F: Physical responses & physiology
F.2 Health assessment (incl. Thermal comfort)

Assessment of the Perceived Indoor Air Quality: Comparison of Sensory Testing of Indoor Air and Chemical Indoor-air Analysis based on Odour Threshold-based Evaluation

Carmen Kroczek[1], Matthias Schmidt[1], Jörg Mertens[2], Norbert Weis[2] and Jörg Thumulla[1]

[1] anbus analytik GmbH, Fürth, Germany
[2] Bremer Umweltinstitut GmbH, Bremen, Germany

[*]Corresponding email: jt@anbus-analytik.de

Keywords: Odour guideline, Indoor odour assessment, Odour-indoor air guide values, Odour intensity

SUMMARY

The perceived indoor air quality gains nationally and internationally more and more relevance because of increasing complaints of odour problems. Therefore, different concepts for assessing the indoor air quality have been published recently. To compare the validity of the different methods, we present the results of 3 case studies using different approaches. The indoor air quality was evaluated with olfactory tests using human panels and chemical analysis in regard to Odour–Indoor Air Guide Values (vGLW I and II). In this study we show that chemical analyses alone do not contribute to the solution of indoor odour problems. Moreover, our results show no sufficient correlation between odour annoyance of the occupants and the chemical analysed indoor air quality. This is true, despite vGLWs were exceeded in some cases no odour annoyance was observed and vice versa. In summary, the chemical analysis and the assessment of indoor air concerning vGLWs are useful to get a hint of an odour problem and to assess a potential health risk. For the solution of odour problems due to lower chemical concentrations, sensory testing with human panels is needed to assess if and which type of response (e.g. deconstruction, ventilation system) is adequate.

INTRODUCTION

The perceived indoor air quality gains nationally and internationally more and more relevance because of the lack of hygienic sufficient air change due to airtight buildings. Therefore, prolonged indoor stay is increasingly reasonable for occupants' odour and health problems. Sources of odour can be located inside or outside of buildings.

Therefore, different solutions with different approaches for assessing the perceived indoor air quality / IEQ have been published recently:

- The Austrian ministry of the environment together with the German consortium of ecological research institutes (AGÖF) presented 2013 the final version of a guideline for indoor odour measurement and evaluation with regard to their reasonability (indoors odours - olfactory sensory analysis and evaluation; Gerüche in Innenräumen – Sensorische Bestimmung und Bewertung).

- ISO 16000-30:2014-09: Indoor air - Part 30: Sensory testing of indoor air
- The assessment of odours in indoor air with chemical analysis with the help of Odour-Indoor Air Guide Values based on the odour threshold with use of the Level of distinct Odour Awareness (LOA) published by the dutch national institute for public health and the environment (RIVM, Ruijten et al. 2009). Examples of Odour-Indoor Air Guide Values, based on the Odour-Threshold multiplicated with fix factors, are published as a draft of the german ad hoc working group. Its members are delegates from the Indoor Air Hygiene Commission (IRK) and the permanent working group of the Highest State Health Authority. The guide values are based on chemical indoor air analyses and are presented for public discussion till the end of December 2015.

For the evaluation of perceived indoor air, both mehods, sensory testing method and chemical analysis based on odour thresholds, are used. However, often these different approaches lead to different results. Therefore, the study of practical examples will help to improve the methods and to understand their limitations.

METHODOLOGIES

Sensory testing and the evaluation of indoor odours using human panels

Sensory testing was performed on-site or in laboratories; in the latter case, by means of air in sampling containers, which were collected from the site. The aim was to assess the perceived indoor air quality (odour intensity, hedonic scale and acceptance) using human panels.

