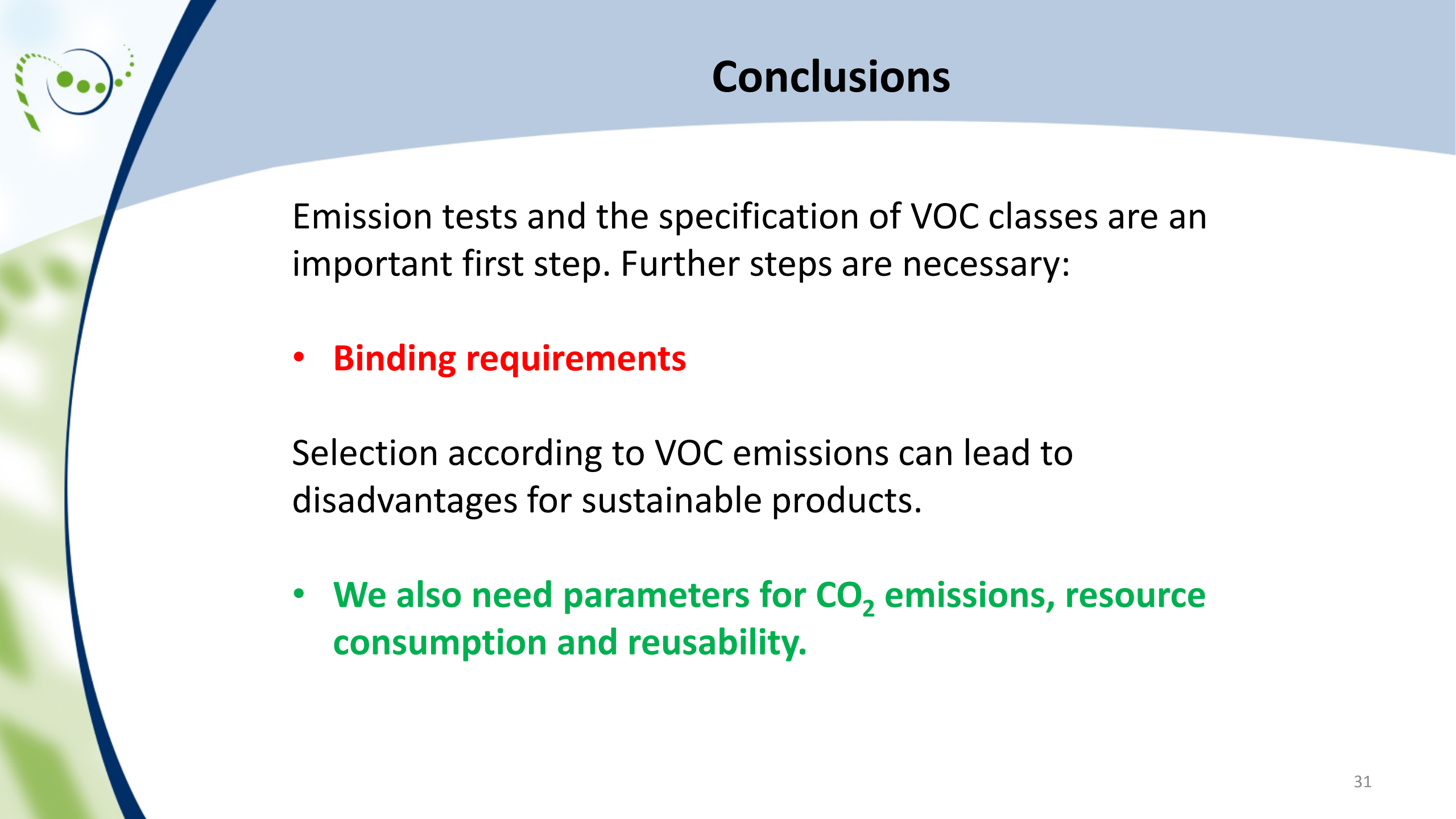
Indoor air / Construction products

- 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 CO₂ emissions, resource consumption and reusability.**



Thank you
for listening