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Sensory Pollution and Microbial Contamination of Ventilation Filters

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Abstract The sensory pollution load and microbial contamination of glass-fibre filters at high and low relative humidity were investigated in an experimental set-up in the laboratory. Dust and particles from the outdoor air were collected in two EU7 glass-fibre filters for a pre-conditioning period of 16–18 weeks during which there was a constant airflow with a velocity of 1.9 m/s through the filters. One of the filters was exposed to outdoor air of approximately 40% relative humidity and 10°C, the other to outdoor air of approximately 80% relative humidity and 5°C. The dust in ventilation filters can constitute a serious pollution source in the indoor environment, causing deterioration in the quality of the supply air even before it enters the ventilated spaces. The sensory pollution load from the used filters after the continuous operating time of 16–18 weeks was significantly higher than the sensory pollution load from new filters but the sensory load at 40% and 80% relative humidity did not differ. The microbial contamination of the supply air downstream of the filters, which on average had been exposed to outdoor air of 40% and 80% relative humidity, was negligible.

Key words Indoor air quality; Perceived air quality; Sensory pollution source; Ventilation filter; Microbial contamination; Dust

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Introduction

The aim of mechanical ventilation in office buildings is to remove and dilute emitted pollutants by supply and removal of air to the space in order to achieve an acceptable indoor air quality for the occupants of the ventilated spaces. However, during the last decade, numerous studies have reported that a significant percentage of occupants in non-industrial spaces may be exposed to indoor environmental conditions that can cause discomfort, reduced performance and even adverse health effects (Burge et al., 1987; Finnegan et al., 1984; Jaakola et al., 1991; Kröling, 1988; Robertson et al., 1985; Skov et al., 1987; Sundell et al., 1994; Turiel et al., 1983; Zweers et al., 1992). A major cause of the problems may be the mechanical ventilation or the air-conditioning system since several studies report more complaints and symptoms among occupants in mechanically ventilated or air-conditioned buildings than in naturally ventilated buildings.

Ventilation systems as a potential source of contamination in buildings have until recently been ignored in ventilation standards and guidelines (ASHRAE, 1989; NKB, 1981). The introduction of the sensory units, olf for sensory pollution source strength and decipol for perceived air quality, made it possible to quantify all pollution sources in a space (Fanger, 1988). Investigations in more than 50 buildings comprising offices (Fanger et al., 1988; Pejtersen et al., 1990), assembly halls (Fanger et al., 1988), schools (Thorstensen et al., 1990), kindergartens (Pejtersen et al., 1991) and bars (Pejtersen et al., 1988) have shown that the ventilation system often contributes a major part of the total sensory pollution load. In a more detailed study of eight ventilation systems, rotary heat exchangers, humidifiers and filters were found to be major pollution sources (Pejtersen et al., 1989). Further studies on the sensory pollution load of filters showed that the pollution load was caused by dust in the filters rather than by the filter material itself (Bluyssen, 1990; Hujanen et al., 1991) and that the pollution load increased with increasing operating time and with the amount of dust accumulated in the filters (Pasanen et al., 1994).

Ventilation systems may function as a reservoir or an amplification site for microorganisms (Morey, 1988; Ager and Tickner, 1983). Microorganisms need water and nutrients to be able to grow (Miller, 1992; Pasanen et al., 1991). Since ventilation filters are often placed close to the outdoor environment, the relative hu-

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midity in filters is typically high. In a ventilation filter in which the outdoor air is filtered, the organic material collected, together with dirt and debris, is sufficient to support microbial growth; filters are therefore always contaminated with microorganisms (Burge, 1987). If the filter is kept dry and unaffected by mechanical vibrations, the microorganisms will not be transferred to the supply air and will not therefore present a health risk. If the filter is wet, however, the accumulated organic material provides an excellent culture medium and microorganisms can grow through the filter to the downstream side and become airborne. Elixmann et al. (1989) found that this took place when the relative humidity of the air was above 70% rh. They found that the microorganisms present in the filters gave rise to an allergic reaction among 135 out of 150 allergic subjects who were exposed to the organisms. The presence of microorganisms in ventilation filters when the relative humidity is high has been verified by Martikainen et al. (1990) and Sverdrup and Nyman (1990).

The aim of the present study was to investigate whether the microbial contamination of a particle filter under winter conditions was responsible for the sensory pollution load from the filter and to investigate whether it was possible to reduce the sensory pollution load by keeping the relative humidity at a low level on the upstream side of the filter.

