Documentation of mould odour remediation in flats

H.N. Knudsen*

Energy and Indoor Climate Division, Danish Building and Urban Research, Denmark

ABSTRACT
To ensure that mould remediation in flats is successful, it is important that mould odour is eliminated before occupants return to their flats. Otherwise, occupants will associate the mould odour with continued mould contamination of the flat. The objective of the study was to document the efficacy of mould remediation in flats with respect to mould odour. Eight flats were studied, which had been evacuated due to problems with mould growth. A practical method was used where a sensory panel comprising 20 assessors performed sensory assessments in the evacuated flats before and after renovation and again when the flats were re-occupied. The panel assessed the immediate acceptability and the intensity of the selected odour descriptors moulds, tobacco smoke, building materials and food. The proposed method was shown to be useful for documenting that renovation of the contaminated mouldy flats significantly improved the perceived air quality and eliminated the mould odour.

INDEX TERMS
Air quality; Mould; Odour; Perceived air quality; Water damage

INTRODUCTION
Excessive moisture in the building envelope can lead to mould growth. Moulds indoors can cause a musty odour and health problems among occupants. The work presented in this paper was initiated by an enquiry related to renovation of apartment buildings with such problems. The occupants' health was given high priority, hence, some flats were evacuated due to extensive problems with mould growth. It was discussed among the involved parties what kind of remediation was needed to satisfy human requirements to a healthy and comfortable flat, and at what cost. It was decided to test the efficacy of various remediation measures by several independent evaluation methods to document whether the suggested remediations were useful based on measurable criteria for the prevalence of moulds after renovation. One success criterion was that the mould odour was eliminated after the remidiation. Otherwise, it was expected that occupants would associate the mould odour with the continued contamination of the flat, even though no living moulds were present. This should be documented by an impartial third party.

The buildings investigated were two-storey terrace houses, with around 400 flats, made of concrete with light facades and flat roofs, built in 1974 and situated north of Copenhagen. The construction is of a relatively poor quality, which has led to the following problems: low ventilation rate of 0.2 h^{-1} in average, leaky flat roofs, poorly functioning drains outdoors, leaky drain pipe in bathrooms and condensation of water on the concrete foundation that sucks up into the wall from a poorly ventilated crawlspace. The flats have been investigated and considerable mould growth was observed in approximately 50% of the flats.

The remediations to stop the presence of moisture in the construction were: rectification of defects like leaky and poorly functioning drains, leaky roof by establishing double-pitched roof, renovation of bathrooms, establishment of a central mechanical exhaust ventilation

* E-mail: hnk@dbur.dk

system connected to the bathroom and cooker hood, ventilation openings in window frames, establishment of mechanical exhaust ventilation in crawlspace. In addition mould-infested surfaces were cleaned or removed.

The objective of the study was to document the efficacy of mould remediation in flats with respect to mould odour by using a sensory panel of assessors. The application of the method used is discussed as a practical method to assess odour problems in buildings.

METHOD

A sensory panel of 20 untrained assessors (9 ± 1 women and 11 ± 1 men) performed sensory assessments three times: (1) April 2001 before the renovation, flats unoccupied for 3–4 months, (2) November 2001 after the renovation, unoccupied and (3) November 2002 when the flats had been occupied for 10–11 months. The assessors were recruited among a group of 50 assessors who have previously assisted in sensory measurements in laboratory experiments.

On the day of the measurements the assessors were given a short introduction. They were asked to assess the immediate perceived air quality on entering a flat by using the acceptability scale shown in Figure 1 (Gunnarsen and Fanger, 1992). The panel was also asked to assess the intensity of each of the four odour descriptors moulds, tobacco smoke, building materials and food, see Figure 1. Besides, the assessors had the possibility of including a descriptor ('other') of their own choice. This descriptor was included as a 'safety valve' to enable assessors to express other odour descriptors than the four selected.