On-site sensory testing

Essential element for measuring on-site the odour intensity is the on-site sensory calibration of the human panel with n-butanol dilutions (Method description according to ÖNORM S 5701, AGÖF guideline). The panel performed the calibration on-site via calibration standards in tubes at an olfactory neutral location. The butanol calibration standards (1ml in 4ml tubes) were composed as follows:

0: „neutral“ (0 mg n-Butanol /l H_2O),
1: very weak odour (1,0 g/l),
2: weak odour (5,0 g/l),
3: medium-strength odour (25g/l)
4: strong odour (90 g/l, saturated solution)

For the adjustment of the olfactory sense to the odour intensities, the panel performed a quick smelling after opening the tube. For the calibration, the tube was kept in a distance of 1 cm to the nose for 5 sec, which is the essential time point for the adjustment.

Sensory testing in laboratories

The olfactory tests were not conducted on site, the air was collected in sampling containers and transported to a laboratory to be tested by a human panel (method description: ISO/DIS 16000-30). The time span between sampling and testing did not exceed 24 h. The testing was performed in an odourless testing room. The temperature and humidity in the testing room were set, such that the conditions were normal and comfortable (e.g. 23 °C, 50 % relative humidity). The air was presented to the panel members by a comparative scale in a constant flow through a funnel (the set-up of a comparative scale is described in ISO 16000-30). The chosen volume flow rate was 0.8 l/s to avoid any dilution of sample air with the room air before the presentation to the nose. The panel performed the calibration in the laboratory via acetone calibration standards according to ISO 16000-30. To guarantee that no changes occurred in the sampled air during storage, chemical analyses were performed during sampling and directly before the odour testing in the laboratory.

Assessment of odour parameters

- Intensity: intensity of odour perception released by olfactory stimuli. Evaluated in a category scale between 0 (neutral) and 5 (very strong).
- Hedonic: effect of olfactory stimuli described with the characteristics "very comfortable" und "very uncomfortable". Evaluated in a category scale between + 4 (very comfortable) and - 4 (very uncomfortable).
- Acceptance: Scale of satisfaction with indoor odour in consideration of the room usage. Evaluated in a category scale between + 1 (clearly acceptable) and – 1 (clearly not acceptable). PD value was calculated.
- Odour quality: Description of odour with intuitive keywords (not considered in evaluation)

Determination and evaluation of the PD-value

The PD-value was calculated by means of the following formula:

$$PD = \frac{n_d}{n} * 100 \ \% \qquad (1)$$

Where n_d is the number of dissatisfied people and n is the total number of people.

The assessment of an acceptable PD-value was performed according to the EN 15251. This standard proposes four different categories for indoor air quality with regard to the degree of dissatisfaction:

- category I: PD < 15% (highly sensitive persons)
- category II: PD < 20% (new buildings)
- category II: PD < 30% (old buildings)
- category IV: PD > 30% (unacceptable annoyance, permanent exposure should be avoided)

Chemical analysis of indoor odours

The determination of odorous volatile organic compounds in indoor air was performed by active air sampling on Tenax TA sorbent, thermal desorption and GC/MS (Gas chromatography/mass spectrometry). Finally, the results were compared with the Odour-indoor air guide values.

Statistical analysis

The arithmetic mean and the standard deviation of the responses are calculated, as is the 90 % confidence interval of the mean. The accuracy of the evaluation of the hedonic tone is considered sufficient, if the half width of the 90 % confidence interval of the mean does not exceed 1**.**

RESULTS

Complaints of indoor odour problems have strongly increased in the past few years. Therefore, different concepts with different approaches for assessing the perceived indoor air quality have been published recently.
In order to compare the validity of the different methods, we present the results of 3 case studies using different approaches.

Project 1 (Thumulla, 2014)
Occupants of a school building in Bavaria/Germany were complaining about intensive indoor odour and health problems. In several rooms of the first and second floor, the floor covering was renewed in 2013, some weeks before the intensive odour was detected. The questions arised about the source and the nature of the smell and the risk and severity of potential health effects.

Therefore, 10 rooms of the school building were tested on-site by a trained panel of 5 persons. We performed two sensory testings: one was simulating the situation in the morning, when the pupil enter the room without any ventilation. Hence, the windows were closed for 12h hours and the heating was constantly on. The other testing simulated the situation after 10 min. ventilation.