Method

Experimental Plan

The sensory and microbial pollution caused by two EU7 glass-fibre filters were investigated in an experimental set-up with two ventilation systems in the laboratory. Dust and particles from the outdoor air were collected in the filters for a pre-conditioning period of 16–18 weeks during which the ventilation systems were running continuously at an airflow of 0.6 m^3/s, corresponding to an air velocity of 1.9 m/s through the filters. A heating coil installed on the upstream side of one of the filters made it possible to expose the filter to outdoor air of approximately 40% relative humidity (dry filter). The second filter was exposed to outdoor air of approximately 80% relative humidity (humid filter). The filters were investigated after 1 week, after 16 weeks and after 18 weeks. The measurements after 1 week were made at an airflow of 0.6 m^3/s through the filters, after 16 weeks at an airflow of 0.6 m^3/s and 0.3 m^3/s and after 18 weeks at an airflow of 0.3 m^3/s and 0.15 m^3/s. During each experimental day, air samples were continuously exhausted before and after the filters. The air samples were assessed by a sensory panel, the members evaluating the perceived air quality c rectly in the sensory unit decipol. As a contr measure, the sensory panel also assessed the perceiv air quality before and after a new filter which was i stalled in the ventilation systems on the experimen day.

The amount of airborne bacteria and microfungi b fore and after each filter was measured after 16 and weeks, and the genus of microfungi was identifie The presence of bacteria and microfungi on the clea and soiled side of the filter material of the used filt was also investigated. The airflow in the ventilatio system was measured using the tracer gas technique

Facilities

The filters were tested in two ventilation systems s up in the laboratory as shown in Figure 1. The outdo air intake and the exhaust were placed on the roof c the laboratory which is situated in a surbub of Copen hagen. To maintain a low relative humidity in the sup ply air of one of the ventilation systems, an electric heating coil of 10 kW was installed upstream of th filter section in the ventilation system. During the con ditioning of the filters as well as during the experi ments, the airflows were kept the same in the two ven tilation systems.

Air samples were exhausted before and after the fil ters through exposure equipment as shown in Figur 1. The airflow in the exposure equipment was kept a 0.6 L/s, corresponding to a maximum air velocity o

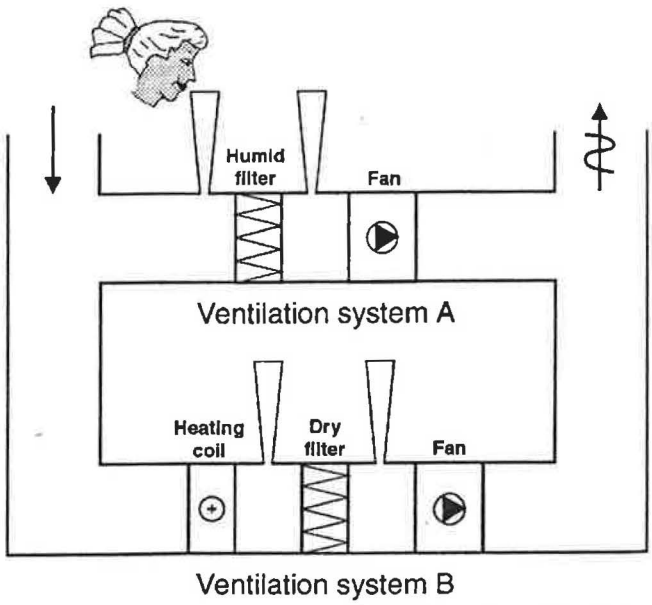


Fig. 1 The experimental facilities for testing filters. Ventilation system A for exposing filters to humid outdoor air and ventilation system B for exposing filters to dry air. Air samples were exhausted before and after each filter

0.6 m/s in the outlet of the tubes. The air temperature in the exposure equipment was maintained at 23°C.

Before assessing the air quality in the exposure equipment, the panel freshened up their olfactory and general chemical senses by inhaling outdoor air which was presented to them in an exposure hood at a temperature of 20–22°C.

During the pre-conditioning period of 16–18 weeks, the relative humidity and the air temperature before and after the filters were measured every 15 minutes using 4 VAISALA HMP130Y temperature and humidity sensors connected to a computer and a datalogger. The air temperature and relative humidity of the air exhausted from the ventilation systems by the exposure equipment were measured with a Brüel and Kjær Indoor Climate Analyzer Type 1213. Measurements of the airflow in the ventilation systems were performed with a Brüel and Kjær Multi-gas monitor Type 1302 and a Multipoint Doser and Sampler Type 1303 together with the Ventilation software Type 7620. The airflows were measured using the constant dosing method (Charlesworth, 1988).

