PARTICLE RELEASE OF FINE FILTERS DURING DIFFERENT OPERATIONAL CONDITIONS OF VENTILATION SYSTEM

Helmi Kokotti[1], Raimo Halonen[1], Liisa Kujanpää[2], Timo Keskikuru[1], Matti Lehtimäki[3], Aimo Taipale[3] and Marjut Reiman[2]

[1] *University of Kuopio, Kuopio, Finland*
[2] *Regional Institute of Occupational Health, Kuopio, Finland*
[3] *VTT Automation, Tampere, Finland*

ABSTRACT

The fine filter (EU7) was included in the ventilation system which operated at full capacity only during working days. The first three months the filter was located in the ventilation system of the office building and it was later moved for one month period into the laboratory chamber. The aim of the study was to investigate whether particles or microbes are released from the filter during the turn off and start up of the fan. The released particle (size range of 0.3 µm) concentration was below 10 #/dm^3 in normal field conditions. In some cases the particle concentrations increased also when the fan was turned on. The concentration exceeded simultaneously 100 #/dm_. The final material sampling after field and laboratory tests revealed the more abundant microbial growth in lower parts than in the upper parts of the filter bag. During start up of the fan, release of airborne microbes e.g. *Aureobasidium* could be observed, however, only during field tests. The possible explanation for that could be the change in the conditions.

KEYWORDS

Supply air, particles, infiltration, operation time

INTRODUCTION

In moderate climates as in Finland it is common practice to operate air conditioning devices intermittently because of energy saving aspects. It has been found out that microbes may transport via supply ventilation ducts (Halonen *et al*. 1999). The aim of our study was to focus on the possible release of particles including microbes from filters during the turn on the fan.

MATERIALS AND METHODS

The glass fiber bag filter (EU7) was included in the ventilation system which operated periodically so that it used full capacity only during working days. The temperature and relative humidity were monitored continuously for four months during spring (Vaisala HMP 143 A and Vaisala HMP 230) and data taker (Grant SQ 1027). The first three months the filter was located in the ventilation system of the office building and it was later removed for one month period into the test ventilation system (figure 1). Temperature, humidity and amount of air flow rate were changed both in the field and in the test chamber having the HEPA filter as the pre filter for the tested filter. Thus, the observed particle concentrations in the test

chamber were caused by the particle release of the used filter. The microbial contamination was examined by material samples of the fine filter.

The concentration of particles was detected by particle counter MetOne 237. The particle concentrations are presented as cumulative concentrations meaning that the number concentrations in different size ranges (0.3 µm, 0.5 µm, 0.7 µm, 1.0 µm, 2.0 µm and 5.0 µm) include all the detected particles above the mentioned range. The weakness of this particle measurement method is that it does not measure reliably particle concentrations at the range above 10 µm.

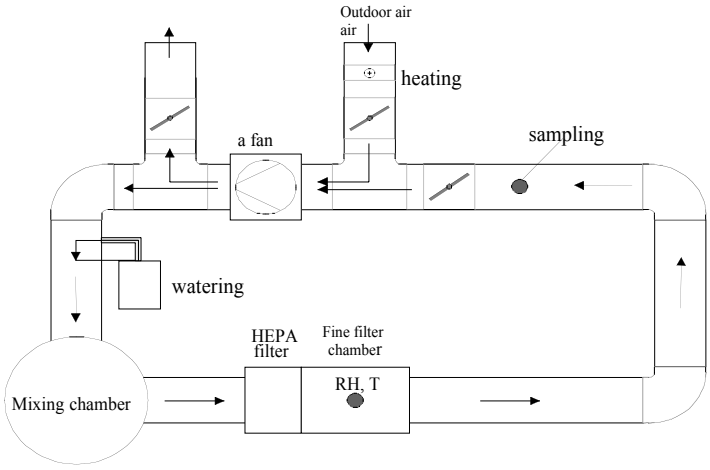


Figure 1: The drawing of the test ventilation system in the laboratory.

