Table 3. Outdoor Air Supply for Occupants (m3/hour,person)

Name of Building	Dirty Sensation Male	Dirty Sensation Female	Odor Sensation Male	Odor Sensation Female	Discom. Odor Sensation Male	Discom. Odor Sensation Female
BJ College	5.8	4.5	5.8	5.8	7.1	7.2
SK College	6.7	5.5	7.4	6.2	8.5	8.7
SO Building	13.4	10.0	13.4	12.1	14.3	12.9

odor, the quantity of outdoor air supply per hour, person is 5 - 10 m3/hour,person. This is coincident with the result of experiment in the laboratory2).

Conclusion

The results obtained from the investigations conducted on many and unspecified students and persons receiving lectures in actual class rooms and lecture halls where smoking is prohibited or not conducted, for obtaining the relationship between the reports on contamination and odor sensations with respect to indoor air are summarized as follows.

1. The subjects (occupants) are difficult to clearly discriminate contamination and odor of air even when the concentration of CO_2 within the room becomes as high as 5,000 ppm or more. This is because they are accustomed (adapted) to the conditions.
2. The panels (corresponding to visitors) can clearly discriminate contamination and odor of indoor air,and a good correlation was found between their reports on odor sensation and CO_2 concentration.
3. When the quantity of outdoor air supply is determined similarly as reported before2) with the panels as objects and references are set on "slightly clean" in the dirty sensation, "smell" in the odor senation and "slightly discomfort" in the discomfort odor sensation, it becomes substantilly 5 - 10 m3/hour,person.
4. Such a tendency that the male panels sense contamination and odor more strongly than the female panels was observed partially when the CO_2 concentration is high. However, any difference caused by the sex of the occupants was not observed.

References

1. Minamino, O. : A Study on the Outdoor Air Supply for Occupants to Control on the Tobacco Smoke Odor. Proceedings of CLIMA 2000, Vol.4 (1985),pp351-356. (English)

2. Minamino, O. et al : A Study on the Outdoor Air Supply for Occupants in Building---Part 1. Experimental Study on the Body Odor. Transaction on Environmental Engineering in Architecture, No.4 (1982)pp53-58. (Japanese)

3. Minamino, O. et al : Same as above---Part 2. Experimental Study on the Tobacco Smoke Odor. Same as above, No.5 (1983)pp193-199. (Japanese)

MEASUREMENT OF CARBON DIOXIDE OF THE INDOOR AIR TO CONTROL THE FRESH AIR SUPPLY

Ivo Fecker, Markus Hangartner, Hans-Urs Wanner
Federal Institute of Technology,
Department of Hygiene and Applied Physiology
ETH-Zentrum, CH-8092 Zürich

Abstract

In order to save energy, i.e. ventilation heat losses, the fresh air change rate should be adapted to the prevailing need. Even though it is a fact, that reducing the fresh air change rate will result in a ventilation heat gain, the fresh air flow rate should not be kept too low, so that pollutants, humidity and body odour can accumulate. The results of measurements in a climatic chamber and in a lecture theatre show a significant relationship between temperature, concentration of carbon dioxide and body odour of the indoor air under nonsmoking conditions. The upper limit of carbon dioxide, where the indoor air quality is still acceptable to persons entering a room, is between 0.1% and 0.15% vol, whereas for occupants in the room this limit may be set higher because of adaptional effects.

Introduction

Since many people spend an important part of their time in artificially ventilated or climated rooms, a healthy and comfortable indoor climate will attract more and more attention. In other words: the temperature should be adapted to the activities of the occupants and humidity, pollutants and annoying odours must not accumulate (1). The prevailing need of fresh air depends on the number of persons and on their activities in a certain space. Often, the fresh air supply is controlled by temperature; but does temperature really reflect the effective occupancy of a room ?

Animals as well as human beings exhale carbon dioxide as combustion product of their biological metabolism; for man in sitting position the amount is around 20 l per hour, and so, the concentration of carbon dioxide seems to be suitable to control the fresh air supply if man is the only source of odours and pollutants in a room.

The aim of this work is to point out the relationship between temperature, concentration of carbon dioxide and body odour of the indoor air.

