Sensory pollution load from a used ventilation filter at different airflow rates

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ABSTRACT
Used ventilation filters have been identified as being potential sources of sensory pollution. Recently, it has been shown that the sensory source strength of a used filter increases proportionally with the flow rate. However, this relation was demonstrated only at flow rates smaller than those commonly used. The purpose of the present study was to investigate the sensory emission rate of a used filter at airflows used in practice.

Samples of a 6-month-old EU7 ventilation filter were installed in four 200-l glass boxes located in a climate chamber providing control of temperature and humidity of the supply air to the boxes. The airflows through the filter samples were set corresponding to 25–200% of the nominal flow rate.

An untrained sensory panel assessed the acceptability of the air leaving the glass boxes. The results confirmed that the sensory pollution load is proportional to the airflow even at flow rates well above the nominal value.

INDEX TERMS
Ventilation filters; Sensory pollution load; HVAC system; Material emission; Measurement method

INTRODUCTION
Used ventilation filters are known sources of indoor air pollution (Pejtersen *et al.*, 1989; Clausen *et al.*, 2002). However, the various factors that influence the off-gassing are still not fully understood.

Experiments carried out by Alm (Alm *et al.*, 2000; Alm, 2001) showed that the pollution load from a used filter increases proportionally with the air velocity through the filter surface. The experiments reported by Alm were carried out with a EU7-filter at three different flow rates of 50, 100 and 200 l/s. These flow rates were 10, 20 and 40% of the flow in the original operating condition of the filter, reported to have been 500 l/s.

At higher airflow rates it is questionable whether air velocities several times higher than those previously investigated would allow sufficient time for the chemical desorption processes to take place.

It was the objective of the tests presented in this paper to examine whether the proportionality holds true at airflows up to and above the air velocities that are commonly used in ventilation systems.

METHODS
The experiments were carried out using samples of filter material placed in four 200-l glass boxes situated inside a climate chamber in which temperature, relative humidity and airflow were controlled. The climate chamber measured: $5.4 \times 4.2 \times 2.5$ m ≈ 57 m^3.

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Experimental Set-up

The design and operating principle of the glass boxes used is shown in Figure 1. A box actually consists of two boxes, one inside the other. Air from the climate chamber enters the inlet space through a 25 mm adjustable circular hole in the top plate. Two small fans, placed in the inlet section, draw the air down through the inner box at a constant flow rate. The inlet and outlet of the inner box consists of perforated plates, creating a uniform flow through the cross-section. The air finally leaves the box through a vertical frustum of a circular cone with an exit diameter of 80 mm.

The filter material was locked between two metal plates with 16 circular openings, each of 44 mm diameter, as shown in Figure 2. By maintaining a constant flow rate through the glass chambers, it is possible to vary the velocity through the filter material fastened between the plates by opening or closing a number of the openings in the cross-section.

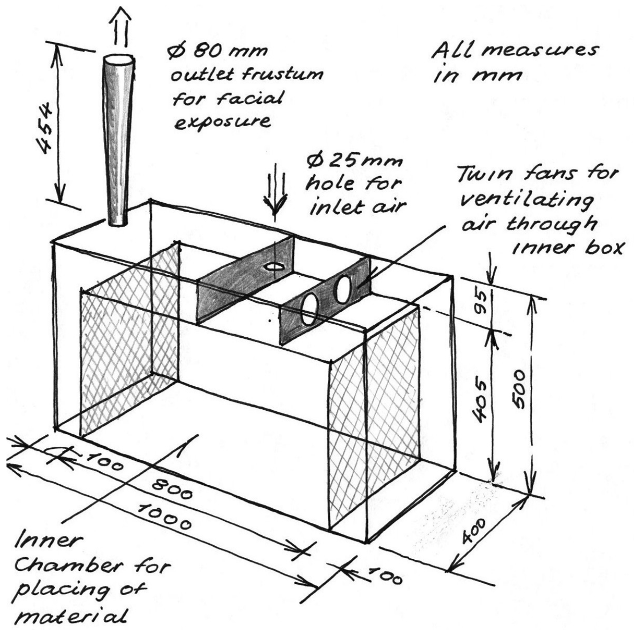

Figure 1 Schematic of glass box used for testing of materials with exhaust cone for sensory assessment by facial exposure of polluted outlet air.

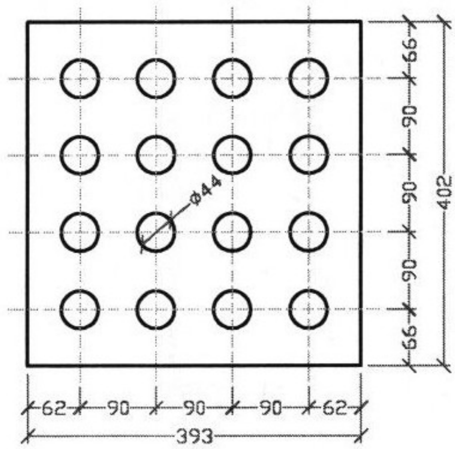

Figure 2 Pattern of twin plated cross-section for sandwiching of filter material.

