2112

SUMMARY

C.Rasmussen, G.H.Clausen, B.Berg-Munch, P.O.Fanger: The influence of human activity on ventilation requirements for the control of body odor. Body odor emitted by 16 occupants at three activity levels (1, 4 and 6 met) was evaluated by 30 male and female judges. The judges assessed, when entering the occupied room, the intensity and acceptance of the body odor. CO_2 concentration and air change were measured. For the same CO_2 concentration the body odor intensity was of the same magnitude whether the occupants were sedentary or engaged in physical activity up to 6 met. But odor caused by physical activity was less acceptable than odor from sedentary occupants. An activity of 6 met required a ventilation rate 11 times higher than at sedentary activity. There was no difference in odor emission from sedentary occupants, whether they were dressed in their normal indoor clothing (~0.8 clo) or were naked (wearing shorts only).

KURZFASSUNG

C.Rasmussen, G.H.Clausen, B.Berg-Munch, P.O.Fanger: Einfluss der menschlichen Tätigkeitsentfaltung auf Lüftungsanforderungen zur Regelung des Körpergeruchs. Der Körpergeruch von 16 Versuchspersonen auf drei verschiedenen Aktivitätsstufen (1, 4 und 6 met) wurde von 30 männlichen und weiblichen Beurteilern ausgewertet. Die Beurteilern schätzten beim Betreten des Versuchsraumes die Intensität und Akzeptabilität des Körpergeruchs ein. CO_2-Konzentration und Luftaustausch wurden gemessen. Einer gegebenen CO_2-Konzentration entsprach einer bestimmten Körpergeruchsintensität, ganz gleich ob sich die Versuchspersonen in Ruhe (sitzend) befanden oder eine physische Tätigkeit bis zu 6 met entfalteten. Der durch physische Tätigkeitsentfaltung hervorgerufene Körpergeruch war aber weniger akzeptabel als der von sich in Ruhe befindenden Personen ausgestrahlte Geruch. Bei einer Tätigkeitsentfaltung auf Aktivitätsstufe von 6 met war eine elffach höhere Lüftungsrate erforderlich als bei sich in Ruhe befindenden Personen. Dabei gab es keinen Unterschied in der Körpergeruchsausstrahlung der sich in Ruhe befindenden Versuchspersonen, wenn sie ihre normale bekleidung (~0,8 clo) trugen oder sie nackt waren (lediglich Shorts tragend).

RÉSUMÉ

C.Rasmussen, G.H.Clausen, B.Berg-Munch, P.O.Fanger: L'influence de l'activité humaine sur les demandes de ventilation pour le contrôle de l'odeur du corps. L'odeur du corps exhalée par 16 occupants à trois niveaux d'activité (1, 4 et 6 met) a été évaluée par 30 juges femmes et hommes. Les juges ont évalué en entrant dans la chambre occupée l'intensité et l'acceptation de l'odeur du corps. La concentration de CO_2 et la ventilation ont été mesurées. L'importance de l'intensité de l'odeur du corps était la même pour la même concentration de CO_2, que les occupants soient sédentaires ou qu'ils soient engagés dans des activités physiques jusqu'à 6 met. Mais l'odeur causée par l'activité physique était moins acceptable que l'odeur exhalée par les occupants sédentaires. L'activité de 6 met a demandé un taux de ventilation 11 fois plus élevé que l'activité des occupants sédentaires. Il n'y avait pas de différence d'odeur des occupants sédentaires qu'ils portent leurs vêtements habituels à l'intérieur (~0.8 clo) ou qu'ils soient nus (en short seulement).

THE INFLUENCE OF HUMAN ACTIVITY ON VENTILATION REQUIREMENTS FOR THE CONTROL OF BODY ODOR

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Introduction

This paper deals with the ventilation of spaces where body odor is the major pollutant. Body odor is difficult to measure. Since man exhales large quantities of carbondioxide, the CO_2 concentration is a potential index of body odor. Previous studies of Fanger and Berg-Munch (1) on body odor emission from sedentary men showed a relationship between CO_2 concentration and the acceptance of body odor. For a given percentage of dissatisfied the corresponding required ventilation rate was established. The aim of this paper is to study the same relation for male occupants, at higher activity levels, where sweating occurs.

Method

It was decided to study body odor from persons at activities of 1 met (sedentary), 4 met and 6 met. The study took place in an experimental lecture room at the Laboratory of Heating and Air Conditioning at the Technical University of Denmark. The lecture room had a volume of 165 m^3 and was equipped with an air conditioning system. Dehumidification was achieved through condensation at the cooling coils, and humidification by boiling of destilled water. During the experiments the air temperature was maintained between 20°C and 22°C, and the relative humidity between 40 and 60%. The air change was varied between 1 h^{-1} and 10 h^{-1} corresponding to 165 and 1650 m^3/h outdoor air. The supply air to the room was maintained at 2200 m^3/h.

During all the experiments the same 16 men, all fit and in good health, were used as occupants. On the first experimental day the occupants were asked to report wearing their normal indoor clothing. Dressed in this clothing the 16 men were seated for two hours in the experimental room. The occupants then took off their clothes and dressed in shorts, athletic socks and shoes. In this almost nude condition they occupied the room for another two-hour period in a sedentary position.

