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VENTILATION REQUIREMENTS FOR THE CONTROL OF BODY ODOR IN SPACES OCCUPIED BY WOMEN

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Abstract

40 female and 39 male judges have each evaluated the intensity and acceptance of body odor 29 times on entering an experimental auditorium occupied by 106 women. During the experiment, which lasted three hours and 50 minutes, the ventilation rate was varied while the air temperature was kept constant around 20-21°C. Carbon dioxide was measured continuously. No substantial difference was found in the ventilation rates required in spaces occupied by women and men. A ventilation rate around 8 l/s•person is required to satisfy 80% of people entering a space.

Introduction

The present paper deals with ventilation of spaces where body odor is the major pollutant. Such spaces comprise lecture halls, class rooms, theatres, and meeting rooms where smoking is prohibited. The spaces are often ventilated constantly corresponding to maximum occupancy. When such a space is unoccupied or lightly occupied the room is overventilated and energy is wasted. Other and more energy conserving ventilation strategies should be considered to optimize the energy utilization. It seems rational to ventilate a space to maintain the body odor intensity at a given maximum permissible level. This raises two questions: how can body odor be quantified and measured, and what is an acceptable odor level? An earlier study with male occupants in an experimental auditorium at the Technical University of Denmark (3) provides answers to these questions. Carbon dioxide was found to be a useful index of body odor intensity and a relation was established between the percentage of dissatisfied among visitors and the CO_2 concentration. For a given percentage of dissatisfied the corresponding required ventilation rate was then defined for spaces occupied by men. The aim of this paper is to study whether ventilation requirements were different for spaces occupied by women.

Body Odor

Body odor originates from sweat and sebaceous secretions from the skin, foul breath, and gases from the digestive tract. Body odor is a mixture of odors from a wide range of organic gases in small concentrations, difficult to measure. The odor emission from the body shows large

individual differences and depends on diet, activity, and personal hygiene, i.e. bathing habits, frequency of clothing change, use of cosmetics, deodorants, perfume, etc.

In general, people find strong body odor unpleasant and it is the aim of ventilation in densely occupied spaces to dilute the odor intensity to a level where it is acceptable to most people. Body odor is especially noticeable by persons entering a space (visitors). The sense of smell is quickly fatigued or adapted, and on that account odor which is readily noticeable, or even unpleasant to a newcomer, may be unnoticed by occupants who have been exposed to it for a few minutes. The quick adaptation may also explain why man is less bothered by his own body odor. He is exposed to it for long periods by inhaling air contaminated by odor from his own body.

Corresponding to the quick adaptation of the sense of smell there occurs a quick restoration when exposed to clean air. An occupant adapted to a strong body odor in a space will, when reentering after having left the space for a few minutes, feel the same strong odor as a visitor. This is one reason why it has been common practice to design ventilation systems which provide body odor levels acceptable for visitors rather than just for occupants.

Method

The experiments took place in one of the two identical experimental auditoria used previously for the study of male occupants (3). The auditorium had a volume of 850 m^3 and was mechanically ventilated. The maximum air change rate was 5.0 h^{-1} corresponding to an air flow rate of 4250 m^3/h. The supply air was discharged through ceiling diffusers and the return inlets were situated in the floor under the chairs. Equipment and instrumentation were installed to measure carbon dioxide, temperature and humidity in the space.

During the 4 1/4 hours experiment 106 females took part as occupants while 40 females and 39 males acted as visitors. The participants were found via newspaper advertisements and notices put up in schools and training colleges. They were aged 18-30 years whith a mean of 21 years, and about 90% were students. On arrival the occupants gathered in a well ventilated auditorium adjacent to the experimental auditorium. They had had their last bath 18 hours before the experiment and changed to clean underwear about 8 hours before the experiment. The occupants had been asked to clothe themselves and use perfume as they would normally do at work/school. They were not allowed to carry overcoats, bags, food or beverages into the test auditorium. After instruction, the occupants entered the test auditorium and were seated, leaving the three back rows free. The ventilating procedure during the occupancy was as follows: First a period without outdoor air supply but with recirculation of the space air. The outdoor air infiltration of 236 l/s corresponded to an air change of 1.0 h^{-1}. During this period (80 min) the odor intensity was planned to increase to a high level. Then a period of 60 min with high ventilation (air change 5.0 h^{-1}) to dilute the odor to a low intensity. Finally another period (90 min) with no ventilation, recirculation and an infiltration air change of 1.0 h^{-1}.

