Some Methodological Aspects of Sensory Testing of Indoor Air Quality

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SUMMARY

The sensory panel assessed the quality of air polluted by building materials commonly used indoors. The materials were placed in small-scale glass chambers and were examined at different area-specific ventilation rates. Different scales and assessment procedures were used. The results extend information on how the sensory evaluations of indoor air quality made by human subjects should be carried with respect to different procedural aspects. The relationships were created between acceptability of air quality, odour intensity and the percentage of dissatisfied with the air quality. These relationships can be used when comfort-based ventilation requirements are set in indoor environments.

INTRODUCTION

Sensory measurements of air quality using humans to assess the quality of air have been routinely used in air quality investigations for more than 25 years. They are used both in laboratory experiments [1] as well as during field evaluations in existing buildings [2]. Sensory assessments have been used to characterize the emissions from building materials and have become a part of some labelling schemes [3]. The requirements regarding perceived air quality (expressed as acceptability of air quality or the percentage of dissatisfied) have become a part of ventilation standards, some of which indicate also how sensory testing should be made [4,5].

Many efforts have been used in the past to study several aspects of sensory measurements. The focus was on the modelling and the method. It has been investigated how sensory measurements made in laboratory settings (so called small-scale measurements) can be used to predict sensory measurements made in field settings (so called full-scale measurements) [1,6,7]. It was also investigated how many people should be used in a sensory panel to obtain reliable measurements [8]. As a result, both small-size trained panels, performing sensory assessments in relation to well-defined reference exposure [9] as well as large-size untrained panels [10] have been used. The model comparing their assessments was developed [11]. It was also discussed which scales should be used during sensory measurements, and as a results both an odour intensity scale [12] and the continuous acceptability scale [10] have been routinely used during measurements.

It is worth discussing not only how the sensory measurements should be modelled and whether trained or untrained panels should be used, but also some other practical aspects of the procedure of sensory measurements. This is because many factors can influence the sensory measurements. Some of them have been investigated in the past. They include, among others, temperature and relative humidity of inhaled air [13], as well as adaptation [10,14,15,16]. It has also been shown recently that the air velocity in the facial region may influence the perception of air quality [17]. Other factors also require attention. For example, during sensory assessments in small-scale (when the assessments are made on the air exhausted from small chambers) the air quality is assessed usually after one inhalation, whereas during sensory assessments in full-scale (in real buildings) several inhalations of air may be taken before the assessments are completed. This could be one factor causing small-scale assessments to differ from full-scale assessments. Furthermore, the assessments in small-scale are blind (people performing the assessments cannot see what is inside the small chambers), opposite to full-scale assessments where it is often difficult to blind people performing the measurements. The impact of information on sensory assessments was investigated in the past [18] but should be further investigated. It has also become customary that a 2-3 min break is made between subsequent sensory assessments to allow sufficient time for refreshment and recovery of sensory system, and thus to avoid gradual reduction of sensitivity. It was not previously examined whether such a long refreshment break between assessments is needed. The impact of possible sensory fatigue due to numerous assessments over several days has neither been systematically investigated. The above information would be useful when developing guidelines on how sensory measurements should be performed; no such guidelines exist at present.

The ratings of acceptability of air quality are used to predict the percentage dissatisfied with air quality [10]. Considering that the ratings of acceptability are correlated with the assessments of odour intensity [19], it would be useful to establish the relationship between odour intensity and the percentage of dissatisfied. Such relationship is especially worthwhile considering that in the past ventilation requirements in buildings were based on the perception of odour emitted by humans, and the moderate odour intensity was arbitrarily used to set ventilation requirements [12].

The objective of the present work was to examine different aspects of sensory evaluations of air quality made by human subjects and to establish the relationship between odour intensity and the percentage of dissatisfied with air quality.

METHODS

A sensory panel assessed the quality of air polluted by different building materials commonly used indoors. The assessments were performed in small-scale glass chambers, each material being examined at three different area specific ventilation rates obtained by changing the material loading and keeping the airflow through glass chambers unchanged. Subjects assessed air quality using different scales and following different assessment procedures.

