Proc. of ASHRAE Annual IAQ Conference and ISIAQ 5th International Conference "Healthy Buildings, September 27-October, 2, 1997, Washington DC, USA, Vol. 2, pp. 243-248

IMPACT OF CHANGING THE FLOOR MATERIAL ON AIR QUALITY IN AN OFFICE BUILDING

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ABSTRACT

Perceived air quality, symptoms, and perception of the environment were studied in a naturally ventilated office building in which a felt carpet was substituted by linoleum on the first floor and by polyolefine floor tiles, known from previous studies to be a low-polluting floor material, on the second floor, while the felt carpet remained unchanged on the ground floor. A panel of 36 untrained subjects occupied the offices on each storey for a period of one hour in a balanced design on a day when normal occupants were absent. The subjects assessed the indoor climate on four different occasions, as follows: on entering the offices they immediately assessed the perceived air quality and after they were seated they evaluated symptoms experienced at that time; 20, 40 and 60 minutes after entering the offices they assessed the perceived air quality, as well as their symptoms, and the condition of the environment. Finally the subjects stated on which of the three floors they would prefer to work. A change of floor material significantly decreased the percentage of those dissatisfied with the perceived air quality from nearly 30% in offices with felt carpet to approx. 15% in offices with polyolefine floor material, and also decreased the sensory pollution load caused by the building from 0.10 olf/m^2 in offices with felt carpet to 0.02 olf/m^2 in offices with polyolefine floor tiles. A preference vote revealed that subjects selected offices with polyolefine floor covering as having the best air quality. These results confirm that decreasing pollution sources is an obvious measure for improving the air quality in buildings.

INTRODUCTION

Building materials have been identified by several studies to be an important source of pollution indoors (1,2). Accordingly, in current new drafts of ventilation standards (3,4), total ventilation rate required for acceptable indoor air quality includes a component required to handle pollution caused by the building. Recommendations are also given regarding source control, i.e. removing superfluous pollution sources, which is considered to be an efficient measure for controlling pollution from building materials. Floor materials in particular can have a negative impact on perceived air quality in office buildings, resulting in increased sensory pollution loads in offices (5) and increased prevalence of symptoms among occupants (6). The objective of this study was to investigate whether substituting a polluting floor material by a low-polluting material in an office building can improve perceived air quality and occupants' well-being.

METHODS

Experimental plan A sensory panel assessed perceived air quality, symptoms and the indoor

KEY WORDS: Carpet; Office Building; Perceived Air Quality; Renovation; Source Control

climate in an office building. Assessments were made during one-hour occupation of offices in the building on a day when normal occupants were absent. The building was heated and illuminated as usual. The occupied offices had three different types of floor material.

Building characteristics The study was carried out in a 25-year-old three-storey naturally ventilated office building with cellular offices located along the corridor in a section facing towards west and a section facing towards east. A unique feature of the building is that each storey has a different type of floor material: a felt carpet on the ground floor, linoleum on the first floor and polyolefine floor tiles, known from another study (5) to be a low-polluting material, on the second floor. Linoleum and polyolefine floor tiles replaced a felt carpet previously used all over the building. The floor materials were changed more than six months before the experiment began.

Sensory panel A panel of 36 healthy untrained human subjects (33% females; 17% smokers) with an average age of 24 years participated in the experiment. None of the subjects had worked in the building prior to the experiment.

Procedure On each storey, 4-5 adjacent non-smoking offices located in the western section were selected for occupation. The offices were similar in size and similarly furnished. Office equipment, e.g., personal computers, facsimiles, copiers, were switched off. The doors to occupied offices were open, while the doors to offices facing towards east were closed. Consequently, occupied offices, together with an adjacent corridor, created on each floor an open-plan office with a total floor area of 130 m^2 and a total volume of 350 m^3. All windows were closed.

The panel was divided into three groups of similar size. Each group occupied the selected offices on each storey for a period of one hour in a balanced design, with a five-minute break outdoors between occupation of each floor. Upon entering the offices the subjects immediately assessed the perceived air quality and just after being seated near a door inside the office, they evaluated symptoms experienced at that time; 20, 40 and 60 minutes thereafter the subjects assessed perceived air quality, as well as their symptoms and the indoor environment. During occupation, the subjects read or studied; they were not allowed to eat or smoke. When all groups had occupied all three types of office in the building, the subjects selected (*preference vote*) the occupied offices having the best and those having the worst air quality. To assess *perceived air quality*, subjects used continuous scales describing pleasantness of air, acceptability of air (7), as well as intensity of odour and irritation of eyes, nose and throat (8). The following *symptoms* were measured: dry, stinging or irritated eyes; watering eyes; dry, irritated or blocked nose; runny nose; dry or irritated throat; hoarseness or pain in throat; dry skin or rash on face; dry, itchy skin or rash on hands; pain in neck and shoulders; headache; difficulty in thinking clearly ("heavy in head"); disorientation; difficulties in concentration; and unnatural tiredness. Assessments of the *indoor environment* included perceptions of: too low temperature; too high temperature; fluctuating temperature; draught; cold feet; dry air; stuffy air; unpleasant air; cigarette smoke in air; noise; static electricity; dust and dirt; and poor illumination. Each symptom and perception of the environment was measured using a continuous scale.

