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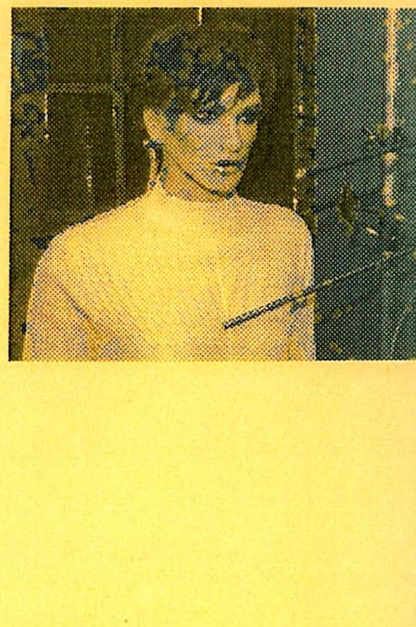

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Measurement of Indoor Air Quality by Means of a Breathing Thermal Manikin

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Measurement of Indoor Air Quality by means of a Breathing Thermal Manikin

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INTRODUCTION

In order to assess the indoor air quality of a ventilated room it is necessary to know at least the pollution load and the air change rate. By means of a simple mass balance it is possible to determine the contaminant concentration of the return air. If the room air is completely mixed and possible concentration gradients are neglected the contaminant concentration throughout the room equals the return concentration. However, the assumption of complete mixing may cause erroneous assessment of the personal exposure if significant concentration gradients prevail for instance close to the pollution sources or in case of displacement ventilation (Brohus and Nielsen, 1996). Errors exceeding one order of magnitude are reported (Brohus, 1997).

When a person is located in a contaminant field with significant gradients the contaminant distribution is modified locally due to the entrainment and transport of room air in the human convective boundary layer as well as due to the effect of the person acting as an obstacle to the flow field, etc. The local modification of the concentration distribution may affect the personal exposure significantly and, thus, the indoor air quality actually experienced. In this paper measurements of indoor air quality by means of a Breathing Thermal Manikin (BTM) are presented.

BREATHING THERMAL MANIKIN

The BTM is shaped as a 1.7 m high average sized woman, developed from an anatomically correct female display manikin consisting of a fibreglass-armed polyester shell, See Figure 1. The shell is wound with nickel wire used sequentially both for the heating of the manikin and for measuring and controlling the skin temperature. The BTM is controlled to obtain a skin temperature and a heat output corresponding to people in thermal comfort (Tanabe et al., 1994). The BTM is wearing tight-fitting clothes with an insulation value of 0.8 clo. Respiration is simulated by means of an artificial lung.

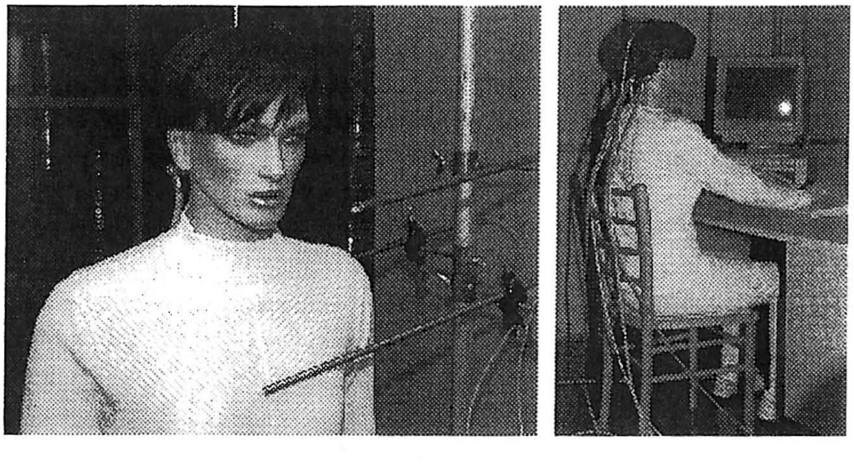

Figure 1. Breathing Thermal Manikin (BTM) used to measure the indoor air quality.

EXPERIMENTAL SET-UP

Two different set-ups are examined in order to demonstrate the use of the BTM. CASE 1: Exposure to a point contaminant source in a uniform velocity field examined by means of the BTM located in a wind channel, see Figure 2. CASE 2: Personal exposure to emission from a "modelled carpet" located in a mock-up of a typical cell office, see Figure 3.