On the second day the experiments at 4 met activity took place, and on the third day the experiments at 6 met were performed. During these experiments the occupants were divided into two groups of eight persons. One group occupied the room during two hours in the morning, the other group during two hours in the afternoon. To establish the 4 and 6 met activity the occupants walked in a circle (5 m diameter), ascending and descending steps. The judges comprised 30 college-age subjects who were seated in a well-ventilated space next to the experimental room.

The judges were divided into three groups of ten persons. Each group entered the experimental room every sixth minute. Just after entering the room the judges evaluated the odor intensity on a slightly modified Yaglou scale (see Fig. 1) and were asked whether they considered the odor to be acceptable or not (see Fig. 2). The judges did not know what was going on in the experimental room. They were separated from the occupants by a curtain, and noise from the occupants was masked by a white noise generator. During all experiments temperature, humidity, CO_2 concentration and air change in the experimental room were measured.

How strong do you find the odor in this room?
Please mark on the scale.

- No odor
- Slight odor
- Moderate odor
- Strong odor
- Very strong odor
- Overpowering odor

Fig. 1. Yaglou's psycho-physical scale for the subjective judgment of odor intensity. For data analysis the following 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).

Imagine that you daily, frequently should enter this room. Would you judge the odor in the room as acceptable?

acceptable ☐
not acceptable ☐

Fig. 2. Question on odor acceptance.

Results

At sedentary activity there was no significant difference between odor emission from persons with or without clothing.

Fig. 3 shows the odor intensity as a function of the CO_2 concentration at three different activities. For comparison, the corresponding relation from a previous investigation by Fanger and Berg-Munch comprising a large

number of male occupants at sedentary activity is shown. There seems to be no systematic impact of activity on the odor intensity/CO_2 relationship.

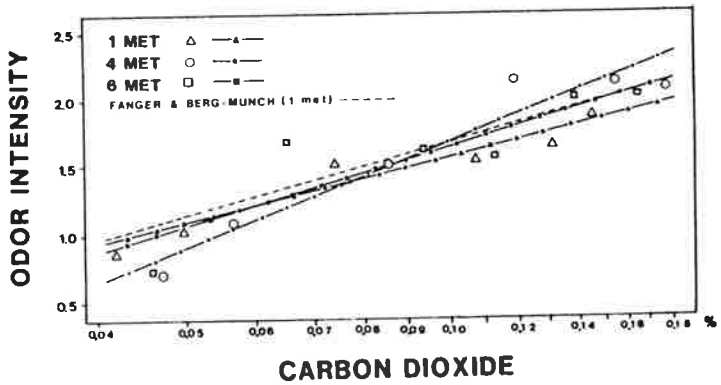

Fig. 3. Odor intensity as a function of CO_2 concentration for 1, 4 and 6 met activity.

Fig. 4 shows the relation between odor intensity and dissatisfied judges. The figure demonstrates that for the same odor intensity the odor at higher activities was judged less acceptable. There was no significant difference between the 4 and 6 met activity level.

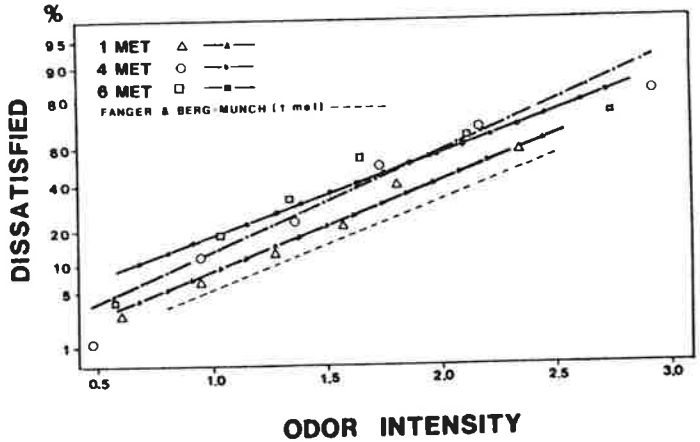

Fig. 4. Percentage of dissatisfied as a function of odor intensity for 1, 4 and 6 met activity.

In Fig. 5 the percentage of dissatisfied is shown as a function of the CO_2 concentration. The percentage of dissatisfied seems to be independent of activity level at low CO_2 concentrations, while at higher concentrations the odor at 4 and 6 met activity was judged as being less acceptable than at sedentary activity.