Physical measurements During occupation of offices, spot measurements of temperature, relative humidity and carbon dioxide (CO_2) concentration were repeatedly performed in the corridor in the vicinity of the occupied offices.

Statistical analysis All assessments were first transformed with pre-defined orthogonal contrasts and were then subjected to analysis of variance in repeated measures design. Duncan test (p<0.05) was used to compare perceptions in offices with different types of floor material. T-test (p<0.05) was used to analyse a possible effect of time of occupation on perceptions. Chi-square test was used to compare preference votes.

Calculations Assessments of air acceptability were transformed into percentage of dissatisfied, using a relationship similar to that of Gunnarsen and Fanger (7). Outdoor air rates and sensory pollution loads from people were estimated using CO_2 concentrations above outdoors, assuming a CO_2 production rate of 19 L/h per person (9). Sensory pollution loads in the offices were calculated from the comfort equation (10), using the assessments of acceptability of air made upon entering the offices. Corrections were made for presence of bioeffluents in offices, assuming that sensory pollution loads are approximately additive (11).

RESULTS

Mean temperatures and relative humidities of air were respectively 22°C and 37% in offices with felt carpet, 22.5°C and 38% in offices with linoleum, and 23°C and 39% in offices with polyolefine floor tiles. CO_2 concentrations were quite similar on each storey and reached 400 ppm before occupation (outdoor concentration), 900 ppm after 1 hour of occupation and 1100 ppm after 2 hours of occupation. The estimated outdoor air change rate was 0.9 h^{-1}, corresponding to an approximate air supply of 7 L/(s·person) or 0.7 L/(s·m^2 floor). Calculated sensory pollution loads from building materials in the offices are shown in Table 1.

Table 1 Sensory pollution loads from building materials in offices.

Offices with	Sensory pollution load (olf/m^2 floor)
felt carpet	0.10
linoleum	0.11
polyolefine floor tiles	0.02

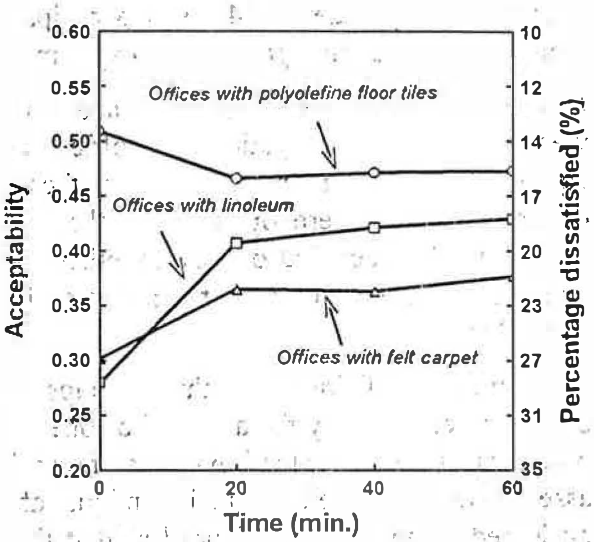

Fig. 1 Acceptability of air and percentage of dissatisfied as a function of time of occupation; the scale was coded: 1=clearly acceptable, 0=just acceptable/just not acceptable, -1=clearly not acceptable.

The air quality caused nearly 30% dissatisfied in the offices with felt carpet and linoleum, while less than 15% were dissatisfied in offices with polyolefine floor tiles (Fig. 1); 5% were dissatisfied with the outdoor air quality. Fig. 2 shows that subjects selected the air quality in offices with polyolefine floor tiles as being the best, while in offices with felt carpet it was considered the worst (p<0.08).

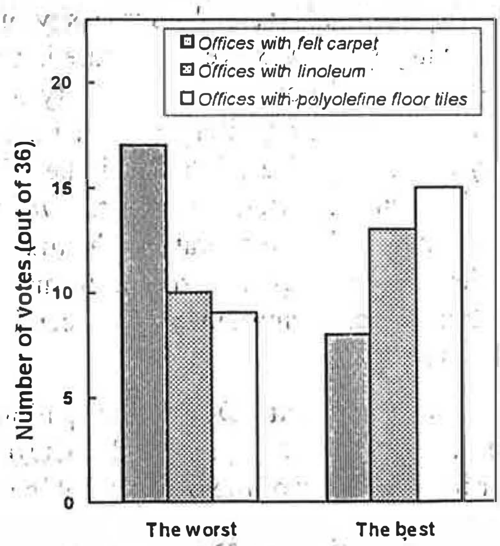

Fig. 2 Results of a preference vote.