The assessments took place in two stainless steel twin chambers ventilated with an outdoor air change rate of 57 h^{-1} [20]. Twenty small-scale ventilated 50 L glass chambers of the CLIMPAQ type [21] were placed in the twin chambers, ten in each. The airflow through the CLIMPAQs was kept constant at 0.9 L/s. Six different building materials were placed in the chambers, each at three different loadings to obtain different exposure levels characterized by the area-specific ventilation rate, a ratio of ventilation rate through small chamber and material loading in m^2 (Table 1); both low- and high-polluting materials were used. The remaining two small chambers were kept empty. The material loading was determined so that the area specific ventilation rates was the same as in the full-scale test room (6x3x3.2 m) ventilated at 1, 2.6 and 6.5 h^{-1}, similarly to what has been done in other experiments [22]. Materials were randomly placed in different CLIMPAQs. The CLIMPAQs were covered with aluminium screens so it was not possible to see their content. The materials used in the experiments were purchased about 3 years prior to the experiment and occasionally used in connection with other experiments. In between experiments the materials were wrapped in paper lined with aluminium foil. Prior to the sensory assessments the materials were conditioned in CLIMPAQs for about a week. The temperature in the chambers was kept constant at 22.8±1°C; the relative humidity was not controlled and averaged 36±8%.

Table 1. Area of building materials in the small-scale chambers

Material type	Description	Area of material (m^2)		
Ceiling	10 mm plain gypsum board covered with plastic coated material	0.155	0.390	1.013
Carpet	6.4 mm tufted loop polyamide carpet with supporting layer of polypropylene web and polypropylene backing	0.155	0.390	1.013
Linoleum 2	2.5 mm linseed-oil-based flooring, 52% wood meal	0.155	0.390	1.013
PVC	2.0 mm homogenous single layered vinyl flooring, reinforced with polyurethane	0.155	0.390	1.013
Paint 1	Gypsum board painted with one coat (0.14 l/m^2) of water-based acrylic wall paint	0.368	0.866	2.187
Paint 2	Gypsum board painted with one coat (0.14 l/m^2) of water-based wall paint with linseed oil	0.368	0.866	2.187

The sensory panel consisted of 40 Caucasian subjects recruited from 59 applicants. The subjects were students, aged on average 23±2.1 years; 21 were females. The intension was to select non-smokers, subjects having no asthma, allergy or other hypersensitivity, with no sensory handicaps and generally in a good health conditions (taking no regular medication or not suffering from upper airway or respiratory infections) as reported by applicants during recruitment. However it was difficult to fulfil these criteria and 2 subjects reported to have seasonal allergy and 2 were smokers (smoking 6-8 cigarettes per day). To better characterize the sensory panel the selected subjects filled the questionnaire with Chemical Sensitivity Scale (CSS) which examines experience with and exposure to odours and sensory irritants [23]. Their average score was 64.6±10.2 and it was similar to the sensory panel selected in another study [19], as well as for cross-section of Swedish population [23,24]. The subjects assessed air quality by using the continuous acceptability scale [10], dichotomous yes-no acceptability scale [25], and category scale for odour intensity [12], Figure 1. The assessments were made on the air exhausted from CLIMPAQs through a diffuser. Subjects received written and oral instructions concerning the sensory assessments.

Sensory measurements were made on 12 days in three consecutive weeks, each week on 4 days from Monday to Thursday. Each day subjects made sensory assessments of air exhausted from all 20 CLIMPAQs according to different protocols, exposures being randomly assigned to subjects in a design balanced for order of presentation. A break of about 3 minutes was made between assessments, the subjects could not see what is inside the small-glass chambers and the assessments were made by taking one inhalation of polluted air exhausted from the chamber unless indicated otherwise below. The break was taken in a well-ventilated hall adjacent to the chambers where the glass chambers were placed.

On the first two days of each experimental week subjects assessed the air quality using either continuous acceptability scale or the category scale for odour intensity; each day only one scale was used for assessments randomly assigned to the subjects to make sure that the evaluations on both scales are independent. These assessments were used to examine whether the sensory evaluations change during the course of 3 weeks experiments and to study correlation between assessments of acceptability of air quality and odour intensity.