Smoking was not allowed and only two occupants left the room for a few minutes during the experiment.

The visitors gathered in another well ventilated auditorium where they were instructed in answering the questionnaires and in practical procedures on entering the experimental auditorium. The visitors had been asked beforehand not to eat strongly spiced foods, not to drink alcohol, not to eat strongly flavoured sweets or throat lozenges. They were also requested not to use spray, deodorant or perfume on the day of the experiment. Neither were they permitted to bring overcoats, food or beverages with them.

The 79 visitors were separated into 2 female and 2 male groups, each comprising 19-20 persons.

Following instruction and a trial vote on the odor scales in an empty auditorium, they began judgements in the experimental auditorium two minutes after the occupants had been seated. Every other minute a group of visitors were led into the auditorium through a door at the back of the space, spread out standing in two rows behind the occupied area and requested to answer the questionnaires. They were questioned concerning their acceptance of body odor (see Fig. 1). Furthermore, they were asked to evaluate the odor intensity on the scale shown in Fig. 2. Both responses were based on the immediate impression of each visitor when entering the space. Each group spent less than two minutes in the space for each judgement. Each group entered the space every 8 minutes during the experimental period of 230 min. This provided in all approximately 2300 replies to each question.

Results

Preliminary results of the experiment are given in this paper. Fig. 3 shows the relation between the percentage of dissatisfied female and male visitors, i.e., those visitors who judged the odor to be unacceptable, and the odor intensity from female occupants. Each point represents 160 judgements.

It is obvious that there is a close relationship between the two subjective judgements. For comparison, the results are shown from our similar earlier study with male occupants (3).

Fig. 4 shows the percentage of dissatisfied female and male visitors as a function of the CO_2-concentration. Each point represents 120 judgements. For comparison the corresponding regression line is shown for male occupants (3), as well as a line based on an analysis of the results from a laboratory study with female and male occupants of Cain et al. (2). The dotted line in Fig. 4 is based on the reported acceptances during Cain's experiments at low humidity, and calculated CO_2 concentrations, assuming a CO_2 production of 16 l/h•person.

Fig. 5 shows the percentage of dissatisfied female and male visitors as a function of steady-state ventilation rate. The curves re-

present the same data as Fig. 4. For a given carbon dioxide concentration and a given carbon dioxide production per person the corresponding steady state ventilation rate was calculated. The carbon dioxide production for the female occupants was estimated to be 12 l/s•person and 16 l/s•person for the male occupants.

Discussion

In an earlier study in the same experimental auditorium occupied by males a relation was established between the percentage of dissatisfied visitors (female and male) and the CO_2 concentration. The present study with females as occupants showed similar results (see Fig. 4) although the variance was larger and the slope of the regression line was less for female than for male occupants. The females are smaller than the males and produce only 0.75 times as much CO_2. Since they still require approximately the same ventilation rate per person (Fig. 5) this indicates that the odor emission per unit surface area of the body is higher for females. There is a remarkable agreement with the laboratory study of Cain et al. (2), who investigated a mixed group of female and male occupants. They found a regression line between our two regression lines for females and males (Fig. 4).

Our studies in an experimental auditorium as well as Cain's laboratory studies show that a substantial part of the population is sensitive to body odor and high ventilation rates are required to satisfy this group (Fig. 5). ASHRAE's new ventilation standard (1) defines acceptable air quality as a condition where the air quality is accepted by at least 80% of the population (i.e. 20% dissatisfied). In spaces with a mixed group of female and male occupants 20% dissatisfied corresponds to a required steady-state ventilation rate of approximately 8 l/s• person (Fig. 5). This is three times higher than the ventilation rate of 2.5 l/s•person in the ASHRAE standard. It is obvious from the present study that higher ventilation rates than recently recommended will be required to satisfy visitors. It should be emphasized that "visitors" comprise all people who enter the occupied space after having inhaled air with low odor intensity outside the space for a few moments.