Intensity of perceived odour and irritation of mucous membranes was quite low, generally below slight (Figs. 3 & 4). Perceptions of the environment were also quite low (Figs. 5 & 6). Responses to symptoms were too low to draw any reasonable conclusions. Duncan tests showed that: (i) perceived acceptability of air in offices with polyolefine floor covering was significantly better than in offices with felt carpet (Fig. 1); (ii) perceived odour intensity was significantly higher in offices with felt carpet, when compared to both offices with linoleum and offices with polyolefine floor tiles (Fig. 3); and that (iii) the air in offices with linoleum was significantly more stuffy than the air in offices with polyolefine floor tiles (Fig. 5). In addition, offices with felt carpet caused the highest nose irritation (Fig. 4) and they were also perceived to be the most dirty (Fig. 6); however, these perceptions were not statistically significant ($p<0.12$). T-tests showed that during the first 20 min. of occupation, perceived acceptability of air improved significantly in offices with linoleum (Fig. 1), and odour intensity decreased significantly in all types of office (Fig. 3). Other perceptions did not change significantly with time of occupation.

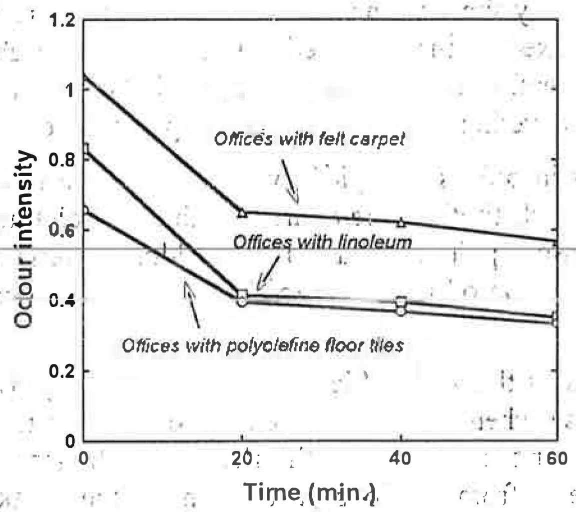

Fig.3 Odour intensity as a function of time of occupation; the scale was coded: 0=no odour, 1=slight odour, 2=moderate odour, 3=strong odour, 4=very strong odour, 5=overpowering odour.

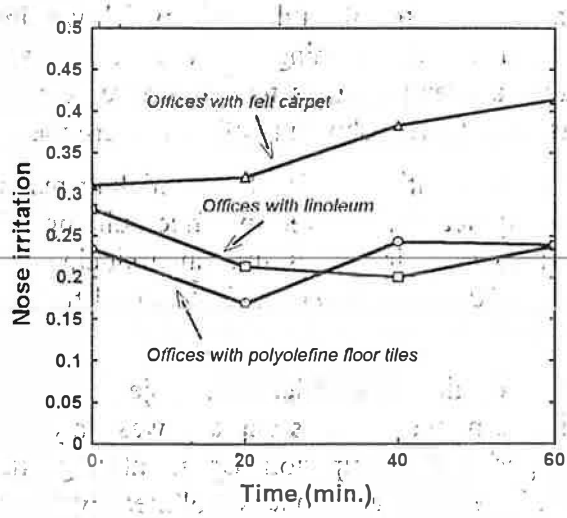

Fig.4 Nose irritation as a function of time of occupation; the scale was coded: 0=no irritation, 1=slight irritation, 2=moderate irritation, 3=strong irritation, 4=very strong irritation, 5=overpowering irritation.

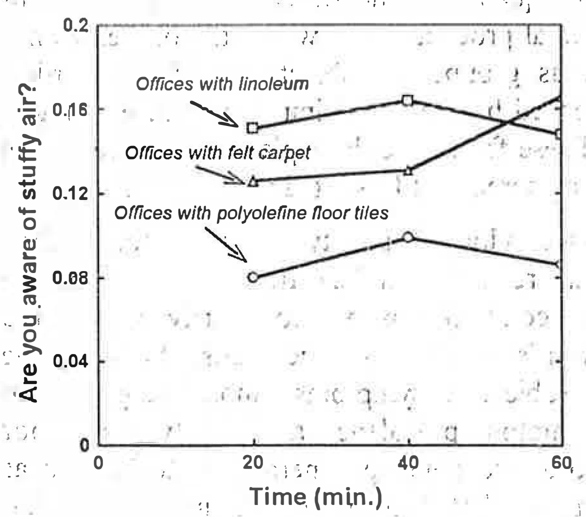

Fig. 5 Perception of stuffiness of air as a function of time of occupation; the scale was coded: 0=not at all aware of stuffy air, 1=aware to a large extent of stuffy air.