The measurements of airborne microfungi and bacteria were performed as 10-minute volumetric measurements (33 L/min) with a BIAP slitsampler using the selective media V-8-agar containing antibiotic and blood agar, respectively. The presence of microfungi and bacteria on the clean and on the soiled side of the filter material was determined by taking imprints from both sides of the filters using Petri-dishes with the same media as for the airborne microorganisms. The exposed Petri dishes were incubated at 25°C and 30°C during 5–8 days and nights (microfungi) and 1–3 days and nights (bacteria). The analyses were performed by the Allergologisk Laboratorium, Denmark.

Sensory Panel

Seven to nine subjects participated in the sensory assessments on each experimental day. The subjects were taken from a group of 15 selected subjects who were trained to assess perceived air quality by comparing the annoyance of the test sample with the annoyance of 5 known reference concentrations of 2-propanone corresponding to an expected perceived air quality of 1, 3, 5, 10 and 20 decipol (Bluyssen et al., 1989). Prior to the experiments, the 15 subjects received three days of two hours' intensive training in assessing perceived air quality, using 2-propanone as reference gas. During the 2-hour training period the subjects, one by one, were exposed to 8–15 different concentrations of 2-propanone. After assessing one of the training concentrations, the subject was told the expected value and the performance was discussed with the experiment leader. In addition to the exposures of 2-propanone, the subjects were exposed to air samples polluted by ventilation components and building materials. For these samples there were no correct answers and the subjects were therefore not given any feedback but it was emphasized that they should assess the annoyance of the air sample rather than the intensity.

Each experimental day the subjects were retrained in assessing perceived air quality. During the 2-hour training period the subjects were exposed to 8–10 different concentrations of 2-propanone. The performance of the panel on the experimental days was followed by exposing the subjects to eight concentrations of 2-propanone which they assessed without any feedback from the experiment leader. The subjects were exposed to the same eight concentrations on each experimental day.

Procedure

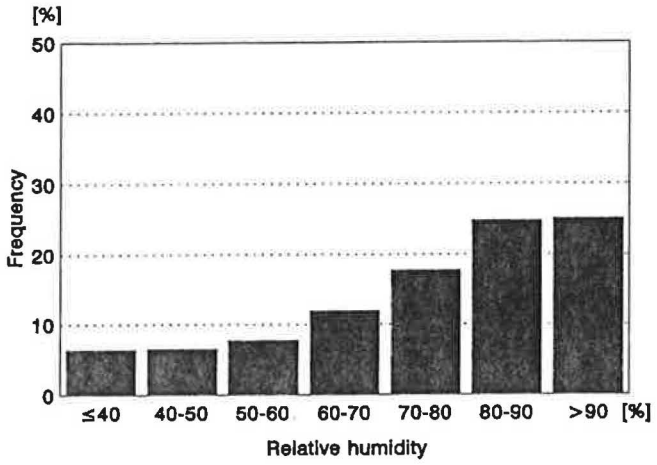
Before the filters were installed in the ventilation systems for the pre-conditioning period, the two experimental filters and the control filter were weighed. Prior to the weighing, the three filters were conditioned in a climate chamber at an air temperature of 20°C and a relative humidity of 20% rh. The experimental filters were installed in the ventilation systems and the control filter was sealed in a plastic bag. The airflows were adjusted and kept at the same level in the two ventilation systems.

Two hours before the sensory assessments, the heating coil was turned off so that the air samples in the exposure equipment were kept at the same temperature during the sensory assessments. The airflows were measured before and after each experiment.

On the experimental day, the subjects went through the two-hour retraining period before they made the sensory assessment of the air samples from the ventilation system which lasted approximately two hours. The subjects were placed in a well ventilated climate chamber. During each round of assessment the subjects one by one went to the climate chamber where they assessed one of the eight performance concentrations

Table 1 Average relative humidity and temperature of the air passing the two filters during the 18 weeks. The standard deviation is included in the table

	Relative humidity [% rh]		Air temperature [°C]	
	Humid filter	Dry filter	Humid filter	Dry filter
Mean	75	44	5.0	12.4
Standard deviation	19	15	5.6	7.6



