Ventilation Efficiency in Rooms with Non-Buoyant Pollutant Sources

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Abstract

The ventilation efficiency in a displacement ventilated room with non-buoyant pollutant sources was evaluated under laboratory conditions. The contaminant removal effectiveness was measured for different positions of the pollutant sources and with different ventilation flow rates. The air change efficiency and the temperature gradient in the room was measured for the different ventilation flow rates. The contaminant removal effectiveness was much dependent on the position of the sources and varied from 30 to 240 %.

Introduction

Displacement ventilation is often used in industrial premises in order to improve the air quality in the occupied zone. The air flow pattern in the room is then mainly governed by the convection flows from the heat sources present in the room, transporting air from the lower part of the room into the upper part. If the contaminant sources are cold the contaminant must be transported into a convection flow in order to be evacuated with the supply air. In this paper some experimental work on the contaminant removal effectiveness will be reported.

Methods

Measurements were made in a test-room 4.6 x 3.6 x 2.64 m (L x W x H) equipped with displacement ventilation. The test-room is situated in a laboratory where the surroundings can be kept at a relatively constant temperature. The lay out of the room is shown in Figure 1. In the room were three person simulators each consisting of 1 m painted ventilation duct covered at the top and with a diameter of 0.4 m. Inside the simulators were bulbs of altogether 100 W. Two of the person simulators were heated by the bulbs and no other heat sources were present in the room. The contaminant source consisted of either a point source (a perforated table-tennis ball) or an extended source (a box with dimensions 0.4 x 0.4 x 0.14 m with a perforated plastic top). Nitrous oxide (N_2O) was used as contaminant and released in one of the positions A-E shown in Figure 1. Air change efficiency and contaminant removal effectiveness were measured for three different airflows with the pollutant source in the different positions. The temperature gradient was measured at the position shown in Figure 1.

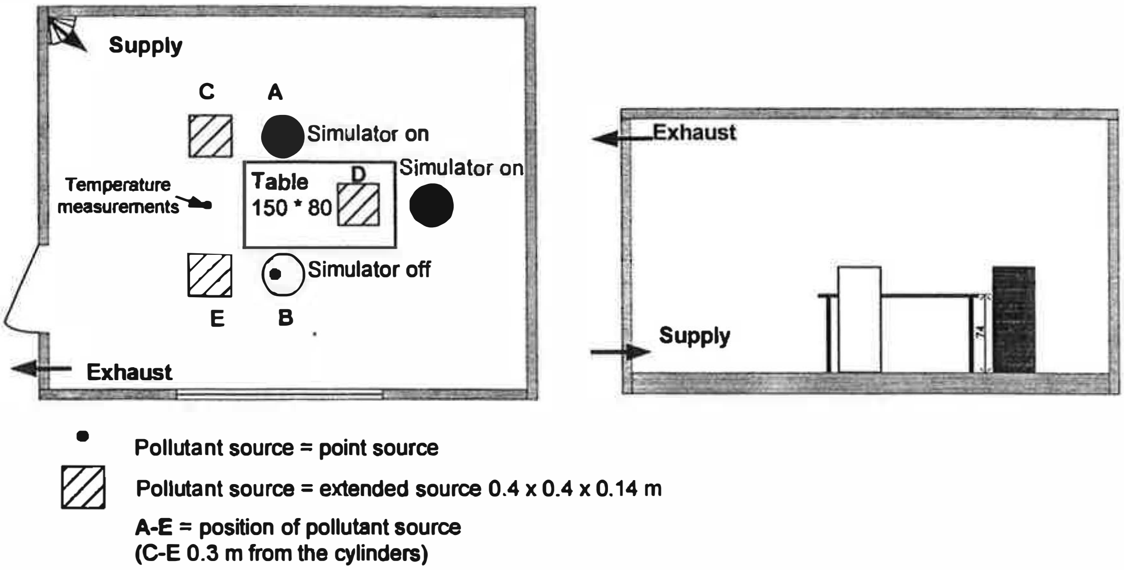

Figure 1. Plan and elevation of the test room

The supply temperature was regulated so all heat emitted in the room was evacuated by the ventilation flow rate. The ventilation flow rates used were 87, 131, 175 m3/h, which equals 2, 3 and 4 ach/h.

The contaminant removal effectiveness, ε^c, a measure of how quickly an airborne contaminant is removed from the room,

$$\varepsilon^c = \frac{C_e(\infty)}{\langle C(\infty)\rangle} = \frac{\tau_n}{\tau_i^c} \cdot 100$$

was measured in the exhaust air for different positions of the pollutant source by the step-up method (1).

