The capability of a needle heat exchanger to prevent moisture and microbial damage of the fine filter

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ABSTRACT

A needle heat exchanger was installed as a pre-filter of a supply air unit in the office building. Relative humidity and temperature were measured continuously in outdoor air, filter and supply air. Averages of relative humidity in the fine filter varied between 20 and 66% during different seasons, and the temperature exceeded +3°C. Smaller amounts of microbes and microbial taxa were detected on surfaces of fine filter chamber than on surfaces of needle heat exchanger chamber. Despite this some untypical moisture thriving species were present in the filter, in the filter chamber and in supply air after the heating unit. Concentrations and diversity of microbes increased with extending running time of the filter. In addition, *Aspergillus fumigatus* was found viable in the unit. The results indicate that the moisture and generally also temperature conditions created by the needle heat exchanger enable the survival of microbes but do not encourage their growth.

INDEX TERMS

Microbes; Supply air; Filtration; Heating; Humidity conditions

INTRODUCTION

A ventilation system is designed to improve indoor air quality. However, it has been found that it may cause deterioration of indoor air (Fanger *et al*., 1988; Pejtersen *et al*., 1989; Morrison *et al*., 1998; Halonen *et al*., 1999, 2000a). Moisture problems of supply air device are considered to be common. Lysne *et al.* (1999) found moisture problems in about 50% of the supply air devices. Microbes remain viable on filter materials even at low temperatures (temporarily even –17°C), if the relative humidity is high enough (Halonen *et al.*, 2000b). The aim of this study was to examine how the needle heat exchanger affects the moisture and temperature conditions of the fine filter during different seasons. An additional aim was to evaluate the effect of conditions on the microbial survival in supply air unit.

MATERIALS AND METHODS

The needle heat exchanger was installed in front of the glass fibre filter (EU7) in the supply air chamber (Figures 1 and 2). It acts as a pre-filter EU3 and a pre-heater of supply air. In addition, the needle heat exchanger does not need any pre-filter and it can be maintained by washing with water. The fine filters were changed once a year during autumn (23.10.01 and 6.11.02). Air samples were taken from the warm air chamber, and surface samples were taken from the filter and needle heat exchanger chambers. The filter material samples were taken twice in the bottom corner of each three used filters.

The temperature and relative humidity were monitored continuously during winter, summer and autumn (Vaisala HMP 143 A, Vaisala HMP 230 and data taker Grant SQ 1027). 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

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glucose agar (TYG) for 7 days at +25°C, and thermophilic fungi on MEA for 5 days at +40°C. Results are expressed as indicated in parentheses for each sample type. The samples were taken from fine filter material (cfu/g, cfu = colony forming units), air (cfu/m^3) and surfaces (cfu/plate) from supply air chamber in cold and warm sections.

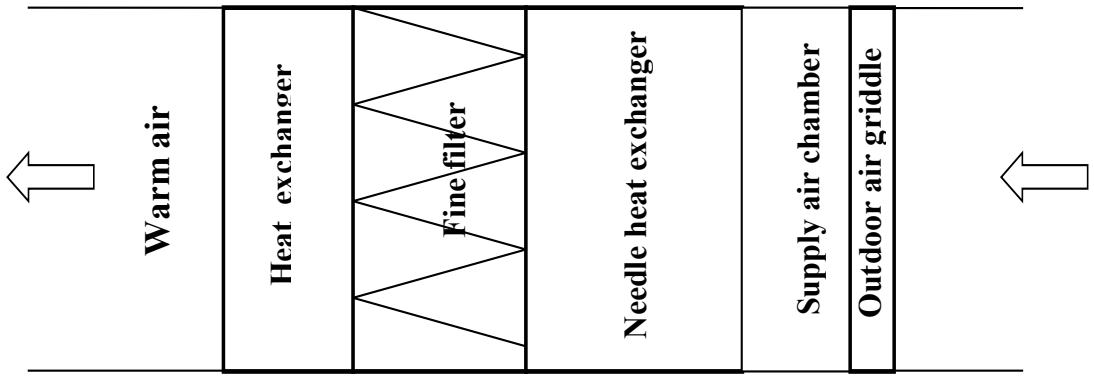


Figure 1 A supply air unit with a needle heat exchanger.