Culturable microbes were determined from the samples to evaluate the microbial contamination. Mesophilic fungi were cultivated on Rose Bengal malt agar (Hagem agar), 2 % malt extract agar (MEA) and dichloran glycerol agar (DG18), bacteria on tryptone yeast glucose agar (TYG) for 7 days at +25 ^{o}C, and thermophilic fungi on MEA for 5 days at +40^{o}C. Results are expressed as colony forming units (cfu). The samples were taken from fine filter material (cfu/g), air (cfu/m^{3}) and surfaces (cfu/plate) from filter chamber and duct after the filter.

RESULTS

Relative humidity and temperature

The average values of relative humidity (RH, %), temperature (T, ^{o}C) and water content (w, g/m^{3}) in the filter of ventilation having system operated from 6 a.m. to 9 p.m. were following 68%; 0.3 ^{o}C; 3.7 gm^{-3} in the field and 75%; 13.4 ^{o}C; 8.8 gm^{-3} in the test system.

When the fine filter was in the office building, surfaces of the filter chamber were contaminated by *Aureobasidium, Cladosporium, Eurotium, Paecilomyces Penicillium,* sterile fungi and yeasts (Table 1). The corresponding air sample included *Aspergillus penicillioides, Aspergillus versicolor, Cladosporium* and *Penicillium* before starting the fan operation; *Aureobasidium, Penicillium* and Sphaeropsidales during the start up and only *Penicillium* after half an hour of the start up. The material sample was taken in the same time and it

included *Aureobasidium, Cladosporium, Eurotium* and *Penicillium* (Table 1). The concentration varied in the range from 10^3 to $7x10^4$ cfu/g. The similar laboratory test did not reveal either microbial contamination of chamber surfaces (Table 2) or any significant release of microbes, only airborne *Acremonium* was observed during the start up of the fan. The final material sampling after field and laboratory tests revealed the more abundant microbial growth in lower parts than in the upper parts of the filter bag. The concentrations of viable fungal spores varied in the range from $0\text{-}6x10^4$ cfu/g (Figure 2a) and those of bacteria varied in the range from 10^3 to $2x10^5$ cfu/g (Figure 2b).

Figure 2a.

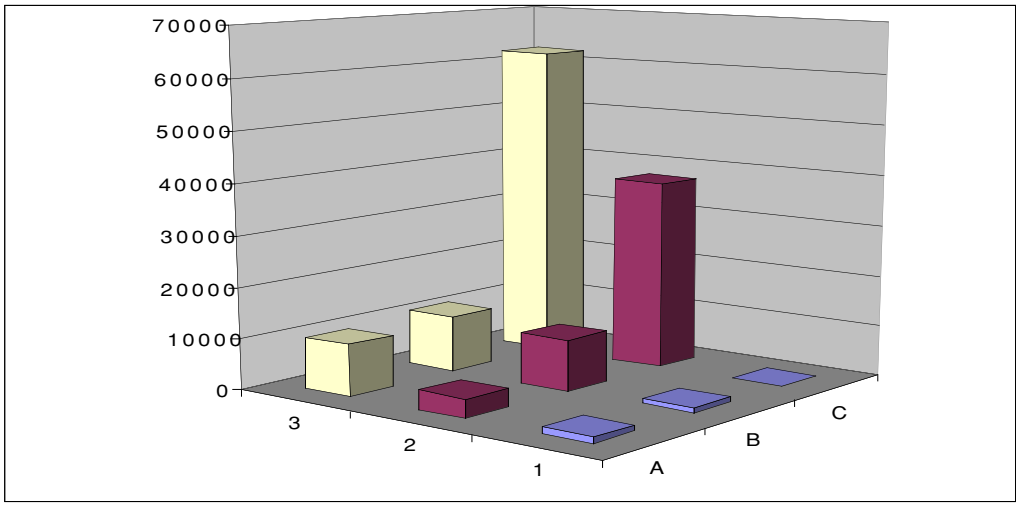


Figure 2b.