On the third day of the first week subjects used a dichotomous yes-no acceptability scale to make assessments. These evaluations were used to create the relationship between the % dissatisfied with air quality (subjects voting no on dichotomous scale) and either the acceptability of air quality assessed using continuous scale or odour intensity.

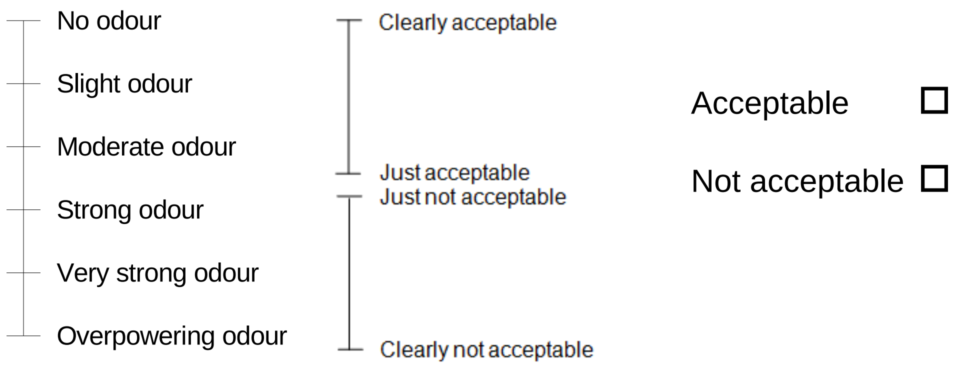

Figure 1. Three different scales used independently by the sensory panel during sensory assessment. Left – category odour intensity scale; the ratings on the scale were coded as follows: No odour=0; Slight odour=1; Moderate odour=2; Strong odour=3; Very strong odour=4; Overpowering odour=5. Middle – continuous acceptability scale; the ratings on the scale were coded as follows: Clearly acceptable=1; Just acceptable/Just not acceptable=0; Clearly not acceptable=-1. Right – dichotomous acceptability scale; the ratings on the scale were coded as follows: Acceptable=1; Not acceptable=0.

On the last day of the first week subjects assessed the air quality using both continuous acceptability scale and the category scale of odour intensity, one scale at a time, taking 3-5 sniffs of unpolluted air in the stainless steel chamber in between assessments while on other days the break between assessments was about 3 minutes. These assessments were used to examine the impact of the length of break between sensory assessments on sensory ratings.

On the last two days of second week subjects assessed the air quality using either the continuous acceptability scale or the category scale for odour intensity but after taking 3 sniffs of polluted air exhausted from the small chamber; each day only one scale was used for assessments randomly assigned to the subjects. These assessments were used to examine the impact of adaptation on sensory ratings.

On the last two days of final week of experiments subjects assessed the air quality using either continuous acceptability scale or the category scale for odour intensity while the chambers were uncovered and the subjects could see what was inside; each day only one scale was used for assessments randomly assigned to the subjects. These ratings were used to examine the impact of information on sensory assessments.

For analyses, the mean ratings±95% confidence intervals were calculated in case of continuous scales. In case of dichotomous acceptability scale the % dissatisfied with air quality was estimated by ratio between not acceptable votes and all votes. The individual ratings were averaged separately for each exposure and for each area-specific ventilation rate (loading) in the chamber.

RESULTS

There were no changes in the sensory ratings made on the air exhausted from the empty chambers during the course of experiments. The average ratings of acceptability of air quality measured using continuous scale and average ratings of odour intensity were plotted against the logarithm of the area-specific ventilation rate separately for each material. The results showed the linear dependence, similarly to previous experiments [1,7,19,22].

The results of sensory assessments made on the first two days of each experimental week showed that week-by-week differences in the ratings of acceptability and odour intensity were fairly small suggesting that under the assumption that the exposures in the chambers were constant during the entire experimental period the ratings of the sensory panel were repeatable and consistent.

Sensory ratings of air quality made with a 3-minute break between assessments and 3-5 sniffs of unpolluted air between assessments were for some materials different and for some materials similar. In case of differences the changes were inconsistent. For some materials a shorter break between evaluations caused the acceptability to be assessed worse and odour intensity to increase, and for some the reverse was observed.