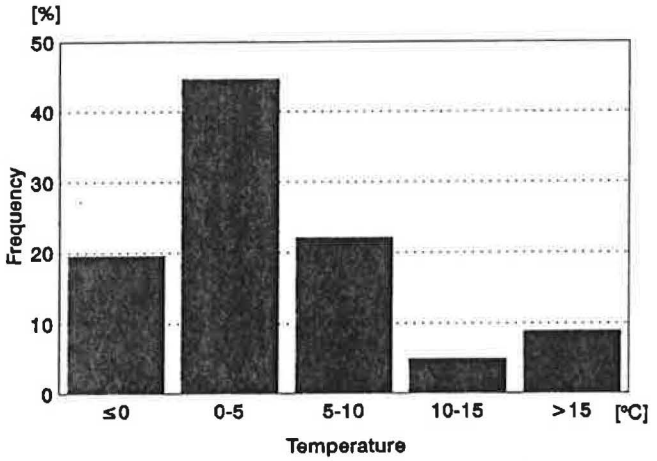


Fig. 2 The frequency distribution of the relative humidity and temperature of the air to which the humid filter was exposed during the conditioning period of 18 weeks

before they went to the ventilation systems. They refreshed their olfactory and general chemical senses by taking two to three inhalations of outdoor air presented to them in the exposure hood. The subjects then assessed one of the air samples exhausted from the ventilation system and returned to the waiting room.

Each experiment was divided into three parts. In the first part the subjects assessed the perceived air quality before and after the dry and humid filter in random order. In the second part the humid filter was replaced by the control filter and the experiment was repeated. In the last part the humid filter was put back into ventilation system A and the dry filter was replaced by the control filter. By using this experimental design the perceived air quality before and after each filter was assessed twice. Between each part there was a break of 10–15 minutes to ensure that the temperature of the filters was in equilibrium with the temperature of the supply air. When a filter was not used in the experiment it was kept in a sealed plastic bag.

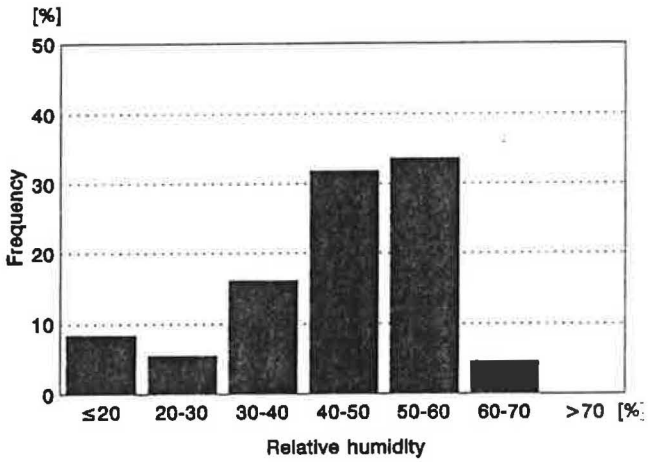
The measurements of bacteria and microfungi w performed immediately after finishing the sensory sessments.

At the end of the experiment the three filters w weighed after a conditioning period of 6 hours at air temperature of 20°C and a relative humidity of 2 rh.

Results

The average air temperature and relative humidity the two ventilation systems during the 18 weeks a shown in Table 1. The standard deviation of the mea urements is included in the table. The frequency dist bution of the air temperature and relative humidi during the 18 weeks is given in Figure 2 for the hum filter and in Figure 3 for the dry filter.

The dust collected during the 18 weeks amounted 129 g in the humid filter, 102 g in the dry filter and g in the control filter.



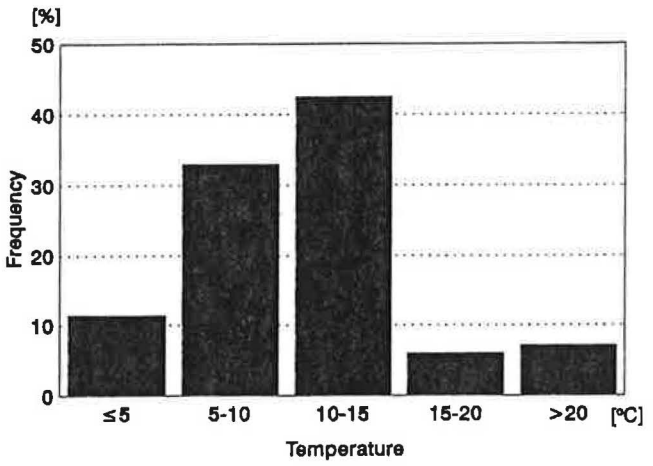


Fig. 3 The frequency distribution of the relative humidity and temperature of the air to which the dry filter was exposed during the conditioning period of 18 weeks

Table 2 Airborne bacteria and microfungi in the outdoor air, the air after the humid and the dry filter, collected by a BIAP Slit-Sampler