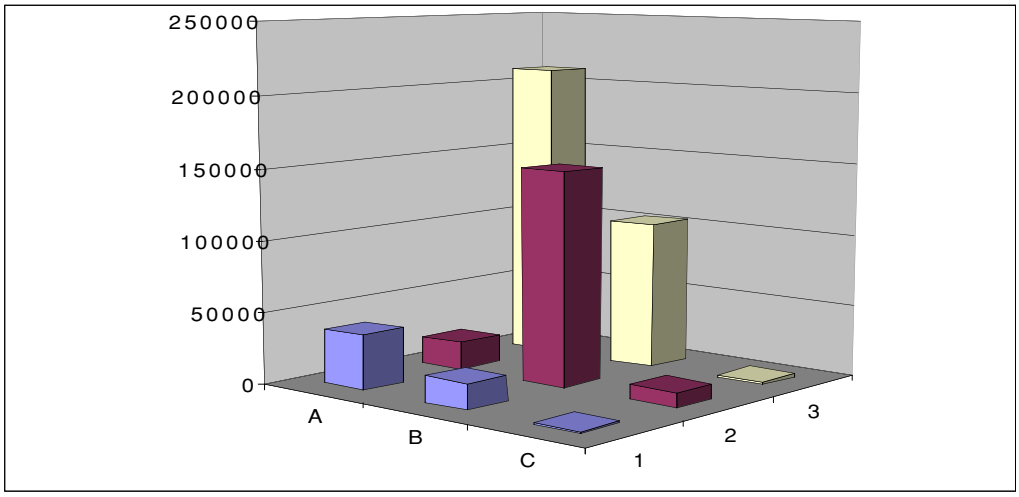


Figure 2: Concentrations of viable fungal spores (cfu/g) (Figure 2a) and bacteria(cfu/g) (Figure 2b) in the material samples of the fine-filter bags (A, B and C) after four months of initial installation in the field ventilation system and two weeks after the laboratory test. The samples from each bag were taken from the face (1), middle (2) and bottom (3) the bag. Detection limit was 100 cfu/g. The filter was kept in the stable conditions, relative humidity of 30 % and temperature of 20^o for a week before the sampling.

TABLE 1
The occurrence of different microbes in air, surface and material samples from air-conditioning unit during field tests on the 3rd of April 2001.
(nd=microbe was not detected).

Microbe	Surface samples from filter chamber (-,+,++)	Air samples before fan operation (cfu/m3)	Air samples during fan operation (cfu/m3)	Air samples 0.5 h after fan operation (cfu/m3)	Filter material (cfu/g)
Aspergillus spp.	Nd	1	Nd	Nd	Nd
Aspergillus penicillioides	Nd	5	Nd	Nd	Nd
Aspergillus versicolor	Nd	5	Nd	Nd	Nd
Aureobasidium	+	Nd	2	Nd	1000
Cladosporium	+	7	Nd	Nd	6000
Eurotium	+	Nd	Nd	Nd	1000
Paecilomyces	+	Nd	Nd	Nd	Nd
Penicillium spp.	++	28	35	7	71200
Sphaeropsidales	Nd	Nd	2	Nd	Nd
Sterile fungi	+	Nd	2	Nd	1800
Yeasts	+	Nd	Nd	Nd	2000

TABLE 2
The occurrence of different microbes in air, surface and material samples from air-conditioning unit during laboratory tests on the 17th of May 2001.
(nd=microbe was not detected).