The present results apply for occupants with a standard of hygiene similar to the subjects' in our study. Both the female occupants in this study and the male occupants in the previous study (3) had on an average taken a bath about 0.8 days before the experiment. The results concerning bathing habits were obtained anonymously by asking the occupants to answer the questions only related to the placing in the auditorium but without name, presumably obtaining more honest answers. The data apply thus for persons bathing approximately every 1.5 days. For other groups of people with different standards of hygiene other ventilation rates may be required. This also applies to groups of occupants of another age, national geographic origin, diet, and at other activities and temperatures.

The visitors judging the body odor in our present and previous study (3) comprised in both cases a group of approximately equal numbers of females and males. Fig. 3 shows that they judged a given odor intensity as equally acceptable whether the odor was caused by female or male occupants. Fig. 5 indicates that there are no substantial diffe-

rences in the ventilation rates required in spaces occupied by women and men.

The present study was performed at an outdoor CO_2 level of 0.035%. At a higher level of outdoor carbon dioxide, all CO_2 percentages in Fig. 4 should be elevated correspondingly.

Conclusions

- There are no substantial differences in the ventilation rates required in spaces occupied by women and men.
- In a space occupied by sedentary women and men a ventilation rate of around 8 l/s•person is required to satisfy 80% of people entering the space (visitors).

Acknowledgement

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References

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Imagine that you should enter this auditorium frequently during your daily work. Would you judge the odor in the auditorium as acceptable?

acceptable ☐

not acceptable ☐

Fig. 1. Question on odor acceptance

How strong is the odor in the auditorium? Please mark on the scale.

No odor

Slight odor

Moderate odor

Strong odor

Very strong odor

Overpowering odor

Fig. 2. Yaglou's psycho-physical scale for the subjective judgement of odor intensity (slightly modified). For data analysis these numbers were assigned to the scale: 0(No odor), 1(Slight odor), 2(Moderate odor), 3(Strong odor), 4(Very strong odor), 5(Overpowering odor). (4)

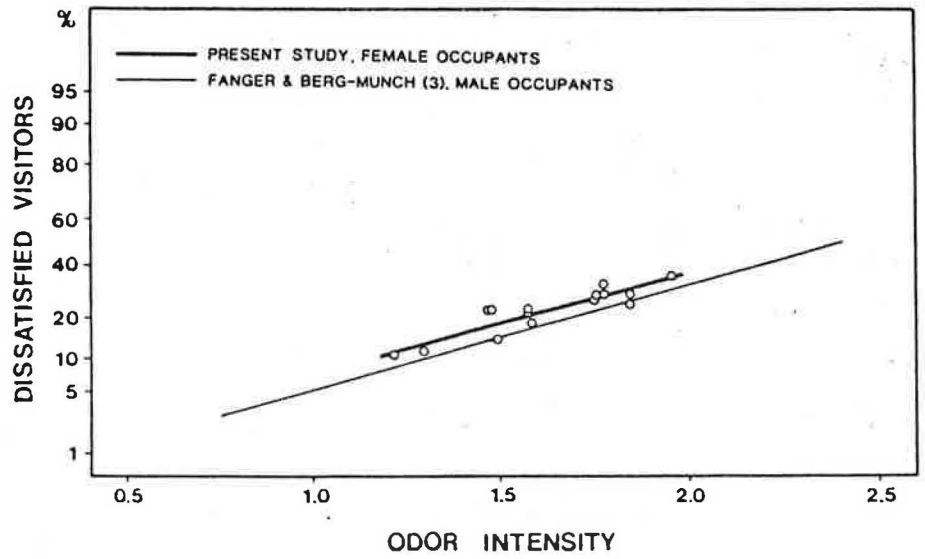

Fig. 3. Percentage of dissatisfied female and male visitors as a function of mean odor intensity for female occupants. For comparison, the results are shown for male occupants from a study by Fanger and Berg-Munch 1983 (3).