Additionally, the determination of odorous volatile organic compounds in indoor air was performed by active air sampling on Tenax TA sorbent before the odour testing. The results of the chemical analysis were assessed with regard to Odour–Indoor Air Guide Values. In the following table, the overview of all evaluated parameter and the overview of the chemical analysis in the 10 rooms is depicted.

Table 1. Overview of all evaluated indoor air parameter and the results of the chemical analyses in 10 rooms, project 1 (Thumulla, 2014), IAQ= indoor air quality

Room	complaints by occupants?	Intensity Mean [0…5]	Hedonic Tone Mean [-4…+4]	Acceptance Mean [-1…+1]	IAQ - Category with respect to the Acceptance Level (EN 15251)	IAQ with respect to Intensity, Hedonic Tone, Acceptance (VDI 4302)	organic acids [µg/m³]	aldehyds [µg/m³]	benzo-thiazole [µg/m³]	Odour-Indoor Air Guide Values exceeded? (vGLWI)
hall first floor	yes	1,9	-0,5	0,08	---	medium				
hall second floor	no	1,0	1,5	0,60	---	medium				
6 (before ventilation)	yes	2,5	-1,7	-0,42	category IV	low				
6 (after ventilation)	yes	2,3	-0,9	-0,07	---	low				
7 (before ventilation)	yes	2,2	-1,3	-0,13	category IV	low	28	52	8	yes
7 (after ventilation)	yes	2,2	-1,3	-0,26	category IV	low	16	28	6	yes
8 (before ventilation)	yes	1,8	-0,3	-0,08	---	low				
8 (after ventilation)	yes	1,8	-0,1	-0,07	---	low				
9 (before ventilation)	yes	2,1	-0,7	-0,01	---	low				
9 (after ventilation)	yes	1,9	-0,8	0,06	---	medium				
10 (before ventilation)	yes	2,2	-1,3	-0,25	category IV	low				
10 (after ventilation)	yes	2,5	-1,0	-0,24	category IV	low				
24 (before ventilation)	no	1,9	0,0	0,18	---	medium				
24 (after ventilation)	no	1,7	0,2	0,24	---	medium				
25 (before ventilation)	no	1,3	0,6	0,29	---	medium	36	110	6	yes
25 (after ventilation)	no	1,4	0,2	0,46	---	medium	38	38	5	yes
26 (before ventilation)	no	1,6	0,5	0,35	---	medium				
26 (after ventilation)	no	1,0	0,3	0,35	---	medium				

Project 2 (Thumulla, 2014)

After renovation in the second floor of an administrative building near Munich/Germany in 2013, the occupants were complaining about intensive indoor odour and respiratory health problems. The status of employee's illness increased 2014 in such a dramatic way that maintaining daily work was simply not possible.
The question arised about the source of the smell and the risk and severity of potential health effects.

41 rooms of the first and the second floor of the administrative building were tested on-site by a trained panel of 5 persons and an untrained panel of 5 persons (staff member of the administrative building). Additionally, the determination of odorous volatile organic compounds in indoor air was performed in 24 rooms by active air sampling on Tenax TA sorbent before the odour testing.

In the following table, the overview of the evaluated parameter of 24 rooms out of 41 is represented because in these rooms chemical analyses were also performed. The mean value of intensity, hedonic tone and acceptance was calculated from the combined results of the trained and the untrained panel. (There was no significant difference between the results of the trained and the untrained panel.)