The filter material used for the investigation was taken from one of ten filters that had been used as outside air filters (no re-circulation) in the same filter bank, and operated continuously for 6 months at a flow rate of 3400 m^3/h. They were full-framed 0.6 × 0.6 m EU7-filters with eight bags. Filter material for the experiments was taken from the same filter and cut out from the centremost filter bags.

The air velocity through a filter is usually in the range 1.5–4.0 m/s. For a common filter with a 0.6 × 0.6 m face area, such velocities correspond to flow rates between 540 and 1440 l/s. In the present tests a flow rate of 1000 l/s and an associated air velocity of approximately 3 m/s were chosen as nominal figures.

The actual air velocity perpendicular through the filter material depends on the number of bags and the bag area. For a 0.6 × 0.6 m EU7 filter with four, six or eight bags the total filter area and associated nominal velocity through the filter material will vary as seen in Table 1.

Table 1 Nominal air velocity through filter material for a 0.6 × 0.6 m EU7-filter with varying numbers of filter bags at a nominal flow rate of 1000 l/s

Number of filter bags	Filter area (m^2)	Nominal airflow rate (l/s)	Nominal face velocity of air (m/s)	Air velocity through filter material (m/s)
4	3.0	1000	2.78	0.33
6	4.5	1000	2.78	0.22
8	6.0	1000	2.78	0.17

The filter material was inserted in three out of four glass boxes—Boxes A, B and C—with all holes open in the cross-section, whereas the last box—with no filter material inserted—was used as a reference. The four boxes were subsequently ventilated continuously with the chamber air for 5 days prior to the start of the experiment to achieve equilibrium on the surface of the filter.

The experiment consisted of four tests. Opening or closing a number of the cross-section holes changed the velocity through the filter material from test to test. The flow rate for Boxes A and Box B covered 33, 67, 100 and 133% of the nominal velocity, whereas flow rates used for Box C covered a wider range from 25 to 200%.

Unfiltered outside air was conditioned to 22°C, 40% RH, and supplied to the chamber at an airflow rate of approximately 540 m^3/h (150 l/s). During the experiments the flow rates through the boxes were adjusted to 1.0 l/s. Depending on the number of openings in the cross-section, the velocity through the filter material varied from 25 to 400% of the nominal velocity for a 0.6 × 0.6 m EU7-filter with eight bags and from 12.5 to 200% for a four-bag filter.

An untrained panel assessed the air quality. The tests were carried out over two days with three assessments on the first day and one on the following day. Boxes were moved between each test in order to help randomize assessments.

A total of 18 persons, mostly employees and students at the Centre, participated. The number of participants in each session was 10–13. Each participant made five assessments in each test. The first, immediately after entry, was an assessment of the air quality of the climate chamber based on whole-body exposure. Assessments by facial exposure of the exhaust air from the four boxes followed.

RESULTS

The panel members assessed the perceived air quality on a continuous acceptability scale in a questionnaire. The mean acceptability and the 95% confidence interval for the three boxes containing the polluted filter are presented in Figure 3.

There was no statistically significant difference between the sensory evaluations for the three boxes. The acceptability was independent of the air velocity through the filter material.

The sensory pollution load was subsequently calculated from the difference between perceived air quality of exhaust air from the glass boxes with filter and the Reference Box without filter. The results are plotted in Figure 4 as a function of the velocity in percentage of the nominal velocity defined in Table 1.