Method

Eight experiments have been carried out in a climatic chamber and twenty two in a lecture theatre. The climatic chamber had a volume of 30 m^3. The volume of the lecture theatre was 950 m^3 and there was space for 160 students. The air inlet was situated at the ceiling and the air outlet on the floor. Fresh air flow rate and humidity were kept constant, while the temperature and the concentration of the indoor carbon dioxide were measured continuously. Discharge air was sucked off and offered to a test panel outside. They subjectively compared the perceived odour intensity with some pyridine reference odours, and they also answered some questions concerning the acceptance of the indoor air quality after 30, 60, 90 and 120 minutes (climatic chamber), or after 15, 60 and 90 minutes (lecture theatre). Together in time, the persons in the chamber replied to those questions, while the students in the lecture theatre did the questioning only at the end of the lectures. The questions are listed in table 1.

Table 1: Questions concerning the subjectively perceived indoor air quality and temperature

1. The odour in this room is:

   acceptable ☐ I am not sure ☐ not acceptable ☐

2. Mark the level of annoyance by an odour on this supposed self rating "thermometer"!

3. The temperature in this room is:

   too cold ☐ right ☐ too warm ☐

In the case of the climatic chamber measurements, the reference odours were produced by dynamic olfactometry, but bottles with different pyridine concentrations in water were used for the lecture theatre. Pyridine concentrations of 0.11, 0.19, 0.35, 0.62, 1.1 mg/m^3 for the climatic chamber and 0.67, 1.2, 2.2, 3.9, 7.0 mg/m^3 for the lecture theatre were used. Direct comparison of the two sets of odours showed, that the odours in bottles were subjectively valued about six times less intense than the odours offered by dynamic olfactometry. In order to be able to compare the results of both of the places, the two sets of reference odours were standardized.

The test panels outside the rooms consisted of 15 students. The answers of them were weighted, and so each person had the same influence on the result. Inside the climatic chamber there were between one and four persons and the number of students in the lecture theatre varied between 21 and 115.

Results

All the answers were divided into subgroups of different carbon dioxide concentrations or different temperature.

These were:

C1:	below		0.08 % abs	(Carbon dioxide)
C2:	0.08	-	0.15 % abs	
C3:	0.151	-	0.22 % abs	
C4:	over		0.22 % abs	
T1:	below		21.0 ^oC	(Temperature)
T2:	21.1	-	22.0 ^oC	
T3:	22.1	-	23.0 ^oC	
T4:	over		23.0 ^oC	

Figure 1 shows an example of the carbon dioxide concentration of one lecture theatre measurement.

The measurements in the climatic chamber and in the lecture theatre confirmed the expected relationship between the concentration of the carbon dioxide and the subjectively perceived body odour. The relationship between the odour intensity and the temperature is not as obvious as figures 2 to 4 show. The subjective perception of temperature showed also some dependence on the indoor carbon dioxide concentration (figure 5).

A Spearman rank order correlation coefficient of 0.66 between the odour intensity and the carbon dioxide concentration was found for the data of the climatic chamber, and one of 0.4 for those of the lecture theatre. These coefficients are the result of the correlations between both of the parameters and the time.

Conclusion

As an upper limit of the indoor carbon dioxide concentration we would propose 0.15 % vol abs. (that is approximately adequate to 0.1 % vol rel. increase). At that concentration not more than 15 % of the occupants inside complained of an unpleasant odour.The percentage of persons, who checked the indoor air from outside the room, is between 30 and 40 percents, because of their higher sensitivity of odour perceptions. A concentration of about 0.15 % abs of carbon dioxide was reached at a fresh air rate of 16 m^3/h pers after 100 minutes (figure 1).

Carbon dioxide fails as a leading component if man is not the only source of pollutants and odour, as during smoking occupancies. In that case, the concentration of carbon monoxide (2), or an air quality sensor may give better results.

The temperature in a room with sedentary working places could be kept at 21^o C.