There were no consistent differences between sensory ratings made after 1 inhalation of air exhausted from the small chamber and after 3 inhalations of air exhausted from the chamber.

The results showed that there were no significant differences between sensory ratings made when the chambers were covered by aluminium screens (i.e., when the subjects could not see what was inside), and the ratings taken when the screens were removed (i.e., when the subjects could see what was inside).

Average ratings of acceptability of air quality using continuous scale were plotted against average ratings of odour intensity (Figure 2). The results showed strong linear dependence between the two sensory ratings even though the evaluations were made on separate days.

The percentage dissatisfied with air quality estimated using the assessments made with the dichotomous acceptability were plotted against the ratings of acceptability of air quality (Figure 3) and the ratings of odour intensity (Figure 4). Logit function was used to create the relationships [26].

DISCUSSION

Different methodological aspects of sensory testing of indoor air quality were investigated. The study showed that there were no differences between sensory ratings taken after 1 inhalation or 3 inhalations of air exhausted from the small-scale chambers; that there were no differences between sensory ratings whether the materials in the chamber were visible or not visible to subjects; that there were no differences in sensory assessments taken with 3-minute break between assessments and with 3 inhalations of unpolluted air between assessments; and that there were no changes in the sensory assessments of the same exposure during the 3-week of experiments.

The results regarding influence of information on the sensory assessments are somewhat different from the results reported previously [18]. In the previous study the odour intensity and acceptability of air polluted by building materials was also evaluated in small-scale measurements. Subjects could not see the materials but were informed, by placing a label on each test chamber, that test chambers contained either synthetic or organic materials. Providing the information caused that, the odour intensity was assessed to be lower and acceptability of the air quality increased in comparison to the sensory evaluation without information. They were thus informed in written form about the exposures while in the present study they could see the materials. This difference could result in the discrepancy between the results. No difference in the assessments of air quality in covered and uncovered chambers in the present study could also occur because the materials used in these experiments are typically occurring indoors and their the odour could have been familiar to subjects.

Previous studies [14,15] showed strong adaptation to pollutants emitted from building materials occurring already after 2 inhalations of polluted air. In the present study no such effect was observed. No adaptation was seen in another study when the sensory assessments were made after 1, 3, 6 and 10 inhalations of polluted air, and the lack of adaptation was attributed to the fact that the first impression could be the most important determinant of the sensory evaluation [16]. Similar mechanism could be observed in the present study. Another reason could be the fact that pollution from building materials may comprise many irritants for which no adaptation is expected. This was the reasoning behind weak adaptation to emissions from building materials in yet another study which showed strong adaptation to human bioeffluents comprising many odours [10].

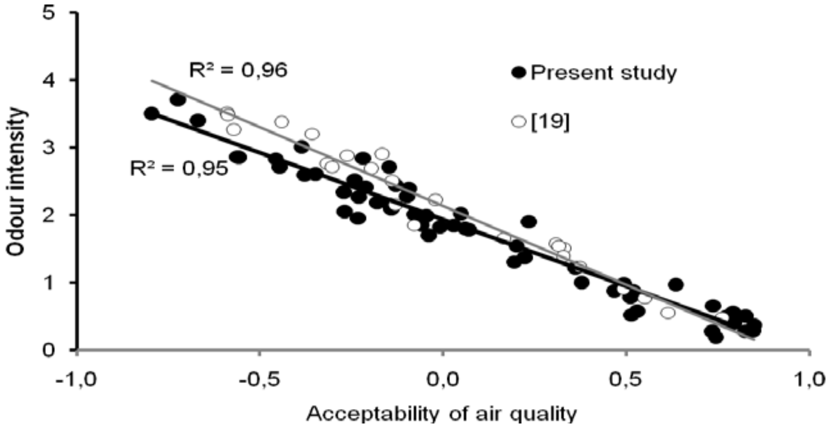

Figure 2. Odour intensity as a function of acceptability of air quality evalauted on the continuous acceptability scale