Figure 2 The fine filter chamber is located in the left, the needle heat exchanger is in the middle and the cold air chamber is located in the right side.

RESULTS

Relative Humidity and Temperature

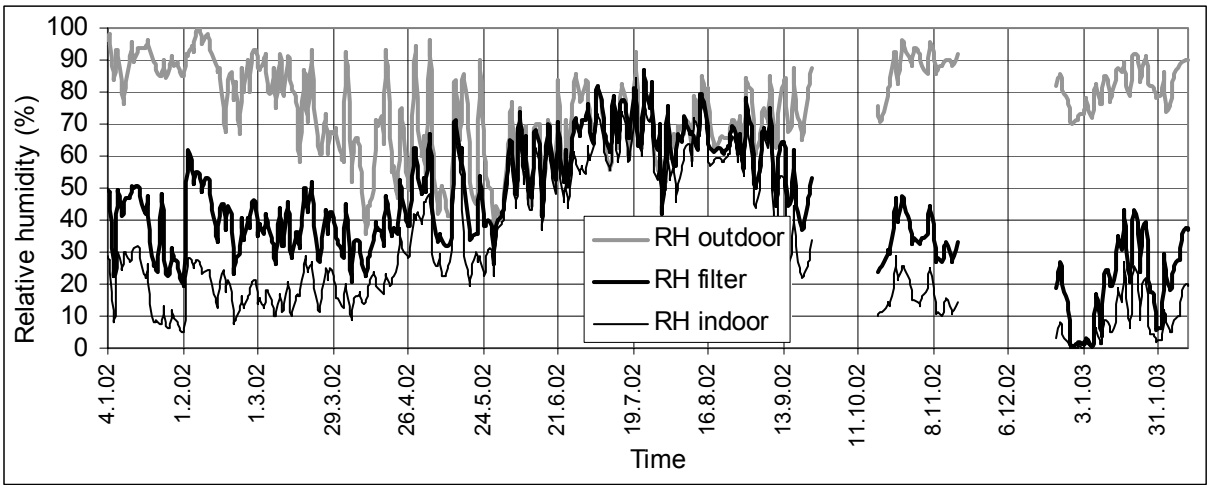
Averages of relative humidity in the fine filter fell below 70% in winter (41%), in spring (40%), in summer (66%), in autumn (43%) and in the second winter (20%). The average temperature in the fine filter bag exceeded +3°C. (Table 1).

The maximum values of relative humidity and temperature in the filter were obtained in summertime and the minimum values were achieved during winter (Figure 3).

Table 1 The temperature (*T*, °C) and relative humidity (RH, %) was followed continuously in outdoor air, in filter bag air and in indoor (supply) air during winter (December–February),

spring (March–May), summer (June–August) and autumn (September–November). Water content (w, g/m^3) is calculated from RH and T values

	Relative humidity (%)			Temperature (°C)			Water content in air (g/m^3)		
Season	Outdoor	Filter	Indoor	Outdoor	Filter	Indoor	Outdoor	Filter	Indoor
Winter -02	88.5	40.3	18.9	–4.6	7.1	19.3	3.3	3.4	3.1
Spring -02	66.4	39.6	24.7	4.2	12.3	19.7	4.4	4.5	4.2
Summer -02	68.2	65.9	60.1	17.1	19.0	19.7	9.9	10.8	10.2
Autumn -02	81.7	43.0	28.0	2.7	11.5	19.4	5.2	4.9	4.6
Winter -03	81.5	20.0	8.3	–12.4	5.1	19.5	2.1	1.5	1.4