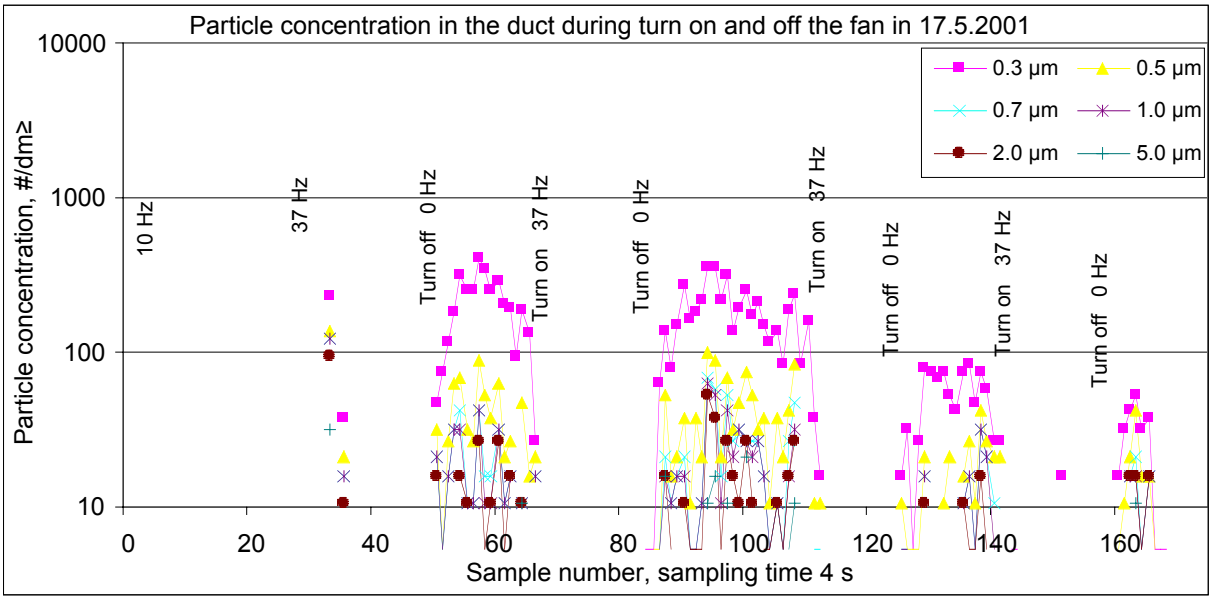
Microbe	Surface samples from filter chamber (-,+,++)	Air samples before fan operation (cfu/m3)	Air samples during fan operation (cfu/m3)	Air samples 0.5 h after fan operation (cfu/m3)	Filter material (cfu/g)
Acremonium	Nd	Nd	2	Nd	1000
Aureobasidium	Nd	Nd	Nd	Nd	2700
Cladosporium	+	Nd	Nd	Nd	9000
Penicillium spp.	Nd	Nd	Nd	Nd	82900
Sterile fungi	Nd	Nd	Nd	Nd	9100
Yeasts	Nd	Nd	Nd	Nd	2700

Particles

The concentrations of released particles were found to be in general low (below 10^4 #/dm^3). Figures 1. and 2. present the concentrations of released particles of the fine filter included previously in the ventilation system which operated at full capacity only during working days. The different air flow rates were adjusted by the frequency inverter ranging from 0 Hz to 37 Hz (0-2,8 m/s). Although the increase in the flow rate by utilizing the adjustment frequency of 37 Hz, probably caused mechanical stress in the filter, the particle release was not observed to increase significantly. When the fan was turned off, the particle concentrations were slightly increased to the level below 10^3 #/dm^3. This increase could be caused by the uncontrolled air flows in the test chamber or the mechanical stress in the contracting filter bags. Even as small as adjustment frequency of 3-4 Hz was enough to dilute the particle release of the contaminated fine filter. The released particle (size range of 0.3 μm) concentration was below

10 #/dm^3 in normal field conditions. In some cases the particle concentrations increased also when the fan was turned on. The concentration exceeded simultaneously 100 #/dm_.