Table 2. Overview of all evaluated indoor air parameter and the results of the chemical analyses in 24 rooms, project 2 (Thumulla, 2014), IAQ= indoor air quality

Room	complainments by occupants?	Intensity Mean-value [0…5]	Hedonic Tone Mean-Value [-4…+4]	Acceptance Mean-Value [-1…+1]	IAQ - Category with respect to the Acceptance Level (EN 15251)	IAQ with respect to Intensity, Hedonic Tone, Acceptance (VDI 4302)	organic acids [µg/m³]	aldehyds [µg/m³]	Odour-Indoor Air Guide Values exeeded? (vGLWI)
323	yes	2,2	-0,8	0,04	---	medium	30	37	yes
319	yes	1,9	-0,6	0,14	---	medium	33	37	yes
220	yes	2,5	-0,6	-0,01	---	low	82	73	yes
221	yes	3,4	-2,8	-0,71	category IV	low	72	70	yes
213	yes	2,6	-1,0	-0,24	category IV	low	57	127	yes
205	yes	2,1	-0,1	0,09	---	medium	78	100	yes
209	yes	2,4	0,1	0,09	---	medium	54	113	yes
211	yes	2,5	-0,8	-0,10	category IV	low	69	90	yes
223	yes	2,6	-0,4	0,06	---	low	97	120	yes
120	yes	2,9	-2,2	-0,54	category IV	low	30	84	yes
110	yes	3,2	-2,4	-0,61	category IV	low	36	62	yes
109	no	2,2	0,2	0,15	---	medium	95	72	yes
108	yes	2,0	0,7	0,26	---	medium	107	88	yes
107	yes	2,4	0,3	0,12	---	medium	168	104	yes
106	no	2,3	-0,1	0,09	---	medium	102	97	yes
104	yes	2,8	-1,3	-0,22	category IV	low	70	85	yes
6	yes	2,1	0,5	0,20	---	medium	83	75	yes
4	yes	2,3	-0,4	0,03	---	medium	40	107	yes
10	yes	2,1	0,1	0,19	---	medium	63	126	yes
12	yes	2,8	-0,7	-0,07	---	low	43	69	yes
13	yes	2,6	0,1	0,08	---	low	44	73	yes
17	yes	2,2	0,5	0,25	---	medium	36	76	yes
19	yes	3,1	-2,0	-0,47	category IV	low	43	106	yes
019a	n.b.	3,7	-2,1	-0,63	category IV	low	37	59	yes

Project 3 (Weis, 2014)

The following case study describes indoor odour problems in an 100 year old remediated office building in Niedersachsen/Germany. The odour was detectable in an office room, in which the remediation was already finished.

Four weeks after finishing the remediation, chemical and olfactory tests of the indoor air of two rooms were carried out: first, in the room with the odour problem and second, in an exemplary room in shell condition (remediation was not finished). The olfactory tests were not conducted on-site. The air was collected in sampling containers and transported to a laboratory to be tested by a human panel. Additionally, the determination of odorous volatile organic compounds in indoor air of two rooms was performed by active air sampling on Tenax TA sorbent.

In the following table, the overview of all evaluated indoor air parameter and the results of chemical analyses in two rooms is shown.

Table 3. Overview of all evaluated indoor air parameter and the results of chemical analyses in 2 rooms, project 3 (Weis, 2014), IAQ= indoor air quality

Room	Intensity Mean [0…15pi]	Hedonic Tone Mean [-4…+4]	Acceptance Mean [-1…+1]	IAQ with respect to Intensity, Hedonic Tone, Acceptance (VDI 4302)	organic acids [µg/m³]	toxiticity level for aldehyds exceeded? (RWI)	Aldehydes [µg/m³]	n-Butanol [µg/m³]	Odour-Indoor Air Guide Values exceeded? (vGLWI)
420	7,8	-1,0	-0,10	low	93	yes	139	202	yes
419	8,1	-0,6	-0,10	low	32	no	33	0	yes

DISCUSSION

The comparison of the results of three different case studies clearly showed that the assessment of perceived indoor air based on chemical analysis and Odour-Indoor Air Guide Values is not sufficient to approach indoor air odour problems. Moreover, we could only detect a low correlation between odour annoyance of the occupants and the chemical analysed indoor air quality. This is true, despite vGLWs were exceeded in some cases no odour annoyance was observed and vice versa.