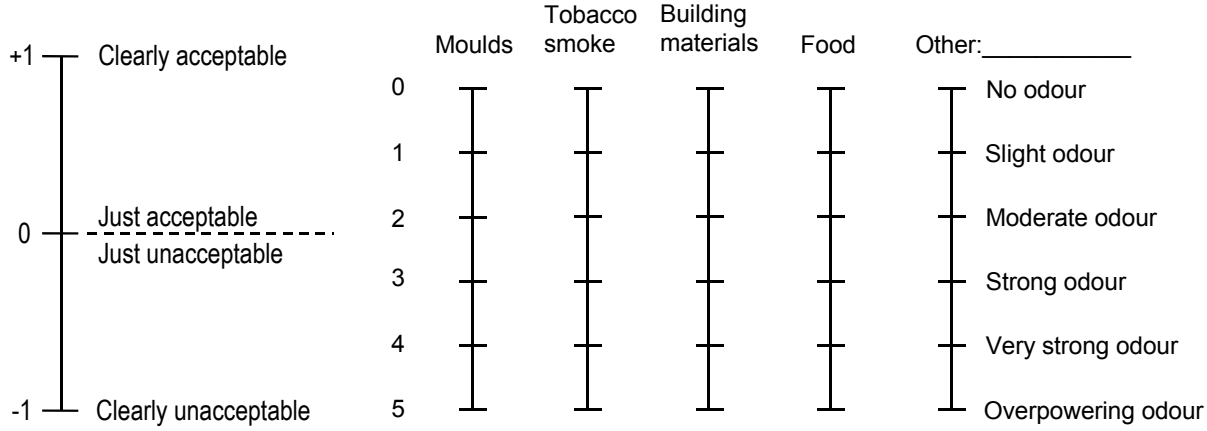

Figure 1 Acceptability scale and scales for odour intensity of selected descriptors. The accompanying questions were: 'Imagine that you daily stay in a room with this air—How acceptable is the air quality?' and 'How strong do you find the odour from the following?'. The scales were not numbered during the measurements, but numbers were used in the following data analysis.

When assessors describe odours by using descriptors, it is important that they share a common language. This is normally achieved by training (e.g. Meilgaard *et al.*, 1991). To ensure that all the assessors knew the meaning of the descriptor 'moulds' and that they were able to recognize mould odour, they were exposed to a sample. The sample consisted of old magazines that had adsorbed mould odour during years of storage in a mouldy basement. The magazines themselves were not infested with the moulds. The magazines were placed in a ventilated test chamber of the CLIMPAQ type (Nordtest, 1998) placed in the air quality laboratory at Danish Building and Urban Research (Ekberg and Nielsen, 1995). The assessors were exposed to the mould odour exhausted from the test chamber through a diffuser, after being told that they were going to be exposed to an example of a mould odour. The air quality laboratory and test chamber were supplied with conditioned and charcoal-filtered outdoor air at 23°C, 45% relative humidity. Since the assessors were experienced in assessing emissions from building

materials from series of laboratory experiments and because they were assumed to know the ordinary odours of tobacco smoke and food they were not trained to recognise these odour descriptors.

The assessors were instructed in how to do assessments in the flats. The flats were entered directly from outdoors. They were instructed to take a breath of air just before entering the flat, hold their breath and follow a previously assigned leader into the relevant room, do their assessment when breathing the first time and immediately fill in their questionnaire. Before leaving for the flat, the procedure was practised in a hall at Danish Building and Urban Research with direct access from outdoors like the flats. An assessment of this location, where no mould growth has ever been observed, was used as a reference measurement with which measurements in flats were compared.

The 20 assessors went to the apartment buildings by bus. On arrival, they were divided into two teams of 10. Each group followed the assigned leader to the flats which were visited according to a plan that ensured approximately 10-min intervals between each assessment and about 40 min between visits of the two groups to the same flat.

It has been shown that increasing temperature and humidity of the air significantly decrease the acceptability of air (Fang *et al.*, 1998). To minimize the sensory impact of temperature and humidity the flats were all heated to around 20°C. The temperature and relative humidity were measured indoors and outdoors on the days of measurements.