A. the first day



B. the last day

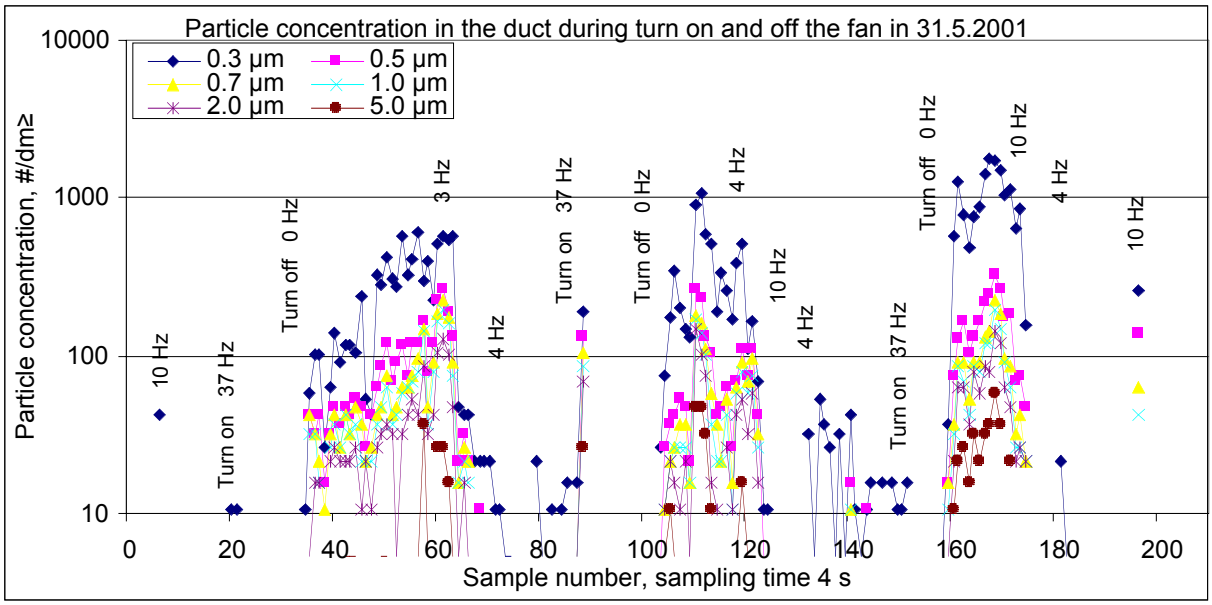


Figure 1: The concentrations of released particles (#/dm^3) of the fine filter included previously in the ventilation system which operated at full capacity only during working days. The different air flow rates were adjusted by the frequency inverter ranging from 0 Hz to 37 Hz (0-2,8 m/s) during the test period. A. the first day and B. the last day.

DISCUSSION AND CONCLUSION

The same species of microbes have been earlier observed (Halonen et al., 1999) in the filter material, in supply air chamber and in the room air e.g. *Aureobasidium,* was found in five transport routes of supply air. On the other hand, the former laboratory studies (Lehtimäki and Taipale, 2000) made by filter material samples with test particle loading indicated that concentrations of particles re-entrained from F7 filters was much lower than form class F5 filters. In general, the measured particle concentrations were found to be low. The shedding from a fibrous material also seemed to depend on the composition of the loading test aerosol and thus, they saw the field measurements also to be necessary. This study utilized the filter loaded for three months in field conditions and kept one month in test conditions. The release of particles or microbes was found to be negligible in normal conditions. However, during the changes in operation of the ventilation system slight release was observed. Therefore, release of particles or microbes via ventilation duct into room air could be less if the ventilation system would operate continuously at the same capacity.

ACKNOWLEDGEMENTS

The study was funded by Ministry of Finance in Finland.

REFERENCES

Halonen, R., Reiman, M., Seuri, M., Lehtinen, L. Keskikuru, T. and Kokotti, H. (1999). Transport of microbes via supply ventilation ducts. *Proceedings of the 8th International Conference on Indoor Air Quality and Climate - Indoor Air '99*, **2**:214-219. Indoor Air '99, Edinburgh, Scotland.

Lehtimäki, M., Taipale, A. (2000) Experimental Study of Particle Shedding from Ventilation Filters. *Proceedings of the 6th International Symposium on Ventilation and Contaminant Control*, 4-7 June 2000, Helsinki. **1:** 200-204.