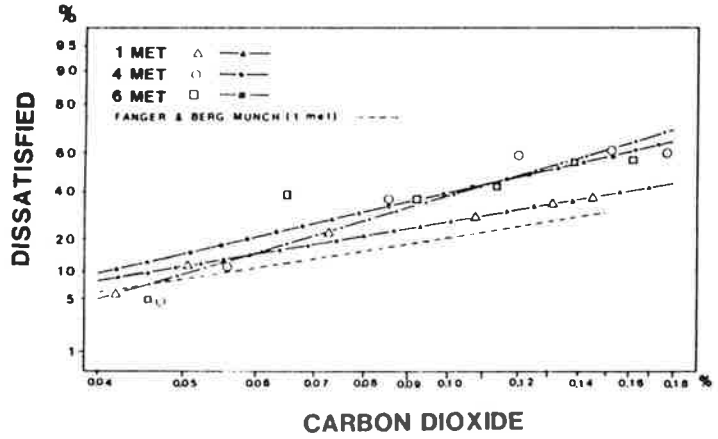

Fig. 5. The relation between CO_2 concentration and percentage of dissatisfied for 1, 4 and 6 met activity.

In Fig. 6 the steady-state ventilation rate vs. dissatisfied visitors has been plotted. The ventilation rate was calculated assuming a 0.035 % CO_2 concentration in the outdoor air and that each person produced 16.9 l CO_2 per hour per met. Fig. 6 shows the dramatic impact of activity on the required ventilation rate. The determination of ventilation rates becomes less accurate as the percentage of dissatisfied approaches 7.7 %, which was the percentage that felt dissatisfied on entering the unoccupied ventilated room.

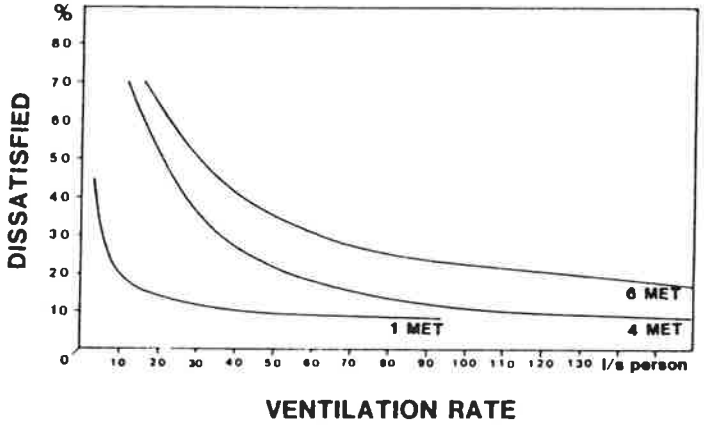

Fig. 6. Relation between percentage of dissatisfied and the steady-state ventilation rate for 1, 4 and 6 met activity.

Discussion

Fig. 3 shows that the relation between body odor intensity and CO_2 concentration was similar for 1, 4 and 6 met activity. This indicates that the magnitude of body odor produced is proportional to the CO_2 production and to the activity level. In Fig. 4 it is shown that even though the body odor intensity was the same, the character of the body odor at 4 or 6 met activity was different from odor at sedentary activity. The judges found it less acceptable. At the higher activity 4 and 6 met, sweating occurred. This probably had an influence on the body odor composition and may explain the difference in character. The change in character resulted in a dramatic increment in ventilation requirements when the activity increased (Fig. 6). The ventilation requirement was not just proportional to activity. To satisfy 70% of visitors entering a room with 4 met activity, a ventilation rate 6 times higher than for sedentary activity was required. To satisfy 80%, a 5 times higher ventilation rate was needed.

At 6 met occupant activity the corresponding ventilation requirement to satisfy between 70 and 80% of the visitors entering was 11 times higher than for sedentary activity. There was no difference in odor emission from the sedentary occupants whether they were dressed in their normal clothing or whether they were naked. Clothing might suppress emission of odor from the skin, but on the other hand there might be emission of odor from the clothing itself. In Figs. 4 and 5 comparison between the results obtained in the present study for sedentary activity and the similar results from Fanger and Berg-Munch shows that the body odor was judged to be less acceptable in the present study. The higher level of dissatisfaction leads to ventilation requirements that are 30% higher than found by Fanger and Berg-Munch. This should be borne in mind when discussing the ventilation requirements indicated at the higher activity levels. The differences may be caused by interpersonal differences in emission and evaluation of the body odor. Such interpersonal differences become more obvious when using small test groups. Considering the relatively small group of occupants (16 persons) used in the present study compared with the several hundred occupants used in the Fanger/Berg-Munch investigation, it is possible that this group happened to emit more unpleasant odor. Another explanation could be that the 30 judges in the present study may have been more critical than the judges in the Fanger/Berg-Munch investigation, when assessing the acceptance of body odor.

Conclusions

For the same CO_2 concentration the body odor intensity was of the same magnitude whether the occupants were sedentary or engaged in physical activity up to 6 met. But odor caused by physical activity at 4 and 6 met was less acceptable than odor from sedentary occupants.

At an occupant activity of 4 met the ventilation requirement was more than 5 times higher than at sedentary activity. An activity of 6 met required a ventilation rate 11 times higher than at sedentary activity.

There was no difference in odor emission from sedentary occupants, whether they were dressed in their normal indoor clothing (0.8 clo) or were naked (wearing shorts only).

References

(1) Fanger, P.O. and Berg-Munch, B. Ventilation and body odor. Proc. of An Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces. ASHRAE, Atlanta, 1983, 45-50.