The air change efficiency, ε_a, a measure of how quickly the air in the room is replaced,

$$\varepsilon_a = \frac{\tau_n}{2\langle\bar{\tau}\rangle} \cdot 100$$

was measured in the exhaust air by the step-down method (1).

Results

In Table 1 is shown the ventilation efficiency measured for the different cases and in Figure 2 the non-dimensional temperature gradient for the different airflows.

Table 1. Contaminant removal effectiveness and air change efficiency.

	Ventilation flow rate				Position of tracer gas release and type of source used
	175 m^3/h n=4 ach/h	131 m^3/h n=3 ach/h	87 m^3/h n=2 ach/h		
ε^c	240	134	155	A	Point source positioned above a warm cylinder 1m above the floor
ε_a	76	77	78		
ε^c	110	101	103	B	Point source positioned above the cold cylinder 1m above the floor
ε_a	77	76	78		
ε^c	47	46	41	C	Extended source positioned on the floor 30 cm from a warm cylinder
ε_a	79	79	79		
ε^c	44	43	57	D	Extended source positioned on the table 0.75 cm above the floor, 30 cm from a warm cylinder
ε_a	79	80	77		
ε^c	30	34	35	E	Extended source positioned on the floor 30 cm from the cold cylinder
ε_a	76	80	79		

Discussion

Table 1 shows that the air change efficiency is rather high in the test room, 76-80, and it did not change much with the ventilation flow rate. The table also shows a large repeatability of the measurements, as the air change efficiency did not differ much between the different series i.e. different positions of the tracer gas release. The contaminant removal effectiveness however differs with the ventilation flow rate and is very sensible to the position of the pollutant source. Both the level of the source and its position relative to the heat sources present in the room influences the contaminant removal effectiveness.

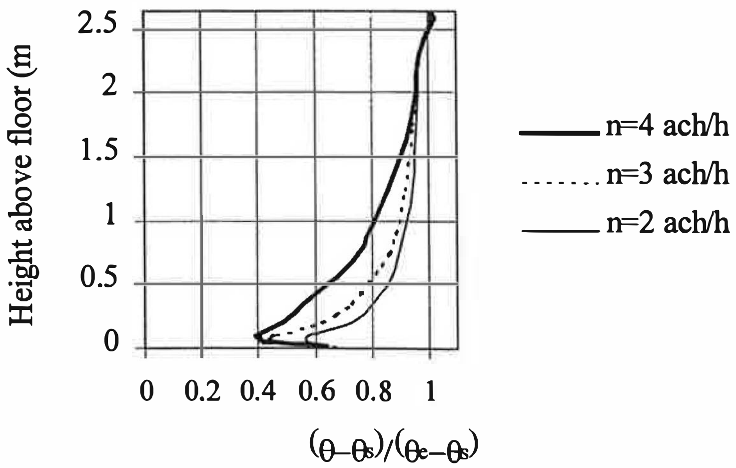

Figure 2. Non-dimensional temperature gradient for three different airflows.

The volume flow rate from each person simulator is at the top 70-100 m3/h (2), this means that the so called border between the upper and lower zones will be at the top of the simulators for the largest ventilation flow rate and below this level for the other ventilation flow rates. The border between the zones is at the level where the sum of the convection flows from the heat sources is equal to the ventilation flow rate. In Figure 2 this can also be seen as the temperature gradient strongly increases at around 1 m for largest ventilation flow rate and at lower heights for the lower ventilation flow rates.

From Table 1 can be seen that when the pollutant source is situated in the upper zone or close to the border between the zones the contaminant removal effectiveness is larger than 100, which is equal to value obtained in ideal mixing ventilation. This applies also for the positions above the cold cylinder. When the pollutant source is on the floor the contaminant removal effectiveness is very low, although significantly higher when it is positioned close to the warm cylinder. The warm cylinder, in spite of the small convection flow around it at the low level in the room, transports the pollutants released in its vicinity from the lower zone to the upper zone. This transportation is also supported by measurements of the particle concentrations under the same conditions (3). The ventilation flow rate did not seem to influence the values obtained for these cases. With the pollutant source positioned on the table however an increase in contaminant removal effectiveness was noticed when the ventilation flow rate decreased. This was probably caused by the fact that the border between the zones in this case was below the height of the table so the source was is this case in the upper zone.

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References
1. Etheridge, D., Sandberg, M. 1996. Building Ventilation - Theory and Measurement, Wiley.
2. Mundt, E. 1996. The Performance of Displacement Ventilation Systems- Experimental and Theoretical studies, Ph.D. Thesis, Bulletin no 38, Building Services Engineering, KTH, Stockholm.
3. Mundt, E. 1999. Particles and displacement ventilation. Submitted to Roomvent 2000, Reading, UK