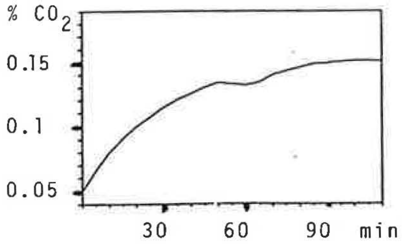
References

1. Wanner, H.U. Luftqualität in Innenräumen. Schweizerische Aerztezeitung 66, (1985) pp 314-317.

2. Weber, Annetta. Acute effects of environmental tobacco smoke. ETS Environmental Tobacco Smoke. Report from a Workshop on Effects and Exposure Levels. The University of Geneva 1983, pp 98-107.

Fig. 1:

Carbon dioxide concentration during one experiment in the theatre. There was a break after 45 minutes. (65 students; 16 m³/person hour).



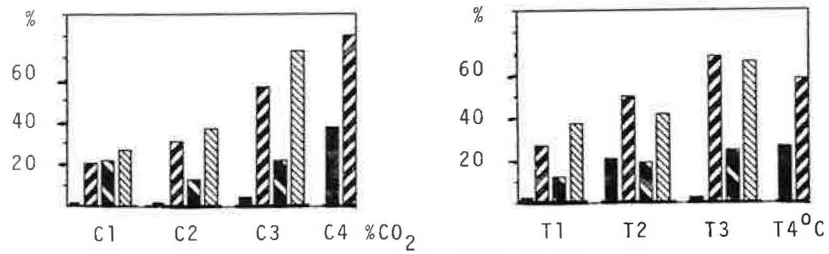


Fig. 2: Percent of the persons who judged the indoor air quality as not acceptable.

climatic chamber: occupants test panel

lecture theatre: occupants test panel

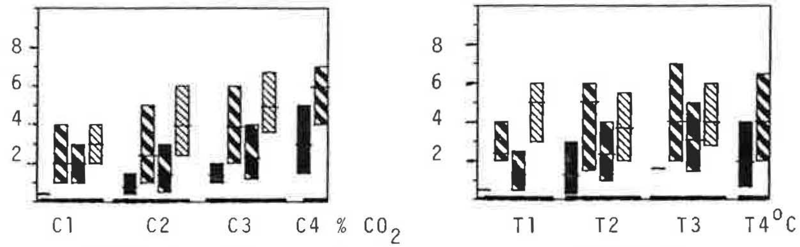


Fig. 3: Annoyance by odourous indoor air (self rating thermometer).
Q1 - median - Q3

climatic chamber: occupants test panel

lecture theatre: occupants test panel

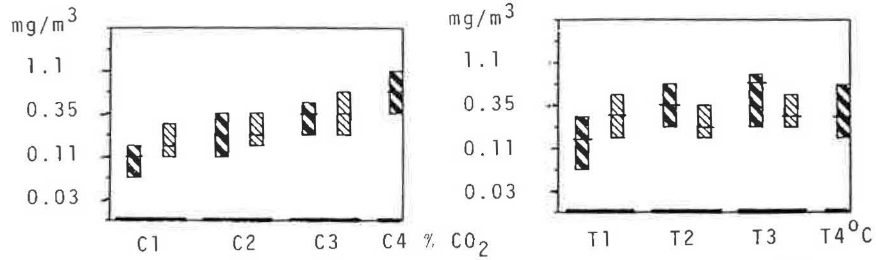


Fig. 4: Comparison of the odour intensity of indoor air with reference odours (pyridine).
Q1 - median - Q3

climatic chamber: test panel

lecture theatre: test panel

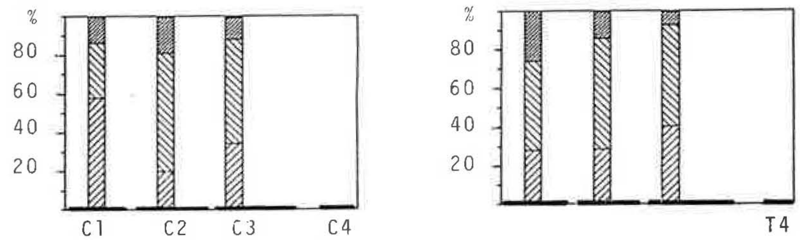


Fig. 5: Subjective perception of temperature (lecture theatre occupants).

too cold right too warm