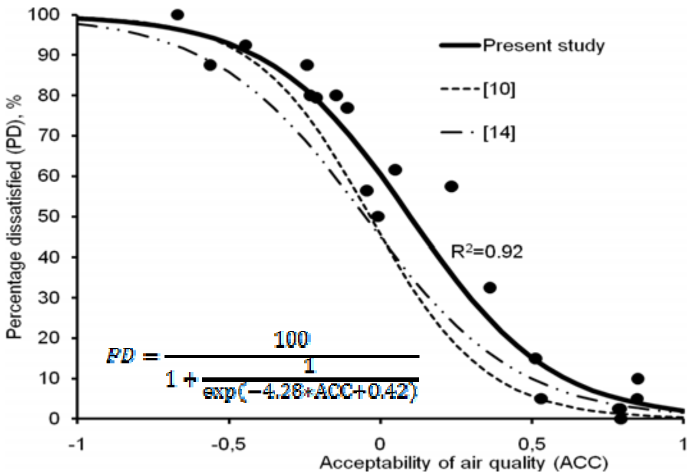

Figure 3.Percentage of dissatisfied with air quality (estimated using assessments of acceptability on dichotomous scales) as a function of acceptability of air quality evaluated on the continuous acceptability scale; previously developed relationships are shown as well

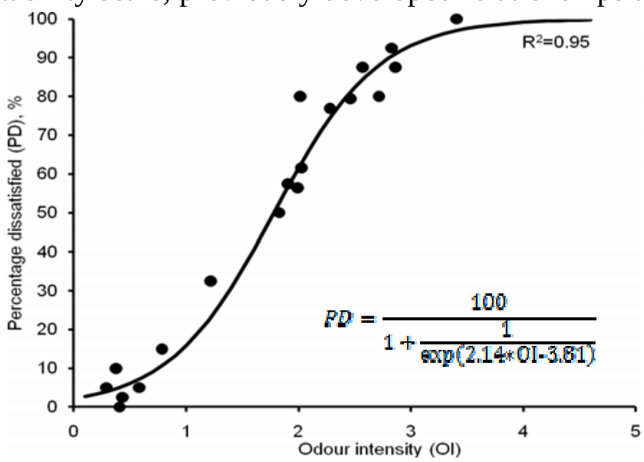

Figure 4. Percentage of dissatisfied with air quality (estimated using assessments of acceptability on dichotomous scales) as a function of odour intensity

The strong correlation between the assessments of acceptability of air quality and the assessments of odour intensity is similar to what has been observed previously [19]. Whether assessments of odour intensity can be used to predict acceptability should be investigated further for pollution sources and exposures other than those examined in the present experiments. This is especially important for odours considered to be pleasant.

The relationship between the percentage dissatisfied with air quality and acceptability of air quality is different from the relationships established previously [10,14]. In the previous studies, the subjects assessed the air quality using continuous acceptability scale and to obtain the percentage dissatisfied number of votes between clearly not acceptable and just not acceptable was counted. In the present study the subjects made independent assessments on two separate days using dichotomous acceptability scale and continuous acceptability scale. This methodological difference could contribute to the observed discrepancies, the approach used in the present study being more suited. Furthermore, the differences observed could be caused by the way the assessments were made. In one of the previous studies [14] and the present study the subjects assessed the air exhausted from the small-scale chambers (i.e., the assessments were based on the facial exposures), while in another study previously reported [10] the assessments were made upon entering full-scale chambers/test rooms (i.e., the assessments were based on the whole-body exposures). Both exposures can lead to differences in sensory ratings [27].

In the early studies in 1930's it was assumed that the ventilation requirements to control body odour should be at a level so that odour intensity is assessed as no more than 'moderate' [11]. The relationship between odour intensity and the percentage of dissatisfied indicates that the moderate odour intensity causes about 50% to be dissatisfied with air quality. Consequently, the present results may suggest that these past recommendations could cause that the ventilation rates were underestimated considering that the present ventilation rates are set to keep between 15 and 30% dissatisfied with the air quality. It should however be admitted that in these past studies human bioeffluents were the main source of pollution [11] while in the present study the main sources were common building materials.

CONCLUSIONS

Based on the present experiments no changes to the currently used methodology for sensory testing of indoor air quality are recommended. The present results show that estimating the percentage of dissatisfied with air quality using the assessments of acceptability with the relationships developed in the past may cause that the comfort-based required ventilation rates are underestimated.

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