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Impact of carpets on perceived indoor air quality

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Abstract. Indoor air quality (IAQ) plays an important role in human health and well-being as people spend most of their time indoors. Among building materials, carpets covering high surface areas and having dense fibres have the potential to impact perceived IAQ. To explore the impact of carpets on perceived IAQ, it was studied whether low-emitting wool carpets can 'clean' the air. To assess the sorption effect of emissions of hardboard (as a permanent source) on carpet, untrained subjects were asked to assess a combination of low-odour emitting carpet and hardboard in one sample container and only hardboard in another sample container of test chamber. The results showed a slight (although not statistically relevant) difference in favour of the combination, indicating a slight adsorption effect.

1 Introduction

People in the Western world spend 80–90% of their time indoors, where indoor air quality (IAQ) has an impact on residents' health and well-being [1]. The concentration of most pollutants indoors is higher than outdoors due to the minimalization of ventilation (including infiltration) as a result of energy-saving measures [2]. The main source of pollutants indoors are people, their activities, and emissions from building materials and furnishings, especially emissions of volatile organic compounds (VOCs, organic compounds with boiling points between 50 and 260°C), very VOCs (VVOCs), and semi-VOCs (relatively low volatile VOCs). Some of these compounds are odorous and prolonged exposure to them may result in several health problems such as nose, throat, and eye irritation, headaches, nausea, loss of coordination, damage to the kidney, liver, and central nervous system, etc. [3].

In previous studies, it was found that building materials with high surface areas like floors, walls, and ceilings reflect a significant role in IAQ through the emission and sorption of pollutants. Moreover, most flooring materials are multi-layered and used to cover substantial surfaces [2], significantly impacting IAQ.

Basically, there are two types of flooring materials: smooth or hard flooring (e.g., wood) and soft or fleecy flooring (e.g., carpet). Among the flooring materials, carpets can considerably impact IAQ due to covering a large surface area indoors in combination with the large surface area of the dense fibre piles of the carpet. About 10 million fibres per square meter make up the carpet piles, which offer a variety of functional chemicals for emission and sink effects of air pollutants [4]. Therefore, several studies have been undertaken to examine how carpets affect IAQ [5].

Additionally, carpets have been shown to have high sorption capacity. Carpets can decrease the levels of VOCs in indoor air due to their ab/adsorption capabilities, although this can be followed by the re-emission of the VOCs over time [6].

It is challenging to investigate reactions of VOCs in an actual indoor environment by physical/chemical analyses due to short-lived, highly reactive compounds indoors and low concentrations. The newly produced reactive compounds may be perceived by occupants, but it is in general difficult to distinguish them using conventional analytical techniques. While, it is possible to study the overall impact of a complex VOC mixture on human perceptions by sensory assessment [7]. Therefore, sensory evaluations are useful for recognizing variations derived from indoor chemistry, particularly for variations missed by the standard analytical methods evaluating indoor air [8]. For example, sensory assessments of ozone elimination with building materials (plasterboard, carpet, linoleum, pinewood, and melamine) were carried out to assess the perceptual impacts. When the carpet was exposed to ozone, the results demonstrated the strongest impact with noticeably high scent intensity. In fact, the exposure to ozone changed the carpet's releases of chemicals into oxidant compounds with unpleasant odour notes [9]. Additionally, in a study with a trained panel of judges to predict how indoor air is perceived when polluted by different materials simultaneously, the results indicated that the total sensory pollution load in a space, as a first approximation could be predicted by the simple addition of the values of the single sources [10].

With regards to the current need for improving IAQ, it is questioned how carpets affect the IAQ from the pollution emission and the cleaning effect (e.g., ad/absorption) points of view. This study was performed to answer the following question: Can low-odour emitting wool carpets 'clean' the air in terms of perceived IAQ?

2 Materials and Methods

2.1 Study Design

The experiments were conducted to assess the answer to the question: "Can low-odour emitting wool carpets 'clean' the air." To answer this question, the carpet with the least odour intensity and highest acceptability was chosen from among eight wool carpets by sensory evaluation using a sniffing table (pilot test). All the

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carpets comprised 100% wool in loop piles and had a backing of polyester felt, polypropylene or jute. Then, the odour of carpets with another pollution source (i.e., hardboard) was assessed by a panel of untrained subjects to determine whether the carpet adsorbed the odorous emissions of that pollution source.

For this study, a stainless steel ‘Sniffing table’ was used, placed in a large lecture room (volume of 828.2 m^3, floor area 142.8 m^2 × 5.8 m height) at the faculty of Architecture & the Built Environment, Delft University of Technology (TU Delft), the Netherlands. The sniffing table supplies air using a fan through a metal funnel from inside a plastic container, which contains sample pieces (Fig. 1) [11]. Aluminium foil was placed over the sample containers to keep the samples hidden from the subjects (to avoid bias).