RESULTS

Measurements of temperature in the flats confirmed that they were heated during the three visits. The mean temperature/relative humidity for the three visits was 19.1°C /51%, 19.3°C /54% and 20.7°C /54%, respectively. The maximum change in indoor air temperature/relative humidity for a flat during the three visits was 3.7°C/12%. The variations were considered modest and any impact on perceived air quality would tend to deteriorate the perceived air quality, i.e. slightly reduce the positive effect of renovation. The outdoor temperature varied from 7.7 to 10.0°C.

Figure 2 shows the mean panel assessments of acceptability in the different flats and the corresponding percentage of dissatisfied calculated by converting mean acceptability votes to percentage of dissatisfied (Gunnarsen and Fanger, 1992). The flats are assigned numbers so that the higher the number the better the perceived air quality on the first visit. The perceived air quality generally improved after the remediations, especially in the flats with the poorest air quality initially.

Figure 3 shows the mean odour intensity of the descriptors moulds, tobacco smoke, building materials and food for the eight flats and the reference location. The intensity of the different

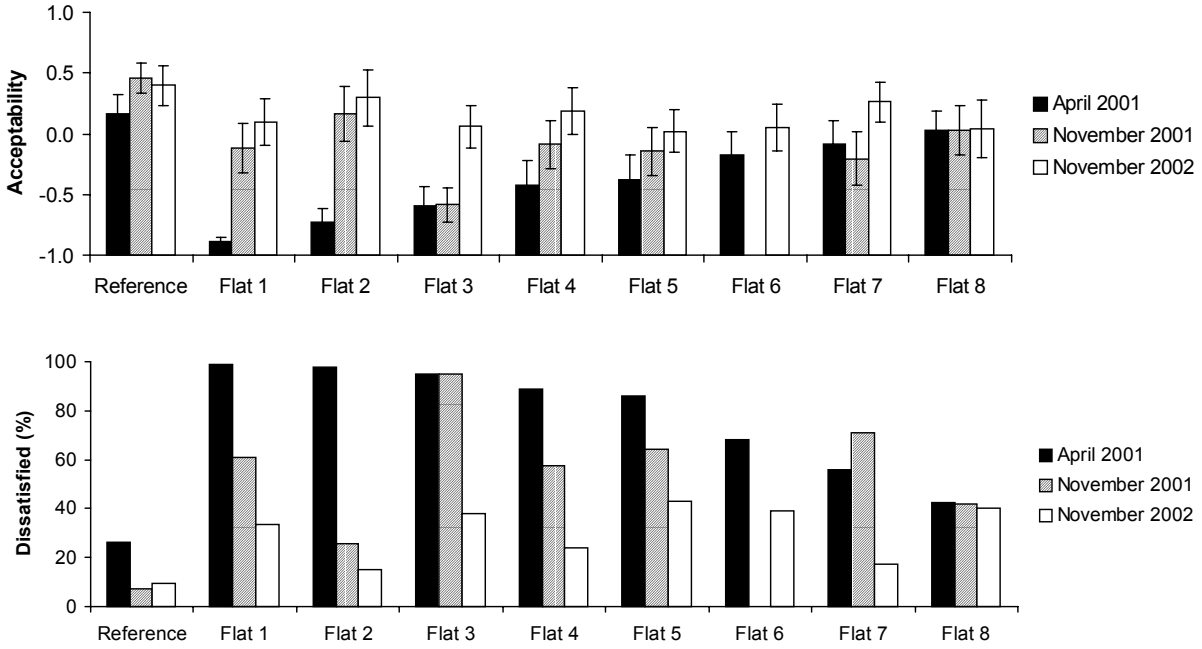

Figure 2 Perceived air quality expressed as the mean acceptability vote (with 95% confidence intervals for the mean vote) and percentage dissatisfied for the eight flats and the reference location.

odour descriptors varies in different ways for the three measurements, i.e. the relative importance of the different odours changes over time. The intensity of mould odour decreases significantly in all flats, except in the flat with least mould odour, to a low level between 'no odour' and 'slight odour' close to the level of the reference. The intensity of tobacco smoke was generally low, except initially for flat 1, 3 and 5. For the second and third measurements, the intensity of tobacco smoke was at a low level between 'no odour' and 'slight odour' close to the level of the reference. The intensity of building materials is generally low for the first and third measurements. For the second measuring period, however, the intensity was higher, which reflects the renovation of the flats with new materials like paints, cleaning agents and disinfectant. The odour of building materials was back to the initial low level, when the flats had been occupied for 10–11 months. Finally, the intensity of food odour was low for the first and second measurements, when the flats were unoccupied and higher for flats 3–8 when the flats were occupied.