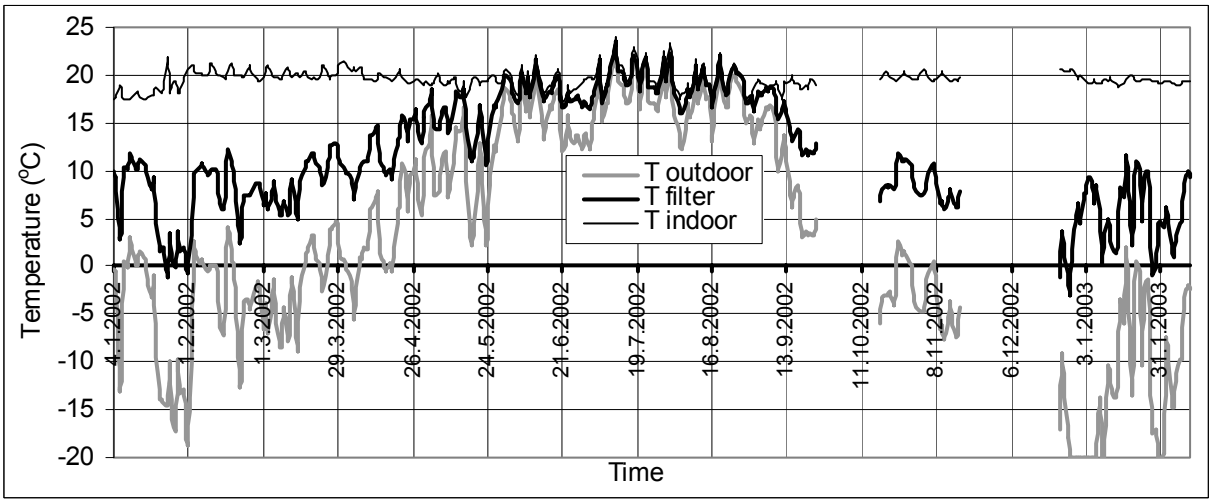


Figure 3 The relative humidity and temperature presented as diurnal averages during the whole measurement period.

Microbes

Tables 2 and 3 present the presence of different microbes in outdoor and supply air, on chamber surfaces and filter material samples.

The microbial concentrations in supply air were quite low (<2–14 cfu/m^3). However, some untypical species (*Aspergillus versicolor*, *Engyodontium*, *Oedocephalum* and *Polyscytalum*) were present in supply air after the heating unit. Highest number (21) of microbial taxa were found in outdoor air. Only three fungi (*Aureobasidium*, *Cladosporium* and *Penicillium*) were found both in outdoor air and in air samples taken behind the filter unit.

Table 2 The presence of microbes in outdoor air (o) and in supply air after the heating unit (x). The presence of viable microbes on the surfaces in the needle heat exchanger (n) and fine filter (f) chambers (– = not present and empty = not measured)

Microbes	11.1.01	5.4.01	28.6.01	15.10.01	3.4.02	3.9.02	19.11.02
Acremonium	– –	– –	– – – – f	o –	– – – – – – –		– – – –
Alternaria	– –	– –	– – – – –	o –	f – – – – – –		– – – –
Aphanocladium	– –	– –	– – – – – – –		– – – – –	o –	– – – –
Aspergillus	o –	– –	– – – – – – –		– – – n	f – –	o – – –
Aspergillus fumigatus	– –	– –	– o – n – – –		– – – – – – –		– – – –
Aspergillus niger	– –	– –	– – – – – – –		– – – – – – –		– – n –
Aspergillus versicolor	– x	– –	– – – – – – –		– – – n	– – –	– – – –
Aureobasidium	– –	– –	f o x n	f – –	f – – n	– o –	o – – –
basidiomycetes	– –	– –	– o – – –	o –	– – – – – – –		– – – –
Cladosporium	o –	– –	– o x n	f o –	f – – n	– o –	o – n –
Eurotium	– –	– –	– – – n	– – –	– – – n	– o –	o – n –
Engyodontium	– x	– –	– – – – – – –		– – – – – – –		– – – –
Geotrichum	o –	– –	– o – – –	o –	– – – – – – –		– – – –
Mucor	– –	– –	– – – n	– – –	f – – – – – –		– – – –
Oedocephalum	– –	– –	– – – – – – –		– – – – – –	x	– – – –
Penicillium	o x	– –	f o x n	f o –	f – x n	– o –	o – n –
Polyscytalum	– –	– –	– – – – – –	x	– – – – – – –		o – – –
Rhinocladiella	– –	– –	– – – – – – –		– – – – –	o –	– – – –
Streptomyces	– –	– –	– – – – – – –		– – – – –	o –	– – n –
Thysanophora	– –	– –	– o – – – – –		– – – – –	o –	– – – –
Trichoderma	– –	– –	– o – – – – –		– – – n	– – –	– – n –
Tritirachium	– –	– –	– o – – –	o –	– – – – – – –		– – – –
Ulocladium	– –	– –	– – – – – – –		– – – – –	o –	– – – –
Verticicladium	– –	– –	– o – – – – –		f – – – –	o –	– – n –
yeasts	– –	–	f o – – f	o –	f – – n	– o –	o – n –