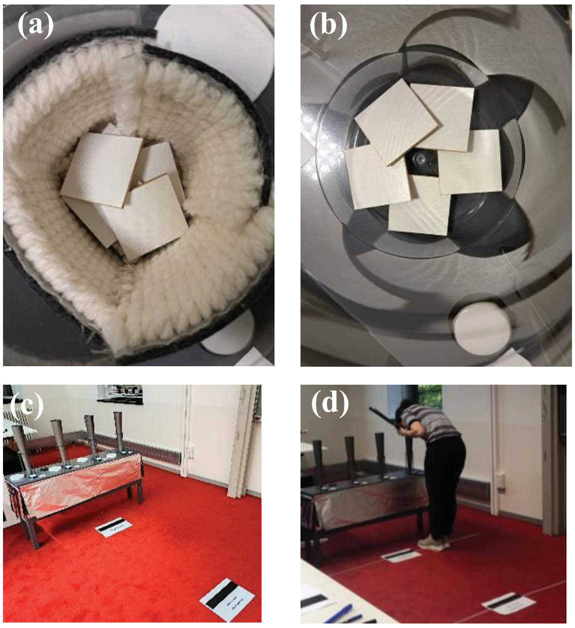

Fig. 1. Sample container of Sniffing table (a) Wool carpet + hardboard, (b) Hardboard, (c) Sniffing table, and (d) subject during sniffing.

2.2 Participants

An untrained sensory panel of MSc students of TU Delft assessed the odour intensity and acceptability of the samples in the experiment. There was no restriction on the distribution of gender, smoking habits, or age.

Fifty-five MSc students of TU Delft, including 29 females (53%) and 26 males (47%) who studied at the faculty of Architecture, participated in the experiment. Their mean age was 26 years old.

2.3 Materials

The wool carpet with the lowest odour intensity comprised 100% bleached wool in loop piles with a polyester felt backing and Niaga adhesive. The first sample container was filled with five pieces of that wool carpet (pieces of 10 cm × 10 cm) and five pieces of hardboard (pieces of 5 cm × 5 cm), whereas the second sample container was only filled with five pieces of hardboard (each 5 cm × 5 cm) (Fig. 1). This hardboard panel comprised of fine fibres of wood pressed together under high pressure, which gives the board a very smooth side added with one white side painting.

2.4 Ethical aspects

The students received an information letter and a link to sign the consent letter by email two days before the experiment. On the day of the experiment, the research team checked the consent forms signed online. Before conducting the experiment, students who did not sign the consent form online were required to read and sign the paper copy of the consent form. Furthermore, the students always had the option to opt out if they no longer wanted to participate. The Ethics committee of TU Delft gave approval for the study on October 6, 2022.

2.5 Experimental procedure

The subjects were divided into ten groups, with 5-6 students. Each group was asked to come to the lecture room every 15 min. The experiments were conducted on October 26th.

Before the first assessment, the 5-6 students were instructed on how to use the scale and the equipment. Every session, the students entered the experiment zone following the researcher and were asked to sniff each of the sniffing table cones, one at a time, and answer a questionnaire regarding their perceived smell. Also, we asked students to do at least two times inhalation between each sniffing if they wanted to repeat sniffing.

Before the experiments, a Photoionization Detector (PID), ppbRAE3000 10.4 eV, was used to monitor the concentration of TVOCs emitted by the selected materials. This VOC-monitoring instrument uses a 10.4 eV lamp that can respond to a broad range of compounds.

2.6 The questionnaire

To assess the perceived air quality coming out of the funnels, a questionnaire was developed based on the questionnaire used by Gunnarsen and Fanger, 1992 [12]. For this study, intensity and acceptability were assessed. The participants were asked: “How strong is the odour that you smell? Give your opinion with a cross or a dash on the scale below (Intensity)” and “Imagine being exposed to this odour while sitting in your study place; how acceptable is the air? Give your opinion with a cross or a dash on the scale below (Acceptability).” In addition, a questionnaire of “What do you smell? please choose one option (Odour recognition)” was used.

The students indicated their immediate evaluation on two continuous scales regarding odour intensity (0 no odour – 5 overwhelming odour) and acceptability of the air (−1 clearly unacceptable, +1 clearly acceptable), from which the percentage of dissatisfaction was estimated.

2.7 Data management and analysis

All data from the questionnaires were manually typed in and stored in IBM SPSS Statistics version 25.0. A second person systematically checked the input of the questionnaire data. First, descriptive statistics such as percentages, range, or arithmetic mean with standard deviation were used to summarize the data. This descriptive analysis was used to describe students' general information (including age, gender, and smoking habit). Finally, paired t-tests were conducted to evaluate whether statistically significant differences between students' assessment of the two smells in the funnels occurred.

3 Results

3.1 VOC-monitoring

A VOC-monitoring instrument was used to measure the emissions coming out from the plastic containers of the sniffing table. It was found that the 10.4ev PID monitor measured 0 ppb for almost all the sources after placing the materials inside the containers.

3.2 Experiment

3.2.1 Intensity

The participants were asked to take a sniff from one of the two funnels and to answer the question regarding intensity. Table 1 presents the mean values of the intensity assessment of the air in the funnels with standard deviations (SD) and standard errors (SE). From Fig. 2, it can be seen that, in general, the participants evaluated the odour of the hardboard as stronger than that of the wool carpet + hardboard.