In both cases the contaminant source comprises nitrous oxide mixed with helium in order to obtain a density neutral tracer gas. In CASE 1 the tracer gas is supplied through a porous foam rubber ball, ø 0,1 m. In CASE 2 the tracer gas is supplied through a perforated and branched plastic tube shaped as an H, located below a perforated plastic film covering the entire mock-up floor. The tracer gas concentration is measured by means of photoacoustic spectroscopy.

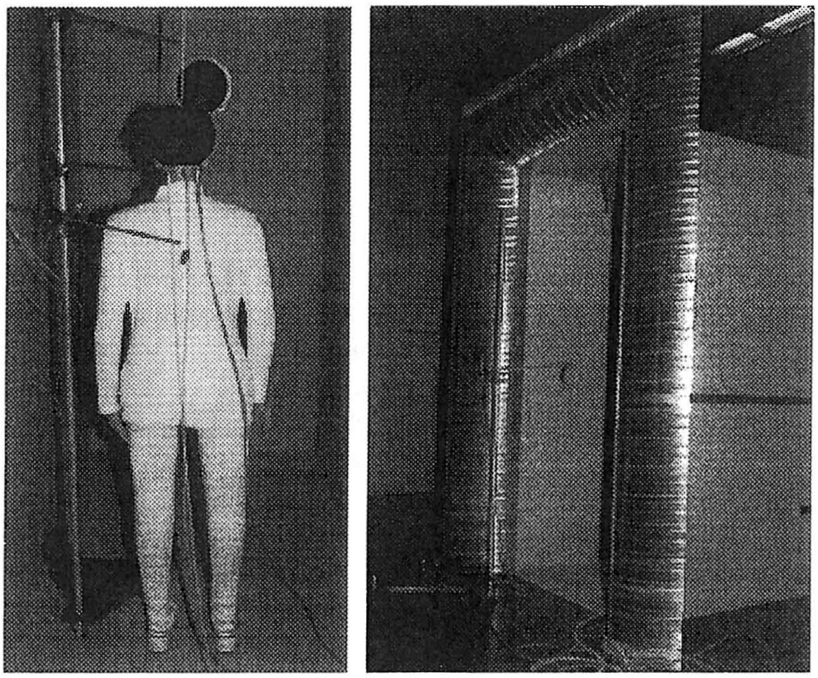

Figure 2. CASE 1. Personal exposure to a point contaminant source examined in the unidirectional flow field of a wind channel.

RESULTS

The measurements performed in the wind channel on personal exposure to a passive point contaminant source in a uniform flow field are presented in Figure 4, showing the measured personal exposure for different vertical locations of the point contaminant source as a function of the velocity level when the source is located at a fixed horizontal distance of 0.5 m from the BTM. For more details see Brohus (1997).

Table 1 shows the results of indoor air quality measured by means of the BTM located in the office mock-up in case of the entire floor acting as a planar contaminant source. Apart from the personal exposure, c_e^*, the contaminant concentration at a neutral location in breathing zone height, c_P^*, is measured. Results from two different ventilation strategies are mentioned. During the old strategy the heating and the supply of fresh air are both provided by the ventilation system. The new strategy separates the heating and the supply of fresh air (isothermal ventilation and heating panels). For more details see Brohus and Hyldgaard, 1998 and Pejtersen et al., 1999.