Project 1 (Thumulla 2014)

In this case study e.g. the occupants of the school building complaint about odour and health problems in the rooms of the first floor but not in rooms of the second floor. During the on-site sensory testing the main perceived odour in the rooms of the first floor was described as rubber-like but not in the rooms of the second floor. The acceptance in the first floor was assessed as negative whereas the acceptance of the perceived indoor air in the second floor was positive.

The chemical analysis identified benzothiazole as typical rubber-like odorous substance. The vGLWI of benzothiazole were exceeded in the rooms of the first floor as well as in the rooms of the second floor. However, a clear chemical discrimination of the perceived indoor air characteristics between the first floor and the second floor was not possible. The detection of benzothiazole indicates to the latex flooring in both levels but it is no explanation for the different perceived indoor air quality. Therefore, no sufficient correlation between odour annoyance of the occupants and the chemical analysed indoor air quality regarding to Odour-Indoor Air Guide Values (vGLW) could be verified in this case study.

Project 2 (Thumulla 2014)

In this case study 41 rooms were olfactory tested. In most of the rooms the occupants complained about odour problems. In 24 rooms the indoor air was also chemically analysed.

The results show that the odour annoyance of the occupants did not match in every case with the evaluation of the perceived indoor air of the panel members. Even in rooms with medium indoor air quality the occupants complained about odour problems. In every 24 rooms an exceedance of vGLWI was detectable. Notably this exceedance is attributed to the detected concentrations of aldehydes and organic acids. The highest concentrations of odorous substances was measured in the room where the perceived indoor was positively assessed by the panel members with a high IAQ. Hence, the results of this case study illustrate that the determination of odorous substances do not reflect the assessment of the perceived indoor air quality by the panel members.

Project 3 (Weis 2014)

In this case study two rooms were evaluated. In room 420, where the odour annoyance occurred, concentrations of aldehydes and organic acids about the factor 3-4 higher than in the other room. Additionally, a concentration of n-butanole in exceedance of the vGLW was detected in room 420. Nevertheless, the panel member rated the perceived indoor air quality in both rooms nearly identical. In summary, only low correlation between odour annoyance of the occupants and the chemical analysed indoor air quality regarding to Odour-Indoor Air Guide Values (vGLW) could be verified.

CONCLUSIONS

Three cases studies show that the evaluation of perceived indoor air based on chemical analysis and the assessment with the help of Odour-Indoor Air Guide Values based on the odour threshold is not sufficient to approach indoor air odour problems. In addition, we could show that there is a low correlation between chemical analysis and sensory testing of perceived indoor-air quality.

Hence, we conclude that the usage of fixed factors to define the Odour-Indoor Air Guide Values based on the odour threshold for odorous substances is not adequate to approach odour annoyance. Therefore, we propose that the assessment of a threshold of annoyance (TOA) for odorous substances, sensorically determined by a human panel, possibly eliminates the non-concordance of the two approaches. Preliminary, we consider the sensory testing as essential to assess the IAQ and the acceptance of perceived indoor air quality.

ACKNOWLEDGEMENT

We thank Dr. Helmut Sagunski and the AGÖF members for helpful discussions.

REFERENCES

AGÖF 2013: AGÖF-LEITFADEN „Gerüche in Innenräumen – Sensorische Bestimmung und Bewertung“. In: AGÖF Conference 2013, Nuremberg, Germany, 24-25 October 2013, pp. 279 f.

ISO/DIS 16000-30 (2012) Indoor air - Part 30: Sensory testing of indoor air

EN 15251 (2007) Eingangsparameter für das Raumklima zur Auslegung und Bewertung der Energieeffizienz von Gebäuden - Raumluftqualität, Temperatur, Licht und Akustik

OENORM S 5701:2008-03-01: Sensorische Bestimmung der Intensität und Art von Gerüchen in der Innenraumluft - Anforderungen für Vor-Ort-Prüfungen