Table 1. Intensity and Acceptability assessment for samples in the sniffing table.

	Intensity		Acceptability	
	wool carpet + hardboard	Hard-board	wool carpet + hardboard	hardb oard
Mean Value	2.46	2.52	-0.17	-0.20
SD	0.85	0.83	0.48	0.38
SE	0.11	0.11	0.07	0.05

The result of paired t-tests between the odour intensity assessments of wool carpet + hardboard and hardboard showed, however, no statistically significant difference ($p = 0.581$).

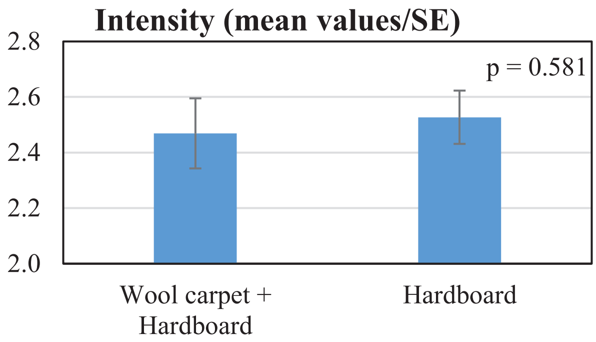

Fig. 2. Intensity assessment for the samples in the sniffing table: mean values and standard errors (SE)

3.2.2 Acceptability

The participants were also asked to answer the question regarding acceptability. Table 1 shows the mean values of the acceptability assessment of samples together with SD and SE Results showed that the participants evaluated the perceived air of the hardboard as less acceptable than the perceived air of wool carpet + hardboard (Fig. 3).

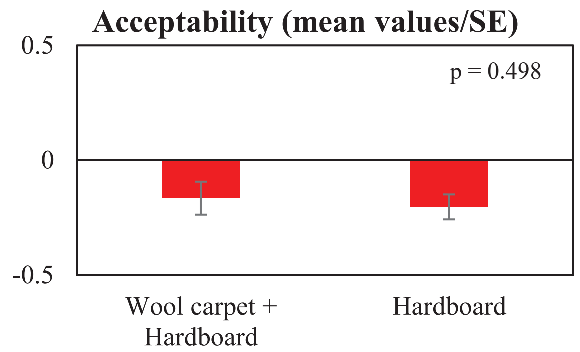

Fig. 3. Acceptability assessment for the samples in the sniffing table: Mean values and Standard Errors (SE)

The result of paired t-tests between the acceptability assessments of wool carpet + hardboard and hardboard shows no statistically significant difference between them ($p = 0.498$).

3.2.3 Odour recognition

For the wool carpet + hardboard combination, 64% of the subjects described the odour as chemical and 36% as natural, while for hardboard only, the odour was described by 84% as chemical, and 16% as natural.

4 Discussion

The main objective of this study was to test the effect of a carpet on the perceived air quality. During the study, the participants were asked to fill in a questionnaire to assess the air coming out of the funnels of the sniffing table. The assessment of the two funnels of the sniffing table took approximately 4-6 minutes per person. This way of assessing was chosen to avoid adaptation to the smell coming out of funnels since adaptation improves the acceptability of the air quality. Besides, the participants were not able to see inside the container of the sniffing table in order to reduce bias.

4.1 Odour sorption

The evaluation of air quality expressed in acceptability reflects perceptual information in combination with psychological and social values [13]. The present study showed that the level of acceptability given by the participants for the hardboard only was lower than for wool carpet + hardboard. The odour intensity of the funnel with the hardboard only, was evaluated as stronger than for the combination of wool carpet + hardboard. Therefore, when the participants assessed the odour to be more intense, they also assessed it to be less acceptable.

With regards to the odour recognition, the participants, in general, described the elements chemically for the hardboard with the difference for the wool carpet + hardboard. However, the levels of intensity and acceptability were assessed slightly different, as shown in Fig. 2 and 3.

It was shown that the participants evaluated the odour of wool carpet + hardboard as less intense than hardboard. This result could be explained by the sorption effect of odour from the hardboard by the wool carpet. Previous studies proved that wool carpets ad/absorb VOCs in experiments by chemical analyses [14–16]. However, previous studies used higher concentrations of VOCs than in actual situations indoors.

4.2 Limitation

For this study, a sniffing table was applied with a fixed airflow rate created by a small fan, which creates different airflows close to the material than in a real-life situation. Fig. 1 presents the setup of the experiment in the sniffing table, where it is shown that the hardboard pieces were positioned on the wool carpet pieces. Future tests in more realistic indoor environmental settings will need to be performed to show a wool carpet positioned on the floor can adsorb VOCs from real-size furniture.

5 Conclusions

The study aimed to assess whether the emission of hardboard can be adsorbed by wool carpet placed in a sniffing table. The sniffing table test was conducted to evaluate the odour of the combination of 'wool carpet + hardboard' and 'hardboard' by a panel of untrained subjects. From the assessments performed with the sniffing table can be concluded that the odour acceptability of the combination was higher and the odour intensity was lower than only the hardboard, although not statistically significant, indicating a slight adsorption effect.

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