	Operating time and airflow					
	16 weeks, 0.6 m^3/s			18 weeks, 0.3 m^3/s		
	Outdoor	After humid filter	After dry filter	Outdoor	After humid filter	After dry filter
Microfungi Number [CFU/m^3] and genus	6 *Mucor Spinosus*	4 *Cladosporium herbarum* 2 *Mycelia sterilia*	No growth	38 *Cladosporium herbarum* 10 *Chaetomium sp.* 6 *Alternaria sp.* 2 *Aspergillus sp.* 10 *Mycelia sterilia*	2 *Aspergillus terreus* 2 *Penicillium sp.* 2 *Trichoderma viride* 2 *Mycelia sterilia*	2 *Aspergillus sp.* 2 *Rhizopus nigricans*
Total [CFU/m^3]	6	6	0	66	8	4
Bacteria Total [CFU/m^3]	280	26	6	336	32	12

The measurements of airborne microfungi and bacteria in the outdoor air and in the air downstream of the two filters after 16 and 18 weeks are shown in Table 2. The measurements after 16 weeks were made at an airflow of 0.6 m^3/s whereas the measurements after 18 weeks were made at an airflow of 0.3 m^3/s. The concentration of airborne bacteria and microfungi downstream of the dry and humid filter was negligible. The growth of bacteria and microfungi on the dishes with imprint samples taken from the clean and from the soiled side of the filter material after 16 and 18 weeks is shown in Table 3. There was massive growth of both microfungi and bacteria on the dishes with samples from the soiled side of both the dry and the humid filter, whereas the growth of bacteria and microfungi on the dishes with samples from the clean side of both filters was negligible. There was no difference between the microbial contamination caused by the two filters and there was no difference between the measurement made after 16 weeks and that made after 18 weeks.

The temperature of the air samples to which the subjects were exposed in the exposure equipment during the experiment after one week was on average 18.3°C with a standard deviation of 0.5°C. The air temperature in the exposure equipment during the rest of the experiments was on average 23.1°C with a standard deviation of 0.3°C. The relative humidity in the exposure

Table 3 The growth of bacteria and microfungi on Petri-dishes with imprint samples from the filter material

	Operating time							
	16 weeks				18 weeks			
	Humid filter		Dry filter		Humid filter		Dry filter	
	Soiled side	Clean side	Soiled side	Clean side	Soiled side	Clean side	Soiled side	Clean side
Microfungi	* *Cladosporium herbarum*** * *Penicillium sp.* * *Rhizopus nigricams*	No growth	* *Cladosporium herbarum* * *Cladosporium* * *Penicillium sp.* * *Trichoderma viride*	No growth	* *Cladosporium herbarum*** * *Chaetomium sp.* * *Gær sp.* * *Trichosporon pullulans* * *Mycelia sterilia*	*** *Chaetomium sp.*	* *Cladosporium herbarum* * *Alternaria sp.* * *Fusarium sp.* * *Mucor spinosus*	*** *Mycelia sterilia*
Bacteria	Massive growth	No growth	Massive growth	Poor growth	Massive growth	Poor growth	Massive growth	Poor growth

*Massive growth, **Dominating, ***Poor growth

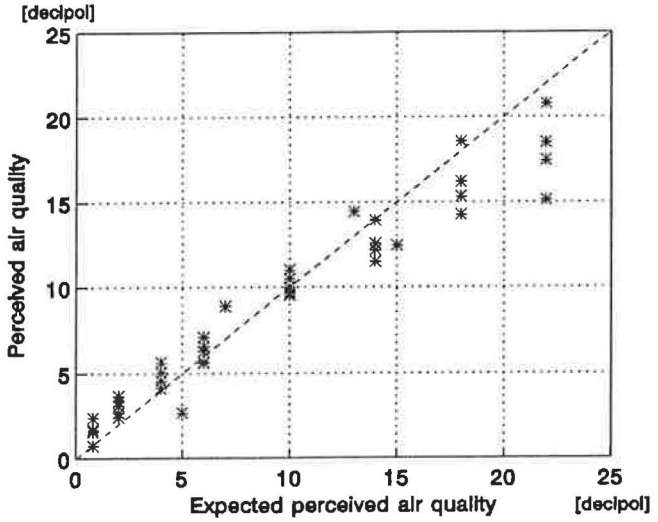


Fig. 4 The perceived air quality as a function of expected perceived air quality when assessing the performance concentrations of 2-propanone. Included in the figure is the line Y=X