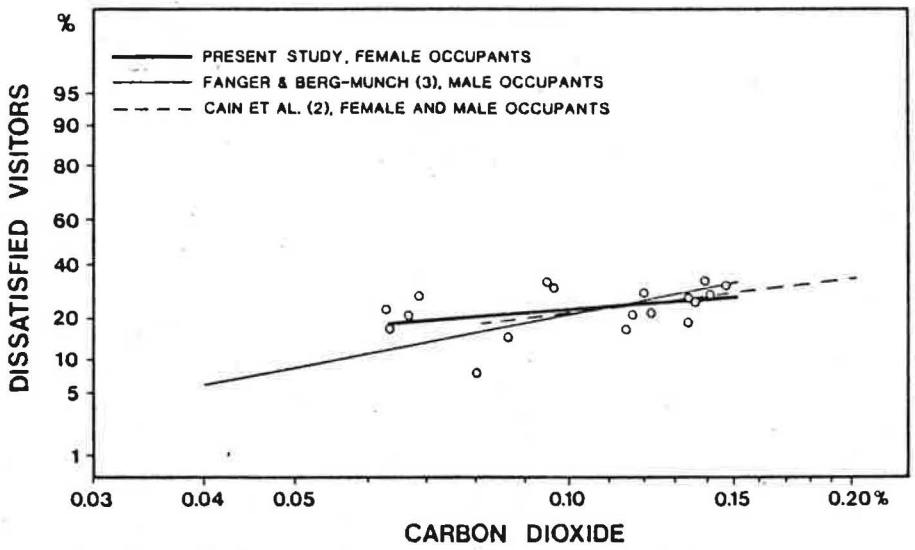

Fig. 4. Percentage of dissatisfied female and male visitors as a function of carbon dioxide concentration for female occupants. For comparison, the results are shown for male occupants from a study by Fanger and Berg-Munch (3) and for a mixed group of female and male occupants from a study by Cain et al. 1983 (2).

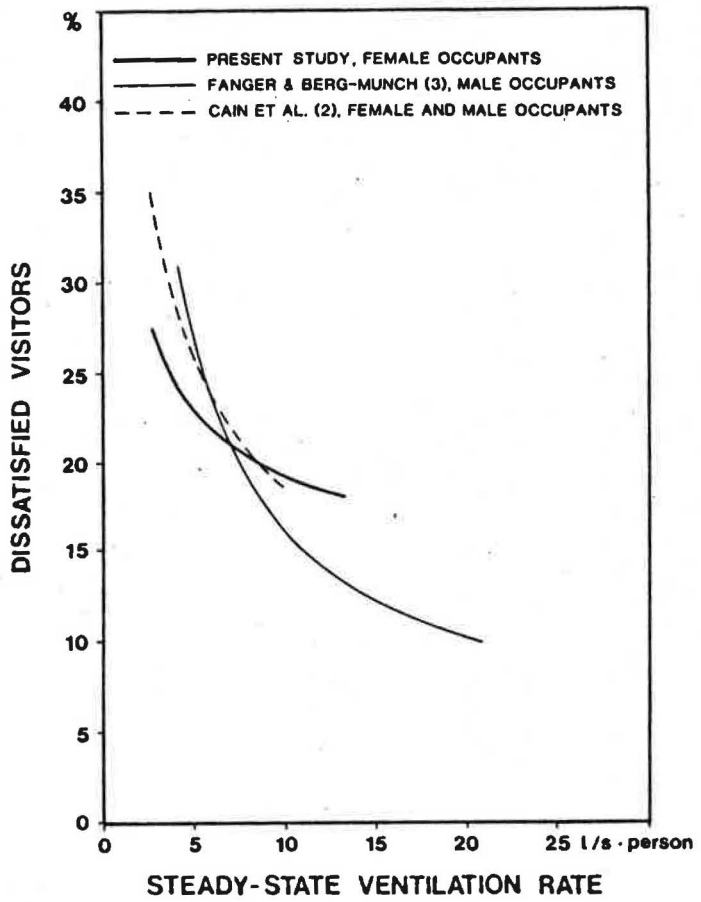

Fig. 5. Percentage of dissatisfied female and male visitors as a function of calculated steady-state ventilation rate for female occupants. For comparison, the results are shown for male occupants from a study by Fanger and Berg-Munch 1983 (3) and for a mixed group of females and males from a study by Cain et al. 1983 (2).