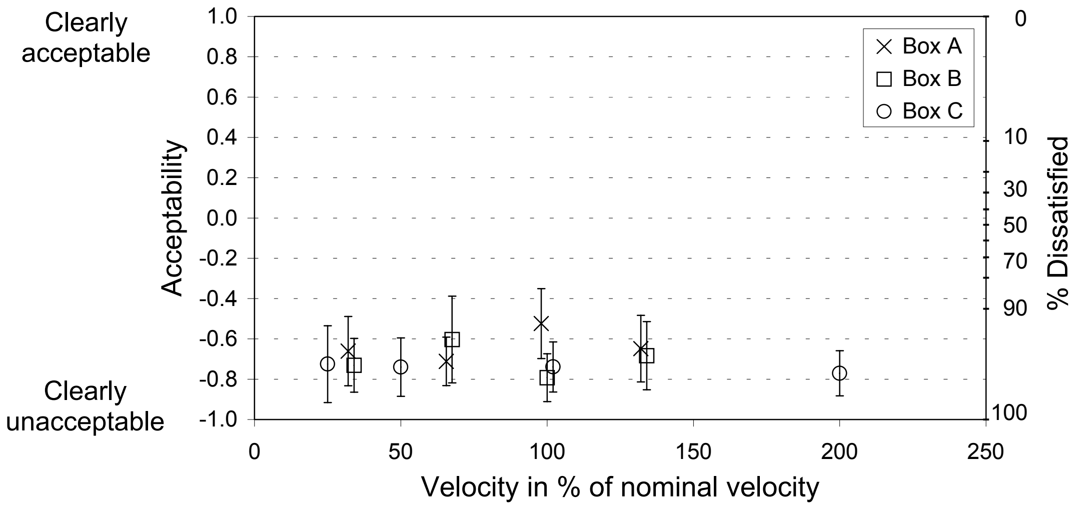

Figure 3 Sensory assessment of air quality from three boxes containing material from the same used filter as a function of air velocity through filter material. Also shown are the 95% confidence intervals.

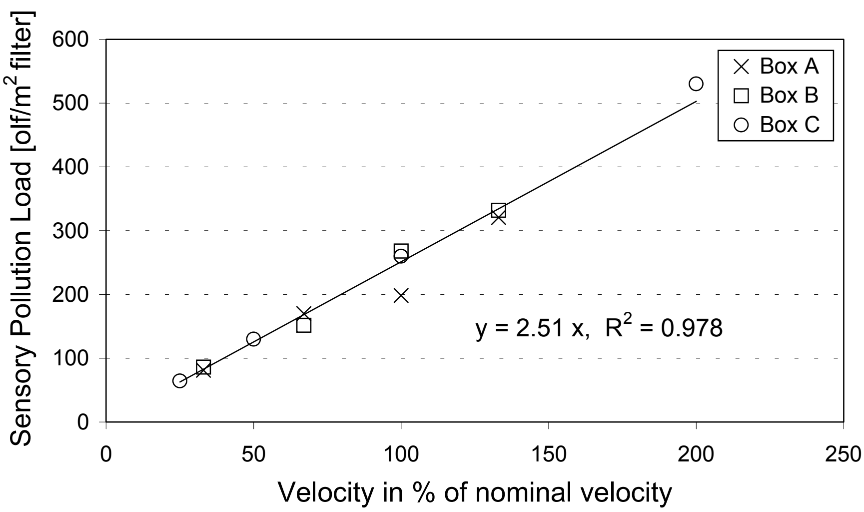

Figure 4 Sensory pollution load of the filter as a function of velocity.

DISCUSSION

The assessments from the three boxes, presented in Figure 3, show no significant difference between the various velocities used in the experiments. This means that pollution from the filter material increases at the same rate as the flow through the material. Thus, there was enough time for the chemical desorption processes to take place, even at the high air velocities.

Figure 4 consequently shows a linear relationship between the sensory pollution load of the filter in olf per square metre filter and the flow rate. This finding is in agreement with the results obtained by Alm, although the present results were obtained at flow velocities much higher. It is thus not possible to reduce the sensory pollution load from a ventilation filter by increasing the air velocity.

To use one of the Centre's climate chambers appears to have been a wise choice for the present study. With controlled environmental conditions, the climate chamber is suitable for controlling the supply air to the glass boxes with respect to temperature and humidity. This is important since temperature and humidity have a marked effect on acceptability assessments, and because the two factors are expected to influence the off-gassing from a used filter.

The use of the glass boxes as vehicles for testing the filter material afforded some obvious advantages compared to e.g. full-scale filter testing. By using a number of boxes, it is possible to perform several experiments at the same time, or, as in this study, to test identical filter material taken from the exact same filter bag in three different boxes simultaneously. Advantage was taken of this facility in the design of the experiments for two of the boxes by varying the airflow velocity in opposite directions in the course of the tests. This would have disclosed any tendency for the filters to be washed clean by the airflow during the experiments, an effect which did not occur.

Another important advantage in this experiment was the possibility to change the airflow velocity through the filter simply by opening or closing a number of the 16 openings in the cross-section of the box, still maintaining the same 1.0 l/s exit flow rate for assessments by facial exposure.

CONCLUSIONS

- Results from the experiments show that the pollution load from a filter is proportional to the flow rate, and that this proportionality holds at airflows up to and well above the flow rates commonly used in ventilation systems. This finding apparently invalidates any notion held previously that it is possible to improve the air quality downstream of a used filter by increasing (diluting) the airflow through the system.
- The set-up used in the experiments was sound considering that tests on four glass boxes could be carried out simultaneously; that the supply air in the glass boxes remained unpolluted and was adequately controlled with respect to temperature and humidity; that the experiments covered the whole velocity range; and that the airflow provided for facial exposure to the panel was kept constant at a flow rate of approximately 1.0 l/s, a temperature of 22°C, and 40% relative humidity.

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