DISCUSSION

The proposed method was used to document the efficacy of mould remediation with respect to mould odour in eight flats. It demonstrated that the remediation, even in the most odorous mouldy flat significantly improve the perceived air quality and reduced the intensity of mould odour to an acceptably low level. Besides, the method was found to be useful for studying the relative importance of contributions from well-defined odour sources and for measuring changes in specific odours over time. The method can be used for solving odour problems by indicating what odour source it is most important to eliminate.

It is necessary for the method to work that the assessors know and agree on the odour descriptors. Before the sensory panel visits a building, it is recommended that the person

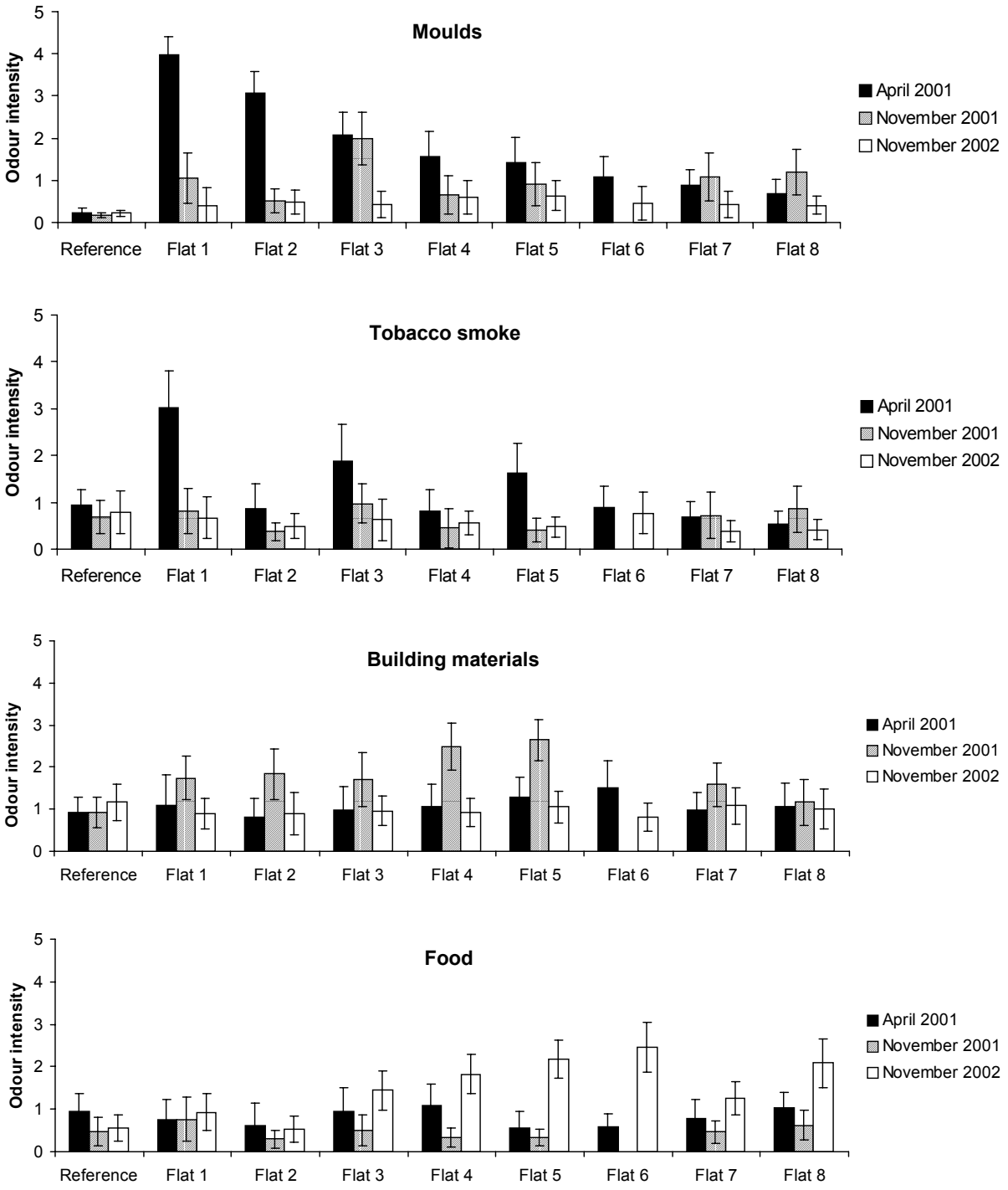

Figure 3 Mean odour intensity of the descriptors moulds, tobacco smoke, building materials and food for the eight flats and the reference location. The 95% confidence intervals for the mean values are shown.

responsible for the sensory measurements visits the locations of measurements and makes a professional judgement on which descriptors are relevant for that particular building. Training may be necessary if the assessors do not already know the relevant and suspected odour sources.

Surveys of the indoor air quality have included the use of sensory panels for assessing acceptability and intensity, without specific descriptors. These measures give useful

information on the perceived air quality but do not give information on what kind of odour sources could possibly cause problems. This survey showed that it is possible for assessors to distinguish between different odour descriptors.

A musty odour is a good indicator that moulds grow somewhere in a building and that action needs to be taken. However, if it does not smell from moulds that is not a guarantee that there are no mould growth in the construction, since some mould species do not smell and moulds may be found somewhere in the construction where the indoor air is not affected by their presence.