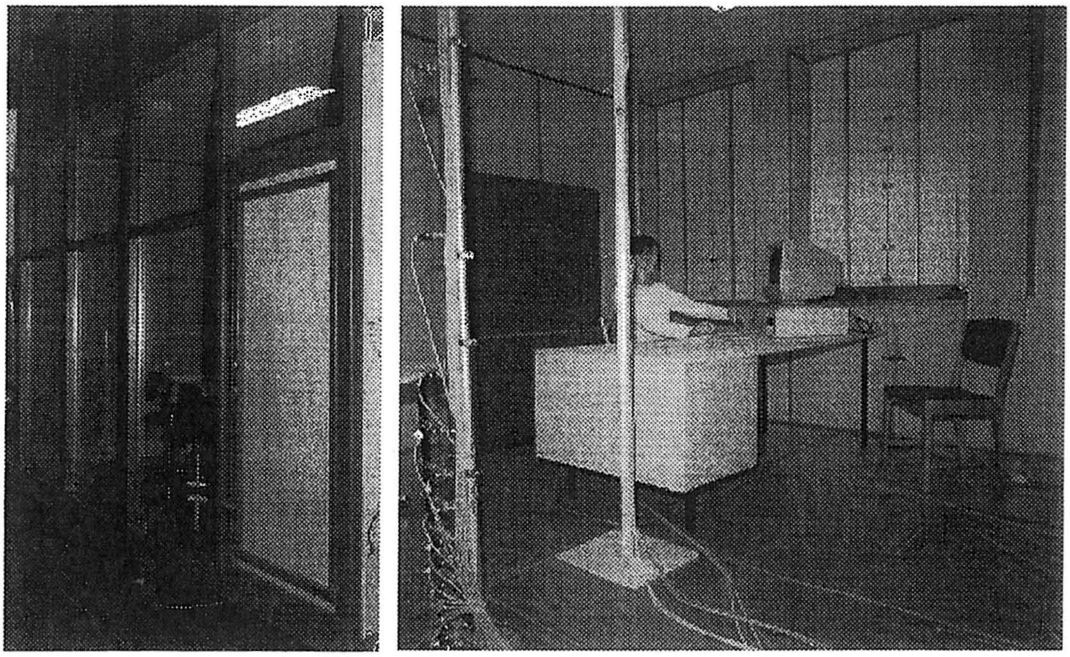

Figure 3. CASE 2. Personal exposure to emission from a carpet in a typical cell office. *Left:* Mock-up seen from outside. *Right:* Mock-up seen from inside.

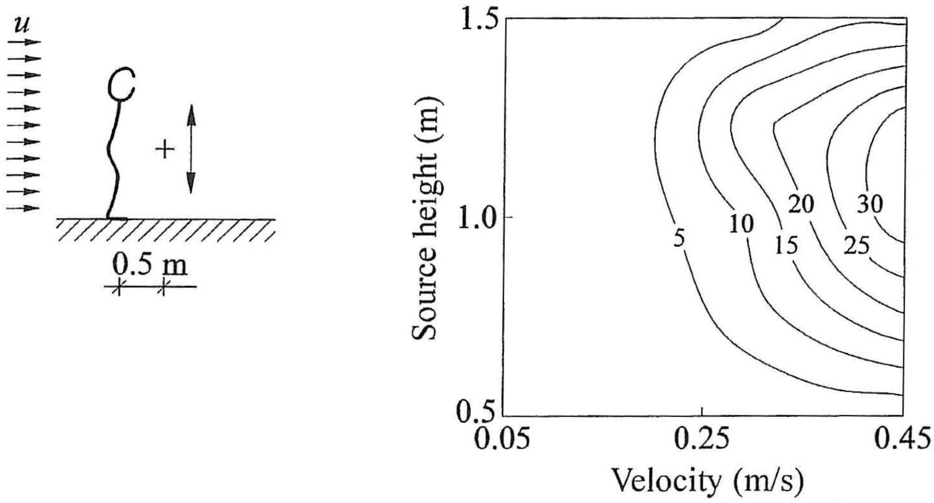

Figure 4. Results from CASE 1. Personal exposure, c_e^*, of the BTM standing in a uniform velocity field as a function of velocity level and vertical point source location above the floor. The results are made dimensionless by dividing by the contaminant concentration measured in the return opening of the wind channel.

Table 1. Results from CASE 2. c_e^* is measured by means of the BTM. c_P^* is measured in the centre of the office at a height of 1.1 m. The results are made dimensionless by dividing by the contaminant concentration measured in the return air.

Ventilation strategy	c_e^*	c_P^*
Old	2.37	1.17
New	1.18	1.06

DISCUSSION

Figure 4 shows the results on personal exposure to a passive point contaminant source in a uniform flow field (CASE 1). The uniform flow field may also represent the local flow field around a person located in a mixing ventilated room. The contaminant source might represent for instance an ashtray. The case shows that the exposure depends strongly on both source location and velocity level. Dimensionless exposure levels exceeding 30 are found, i.e. the actual concentration of inhaled contaminant is 30 times higher than the concentration obtained if the assumption of complete mixing was applied. A distinct influence of the location relative to the wind direction and the contaminant source is reported by Brohus (1997).

The results from Table 1 (CASE 2) clearly show the importance of proper measuring equipment, here, in shape of the BTM. c_e^* and c_P^* are measured at the same height and the difference is due almost solely to the local influence of the person. In case of the old ventilation strategy, the personal exposure is twice as high as the return concentration and also twice as high as the corresponding concentration measured at a neutral location at breathing zone height. Obviously, the convection current along the thermal manikin entrains and transports contaminant from the floor area to the breathing zone.

The results of the full-scale exposure measurements by means of the Breathing Thermal Manikin show the importance of a proper tool for the assessment of indoor air quality in ventilated rooms where concentration gradients prevail. The human convective boundary layer is found to affect the local concentration distribution considerably together with the effect of the person acting as an obstacle to the general flow field.

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