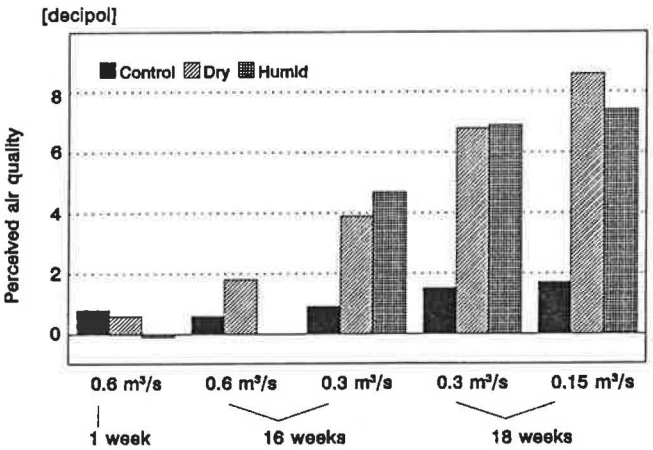


Fig. 5 Mean increment in perceived air quality of the air passing the filters after an operating time of 1 week at an airflow of 0.6 m^3/s and after 16/18 weeks at an airflow of 0.15 m^3/s, 0.3 m^3/s and 0.6 m^3/s. The control filter is shown for comparison

equipment during the experiments was on average 18% rh with a standard deviation of 3% rh.

The sensory assessments of the performance concentrations during the experimental period are shown in Figure 4. The figure shows the mean perceived air quality as a function of the expected perceived air quality.

The results of the sensory assessments before and after the dry, the humid and the control filter are shown in Table 4. The table includes the mean of the subjects' perceived air quality and the standard error of the mean based on two repeated assessments of each subject. The mean increment in perceived air quality of the air passing the dry, the humid and the control filter

after an operating time of 1 week, 16 weeks and weeks is shown in Figure 5.

The sensory pollution source strength for each fi was calculated from the mean increment in perceived air quality across the filters and the airflow through the filter, using the comfort equation (Fanger, 19 The mean sensory pollution source strength for the vestigated operating times and airflows is shown Figure 6.

Analysis

The assessment of the air polluted by the control fi on each experimental day made it possible to comp the increment in the perceived air quality across two test filters with the increment in perceived quality across the control filter. The experiment m at an airflow of 0.3 m^3/s was performed after 16 we and repeated after 18 weeks. From Figure 5 it can seen that the increment in perceived air quality acr

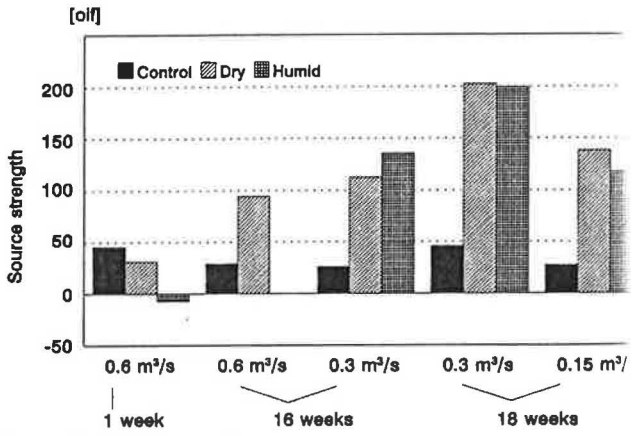


Fig. 6 The sensory pollution source strength after an operat time of 1 week at an airflow of 0.6 m^3/s and after 16/18 we at an airflow of 0.15 m^3/s, 0.3 m^3/s and 0.6 m^3/s. The con filter is shown for comparison

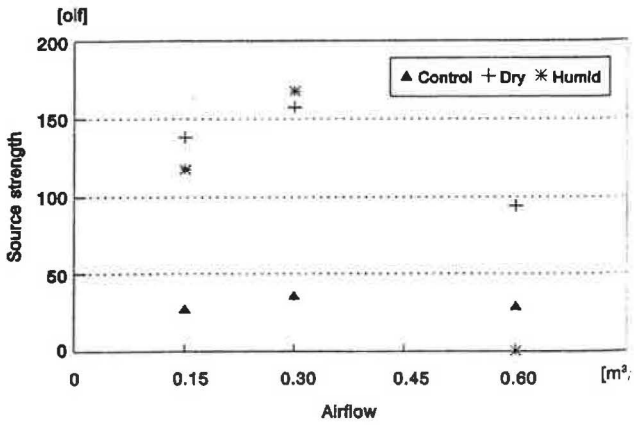


Fig. 7 Pollution load caused by the used filters and by the cont filter as a function of the airflow

Table 4 The subjects' mean assessment and standard error of the mean of the perceived air quality before and after the filters