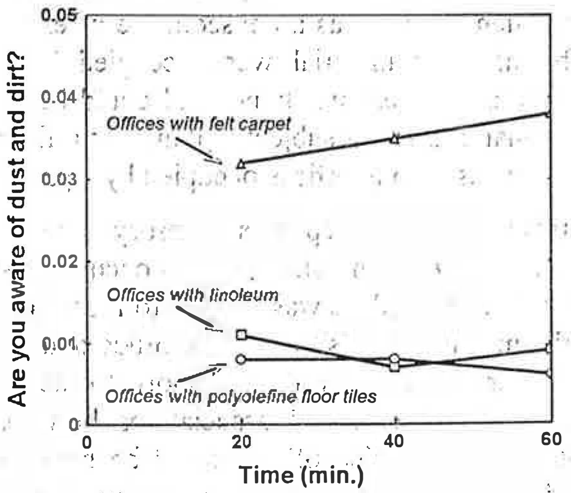

Fig. 6 Perception of dust and dirt as a function of time of occupation; the scale was coded: 0=not at all aware of dust and dirt, 1=aware to a large extent of dust and dirt.

DISCUSSION

The results of the present study show that substituting a polluting floor material with a low-polluting material can improve the air quality in office buildings. Similar results were obtained in another investigation performed in an office building (5), in which a polyolefine floor covering, shown in the laboratory test to be a low-polluting floor material, replaced a polyamide floor carpet (bouclé) recognised as an important source of pollution in the offices.

In the present study, changing a floor material decreased the percentage of dissatisfied with the perceived air quality from nearly 30% in offices with a felt carpet to approx. 15% in offices with a polyolefine floor covering. According to the current draft of the European ventilation prestandard (3), this would correspond to an increase of the air quality from category C to category A. At the same time, the offices investigated in this study were ventilated with comparable rates of outdoor air, which was implied by similar concentrations of CO_2 measured on each floor, assuming that the air was well mixed in the occupied offices. Even though higher air temperatures tend to decrease the perception of air quality (12), an improvement was nevertheless shown in offices where the floor covering had been changed to polyolefine.

Sensory pollution loads of the building materials in offices occupied by the panel were in a range typically measured in office buildings (13). Substituting a felt-carpet with a polyolefine floor covering in offices and thus reducing the sensory pollution load of the building materials from 0.10 olf/m^2 to 0.02 olf/m^2, raised the classification of a building to that of low-polluting (13).

It was originally intended that subjects should assess the air in offices polluted exclusively by building materials. This actually was only the case when subjects entered the offices for the first period of occupation. Upon entering offices for the second and the third time, the air in the offices was additionally polluted by bioeffluents from previous occupation, as the break between the occupation periods was too short. Since the experiments were balanced, however, the degree to which bioeffluents influenced the assessments of air quality is expected to be similar in each type of office. Nevertheless, corrections for the presence of bioeffluents were made when calculating sensory pollution load of the building materials in the occupied offices.

In a preference vote, subjects compared the air quality in the offices with and without bioeffluents. This was a consequence of experimental procedures, in which the offices with a different floor material were occupied by various groups of subjects in different order. Comparisons were not blind, and could be influenced by the visual impression of a changed floor material and a subject's liking for a floor. These factors could explain the differences in preferences among offices occupied by a panel being somewhat lesser than anticipated.

In this study, the independent sensory panel assessed indoor air quality both as visitors - when they first entered the office, and as occupants - while remaining in the office for a period of one hour. This procedure was applied to model real-life conditions, when people arrive at their job in the morning as visitors to the office and afte wards they become occupants. Obviously the one-hour exposure was too short to develop subjective symptoms among subjects and consequently no sound associations between symptom prevalence and the type of floor material in occupied offices could be made. In order to develop general symptoms such as headache, tiredness, etc., longer exposures, up to a whole day, may be required in similar experiments in the future.

A significant change in acceptability of air perceived in offices with linoleum, a modest change in offices with felt carpet, and no change in offices with polyolefine floor tiles was observed during the one-hour exposure. A significant adaptation to odours occurred during the first 20 minutes of exposure in each type of office occupied by the sensory panel. These results are in agreement with previous laboratory studies on adaptation to indoor air pollution (7).

CONCLUSIONS

- Substitution of felt carpet with a low-polluting polyolefine floor covering in an office building improved the perceived air quality and decreased the odour intensity of air.
- Substituting polluting materials is an effective and energy-efficient measure to reduce the sensory pollution load and to improve indoor air quality in buildings.

ACKNOWLEDGEMENTS

Thanks are due to research staff and students at the Laboratory of Indoor Environment and Energy for valuable help and to Dr. Henrik Spliid for assistance in the statistical analysis.

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