The Amount of microbes was lower on the surfaces in the filter chamber than in the chamber of the needle heat exchanger. Also, the variety of species showed the same tendency, the number of taxa in fine filter chamber being 0–5, and that in needle heat exchanger chamber was 6–8 (Table 2).

As expected, the concentrations of microbes increased up to 3×10^4 cfu/g with extending running time of the filter. Same tendency was seen in the number of fungal taxa in two filters (I and III). In the fine filter material, viable moisture thriving microbes (e.g. *Aspergillus fumigatus* and *Aureobasidium*) were present although the conditions in the filter bag were quite dry (Table 3).

Table 3 The presence of viable microbes in the fine filter material samples (filters I, II and III). *t* = running time of the filter in months (m)

Microbe	5.4.01 I *t*=5 m	15.10.01 I *t*=12 m	24.1.02 II *t*=3 m	3.4.02 II *t*=6 m	19.11.02 III *t*=1 m	11.02.03 III *t*=4 m
Aspergillus fumigatus	–	x	x	x	x	X
Aspergillus versicolor	–	–	–	x		
Aureobasidium	x	x	x	x	x	X
Acremonium	–	–	–	–	–	X
Botrytis	–	–	–	–	–	X
Cladosporium	–	x	x	x	x	X
Eurotium	–	–	–	–	–	X
Geomyces	–	–	–	–	–	X
Monocillium	–	–	x	–	–	–
Oidiodendron	–	–	x	–	–	–
Paecilomyces	–	–	x	–	–	X
Penicillium	x	x	x	x	x	X
Sporobolomyces	–	–	x	–	–	–
Trichoderma	–	–	x	–	x	X
Wallemia	–	–	–	x	–	–
Yeasts	–	–	–	x	–	–

DISCUSSION

Temperature and humidity conditions are the main environmental factors affecting microbial growth and survival. The temperature in the fine filter bag behind the needle heat exchanger exceeded +3°C and the relative humidity of fine filter was less than 70%. Microbial growth can be controlled by keeping relative humidity below 70% (Shaughnessy *et al.*, 1999). In a supply air unit without a needle heat exchanger, relative humidity is over 80% and temperature is less than 0°C in the fine filter during the most of the winter (Halonen *et al.*, 2000b). The use of the needle heat exchanger has greater beneficial effect especially on the humidity conditions as control measures of possible microbial problems in air conditioning units than the use of storm grille or pre-filter (Halonen *et al.*, 2000b).

In our earlier studies (Halonen *et al.*, 1999, 2000a) we found out that fine-filter unit only is not effective in preventing the transport of viable microbes, e.g. *Aureobasidium* and *Aspergillus fumigatus*, through the whole ventilation system. In this study, smaller amounts of microbes and microbial taxa were found on surfaces of fine filter chamber than on surfaces of the needle heat exchanger chamber. This may be explained by the capability of fine filter to adsorb particles or by poor humidity conditions for microbial survival in the filter chamber. Despite this, three fungi (including *Aureobasidium*) were found both in outdoor air and in air samples taken behind the filter unit. Interestingly, *Aspergillus fumigatus*, infrequently found viable in any kind of samples, was found in all fine filter materials of this study. In addition, some untypical species (*Aspergillus versicolor, Engyodontium, Oedocephalum* and *Polyscytalum*) were present in supply air after the heating unit. These microbiological findings may result from the conditions created by the needle heat exchanger enabling the survival of microbes although not encouraging their growth.

CONCLUSION AND IMPLICATIONS

The fine filter stays quite dry during all seasons in the supply air ventilation system equipped with a needle heat exchanger. The results indicate that the moisture and generally also temperature conditions for microbial survival are not either favourable or limited.

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