Operating time [week]	Air-flow [m^3/s]	Perceived air quality [decipol]											
		Humid filter				Dry filter				Control filter			
		Before filter		After filter		Before filter		After filter		Before filter		After filter	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	0.6	4.3	0.97	4.2	0.86	3.9	0.79	4.5	0.76	4.3	0.83	5.1	0.95
16	0.6	4.9	0.67	4.9	0.58	5.3	0.65	7.1	1.00	5.3	0.72	5.8	0.80
16	0.3	2.5	0.68	7.2	1.24	2.3	0.73	6.1*	2.1*	3.3	0.64	4.1	1.28
18	0.3	1.9	0.40	8.8	1.35	2.6	0.58	9.4	1.22	3.1	0.59	4.6	1.02
18	0.15	2.2	0.33	9.6	1.19	3.6	0.71	12.2	1.64	3.1	0.49	4.9	0.75

* Mean values based on one assessment made by the panel

both the dry, the humid and the control filter was larger in the experiment made after 18 weeks compared with the experiment made after 16 weeks. An analysis of variance on the increment of perceived air quality across the filters was performed to investigate whether there was any significant difference between the results obtained on the two experimental days. The analysis of variance took into consideration the random effect of subjects and the fixed effect of filter type. The analysis showed that the results on the two experimental days were not significantly different at a 5% level. The data from the two experimental days were therefore pooled in the further analysis.

Figure 5 shows no systematic difference in the increment in perceived air quality across the humid filter compared with the dry filter. Since the airflows through the two filters were identical, there was no difference in the sensory pollution source strength for the two used filters as seen in Figure 6.

Figure 7 shows the mean sensory pollution source strength for the used filters and the pollution load for the control filter as a function of the airflow. The pollution source strength for the used filters measured at an airflow of 0.3 m^3/s was the mean source strength measured after 16 and 18 weeks. It was investigated whether the source strength for the used filters was different from the control filter and whether the source strength was independent of the airflow. An analysis of variance was performed followed by a Student-Newmann-Keuls multiple range test on the effect of airflow. The analysis took into consideration the random effect of subject, the fixed effect of type of filter and the fixed effect of airflow. It showed that the sensory pollution load from the used filters was significantly different from the load caused by the clean control filter (α=5%). The analysis showed furthermore that the pollution load for the used filter measured at 0.6 m^3/s was statistically different from the pollution load measured at 0.15 m^3/s and 0.3 m^3/s (α=5%). The pollution source strength for the clean control filter was independent of the airflow (Figure 7). However, Figure 7 shows that the pollution source strength for the dry and for the humid filter was the same on each experimental day, except after 16 weeks measured at an airflow of 0.6 m^3/s when the source strength for the humid filter was negligible. This was an unexpected result compared to earlier studies on the sensory pollution load caused by used filters (Bluyssen, 1990). If the results for the humid filter measured at 0.6 m^3/s after an operating time of 16 weeks were excluded from the analysis, the source strength of used filters was then independent of the airflow.

Discussion

The sensory pollution load from the used filters was significant compared with new filters. These findings were in agreement with results by Pejtersen et al. (1989), Bluyssen (1990) and Pasanen et al. (1994) and confirm that dust in filters can constitute a serious pollution source in the indoor environment, causing a deterioration in the quality of the supply air even before it enters the ventilated spaces. The challenge of the future may therefore be to develop alternative filtering methods, removing the dust from the air in such a way that the dust gathered is prevented from polluting the supply air.

The sensory pollution source strength for the used filters after 18 weeks' operating time was on average 164 olf (measured at an airflow of 0.15 and 0.3 m^3/s). During the 18 weeks, on average $6.7 \cdot 10^6$ m^3 of air passed through the filters and 116 g dust was collected in the used filters, corresponding to 17 $\mu g/m^3$. The sensory pollution source strength for the filter material obtained from the measurement on the new control filter after 18 weeks was on average 37 olf. The sensory pollution source strength for the dust was calculated by subtracting the sensory source strength of the filter ma-

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terial from the total source strength of the used filter. The sensory pollution source strength for the dust was 127 olf, corresponding to 1 olf/g dust.

The sensory pollution load from the dry filter, which on average had been exposed to air of 40% relative humidity, was no different from the sensory pollution load from the humid filter which on average had been exposed to air of 80% relative humidity. There was no visible indication of microbial growth, neither on the soiled nor on the clean side of the dry or the humid filter. The microbial growth on the Petri dishes with the samples from the imprints taken from the humid filter was no different from the growth on the dish with the imprints from the dry filter, even though there was a large difference in the relative humidity of the air passing the two filters during the pre-conditioning period.