In relation to mould remediation, it is important to know how long a time is needed before the mould odour is eliminated. The mould odour may be present even after removing all infested material since other surfaces, apart from the infested ones, will smell from moulds due to desorption of previously adsorbed odorous compounds from the removed moulds. The present study does not answer precisely how long time the mould odour persists in the flats because the time of the different remediations is not well defined. It is expected that the mould odour will last for some month. For example, the magazines used for training the sensory panel still smelled slightly from moulds after 6 months in the ventilated test chamber.

The suggested method, using a sensory panel, is relatively expensive due to the payment of assessors and time consuming due to training, transportation to the building and individual flats. However, the measurements are very useful documentation when an impartial-third-party measurement is needed. It is suggested to develop methods that allow air sampling in the field followed by sensory assessments in a laboratory. However, before investing in such developments, the market for such a service should be investigated to ensure returns on the investment.

CONCLUSIONS

The suggested practical method was found to be useful as an impartial-third-party measurement for documenting the efficacy of mould remediation measures with respect to mould odour in buildings.

ACKNOWLEDGEMENTS

I thank my two former colleagues Ole Valbjørn and Peter A. Nielsen at Danish Building and Urban Research and Lars-Georg Hersoug at SBMI for their inspiring comments on the method used and many constructive suggestions to this manuscript.

REFERENCES

Ekberg, L.E. and Nielsen, J.B. (1995). A laboratory for investigation of the air quality in simulated indoor environments. *16th AIVC Conference*, Palm Springs, 19 September 1995.

Fang, L., Clausen, G. and Fanger, P.O. (1998). Impact of temperature and humidity on perception of indoor air quality during immediate and longer whole-body exposures. *Indoor Air* **8**(4), 276–284.

Gunnarsen, L. and Fanger, P.O. (1992). Adaptation to indoor air pollution. *Environment International* **18**, 43–54.

Meilgaard, M., Civille, G.V. and Carr, B.T. (1991). *Sensory Evaluation Techniques*. Boca Raton, FL: CRC Press, Inc.

Nordtest Method (1998). NT Build 482, Building materials: emissions testing using the CLIMPAQ, Nordtest, P.O.Box 116, SF-02151 Espoo, Finland.