The results of the present study cannot confirm the results of Elixmann et al.(1989), who found that microorganisms were able to grow through the ventilation filter from the soiled side to the clean side of the filter when the relative humidity of the supply air exceeded 70%. However, the results agree well with the work by Ohgke et al. (1993), who studied *Pencillium*'s ability to grow in filters. The filters were artificially polluted with *Pencillium* spores and even though water was regularly added to the filters, no growth was observed. The results of the present study are supported also by the results of Kemp et al. (1995), who found no microbial growth in a glass-fibre filter that over a span of one year was challenged continuously with outdoor air. However, a subsequent test showed that by continuously exposing a filter to outdoor air of a constant relative humidity of 90%, visible microbial growth was observed within a month.

Microbial activity increases with increasing humidity, the most favourable conditions for the organisms being at 70–100% rh. This has often led to the misunderstanding that keeping the relative humidity in the ambient air below 70% rh will prevent microbial contamination (Gravesen et al., 1994). However, it is rather the water content of a material than the water content in the air that determines the microbial growth (Flannigan, 1992; Nevalainen, 1993; Gravesen et al., 1994). The relative humidity of the ambient air is therefore of less importance as long as there is sufficient water in the material to support the microbial growth (Pasanen et al. 1991). From Table 3 it can be seen that the growth of microfungi and bacteria from the clean side was negligible both for the dry and for the humid filter. Consequently, the presence of microfungi and bacteria in the air after both filters was negligible, as seen from Table 2. However, if the filters are exposed directly to water, causing the humidity in the filter the water activity in the filter material to increase microorganism may grow through the filter and come airborne, constituting a possible health risk (ge, 1987). This applies particularly to microfung which some are toxic, and a number of species can rise to a severe allergic reaction (Gravesen et al., 1 Gravesen et al., 1986).

The microbial contamination on the soiled sid the filters may have an effect on the perceived air q ity since the microorganisms identified may emit atile organic compounds which are perceived as noying by humans. The metabolites of microor isms, the microbial volatiles (mVOC), are vol organic compounds that are emitted by the m organisms during growth (Gravesen et al., 1 Microfungi such as *Penicillium, Trichoderma, Viride Chaetomium* are organisms which can emit micr volatiles that cause an unpleasant odour. It is li that mVOC from these organisms contributed to sensory pollution load caused by the used filters.

In the present study, the total number of CFU of teria in the air and the growth of bacteria on the f material were measured but the bacteria were not i tified. The presence of bacteria in the indoor envi ment is not yet investigated as well as the pres of microfungi. However, Nevalainen et al. (1990) h shown that colonies of streptomycetes were foun 70% of bacterial samples taken at sites with indoo problems. The results have been supported by the fi ings by Ström et al. (1990) who studied microor isms in building materials of sick and healthy bu ings and found streptomycetes in 25% of the sam taken in the sick buildings. Streptomycetes are m philic actinomycetes that produce geosmine wl gives rise to an annoying earthy odour. The bact are able to grow even in the presence of a neglig amount of water and have an optimum growth at 2 (Nevalainen et al., 1990). According to Nevalaine al. (1990), there is no information on the possible he hazard associated with mesophilic actinomycetes. likely that volatile organic compounds emitted fi bacteria contributed to the sensory pollution load fi used filters in the present study.

The sensory pollution source strength for the r filter was significantly lower than for the used fil and was constant during the experimental period, dependent of the airflow. The pollution source stren for the used filters had a weak dependency on the flow when the analysis was performed on all the d The source strength decreased with increasing airfl However, when excluding one data point which not follow the general pattern, the analysis sho

that the source strength was quite constant, independent of the airflow. These findings do not support the results of Bluyssen (1990) who found that the sensory source strength of used filters increased with increasing airflow. However, Knudsen (1994) has shown that the source strength for various building materials may not be independent of the airflow since the emission rate for a material may increase or decrease with the pollution concentration.

Conclusions

Dust in ventilation filters can constitute a serious pollution source in the indoor environment, causing a deterioration in the quality of the supply air even before it enters the ventilated spaces.

The concentration of airborne bacteria and microfungi in the supply air downstream of the glass-fibre filters which for 16 weeks on average had been exposed to outdoor air of 40% and 80% relative humidity, was negligible.

The sensory pollution load from a filter which on average had been exposed to air of 40% relative humidity was no different from the sensory pollution load from a filter which on average had been exposed to air of 80% relative humidity.

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