THE INFLUENCE OF SERVICE LIFE, FILTER MEDIUM, AIR TEMPERATURE AND RELATIVE HUMIDITY ON THE GROWTH OF MICROORGANISMS ON AIR FILTERS IN HVAC SYSTEMS

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ABSTRACT

Concerning artificial ventilation of interiors, microbial processes on air filters are assumed to cause pollution of the supply air with possible damage to the exposed persons' health. Therefore, the reaction of microorganisms on air filters was analysed in this project. The analysis focused on the influence of air temperature, relative air humidity, the filter medium and service life as determinants for microbial growth on air filters.

The experiments showed that the parameters air temperature, filter medium and service life had no significant influence on microbial growth. In contrast to that, relative air humidity proved to have a strong influence on the behavior (growth/dying) of microorganisms on air filters.

INTRODUCTION

HVAC systems are increasingly being used for the ventilation of offices, hospitals, and residential buildings, especially in large urban areas. Epidemiological studies have shown that occupants of rooms artificially ventilated by HVAC systems are susceptible to a number of health hazards that are jointly referred to the sick building syndrome (SBS) (1).

Microbial processes on air filters used in HVAC systems are discussed as a major cause of SBS (2). Microorganisms separated by air filters may survive, multiply, or die on the filters and thus living organisms, their metabolites or lysis products may be released into the filtered air and cause the above-mentioned symptoms in exposed individuals (3).

The aim of the study was to determine the impact of service life, filter medium, air temperature and relative air humidity on the behavior (growth or dying) of microorganisms on air filters.

METHODS

HVAC systems:

To perform the investigations presented, HVAC systems of two large buildings in Berlin area had been chosen. The air intake (440.000 m³/h) of the HVAC-system 1 (library) is located at roof level at a height of approx. 50m. Immediately behind the air intake a brick-walled chamber for outdoor air (at 10th floor level) houses the prefilter unit investigated. After the prefilters a preheater and 4 ventilators are located, which aspirate approx. 440.000 m³ of air/h through the filter unit at day time, operating at a reduced capacity of approx. 100.000 m³/h at night and during the weekend.

In the HVAC-system 2 (convention center) the air (approx. 120.000 m³/h) is aspirated through 2 brick-walled intake towers also at a height of approx. 50 m. Before the air reaches the prefilter unit under investigation, it is conducted down into the 3rd ground floor of the building, passes through a ventilation flap, which is closed when the system is nonoperating and the air is preheated by 2 preheaters, which are activated at outdoor temperatures below 8°C. Heating pipes mounted within the filter chamber also contribute to the warming up of the air filters. The HVAC system is operated regularly also during weekends in accordance with the agenda of the congress center (approx. 7 h/d).

Determination of the concentration of microorganisms on air filters

To determine the concentration of microorganisms on air filters, a filter pocket resp. a filter cell was cut out from the middle of each air filter and samples with a diameter of 64 mm were stamped out. Afterwards each of these samples were put into 50 ml sterile NaCl-solution an shedded at 150 rpm for 60 minutes. From this suspension 0.1 ml were put on blood agar (BA) for cultivation of bacteria and yeasts and malt extract agar (MEA) for the cultivation of molds and yeasts. The colony forming units (cfu) on the agar plates were counted after an incubation of 4 days at 20±2°C (68°F ± 4°F).

Procedure

The scheme of the procedure is shown in figure 1. At the beginning of the investigations in July 1994, two large HVAC systems were equipped each with 3 different types of new prefilters (HVAC system 1 (90 prefilters): glass fiber pocket filters (filter classification according DIN EN 779: F7) from 3 (type 1-3) different manufacturers (each 30 filters); HVAC system 2 (30 prefilters): 10 synthetic fiber pocket filters, F6 (type 4), 10 glass fiber cell filters, F6 (type 5) and 10 cellulose fiber cell filters, F6 (type 6)). After a service life of either 1, 3, 5, 7, 9, 11 and 13 months 3 air filters were taken out of the HVAC systems; 30 samples were cut out from each air filter and the concentration of microorganisms on 20 of these samples was determined immediately (initial concentrations). The remaining 10 samples of each filter (together 30 samples) were installed into several laboratory size HVAC systems (LSH). For 3 weeks, the air in these LSH was adjusted to 60%, 90% or 100% relative humidity (R.H.) at air temperatures of 15°C or 30°C (59°F or 86°F). At the end of the laboratory experiments, the number of

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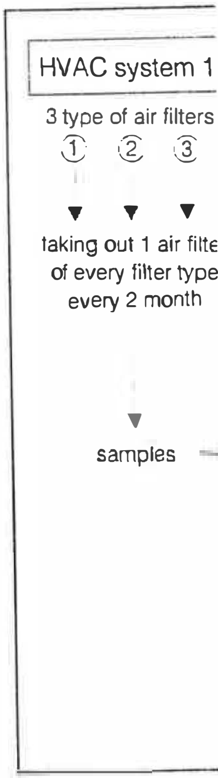


Figure 1: Scheme of

colony forming units (cfu) on these samples also was counted (final concentration). To determine growth or dying of microorganisms on air filters, the percentual ratio "R" between the initial and the final concentrations of microorganisms on the samples was calculated according to formula 1:

$$R[\%] = \frac{c_{final}}{c_{initial}} * 100 \qquad (1)$$

R [%] = Percentual ratio between the initial and the final concentration of microorganisms on the filter samples
$c_{initial}$ = initial concentration of microorganisms on the air filter samples
c_{final} = final concentration of microorganisms on the air filter samples

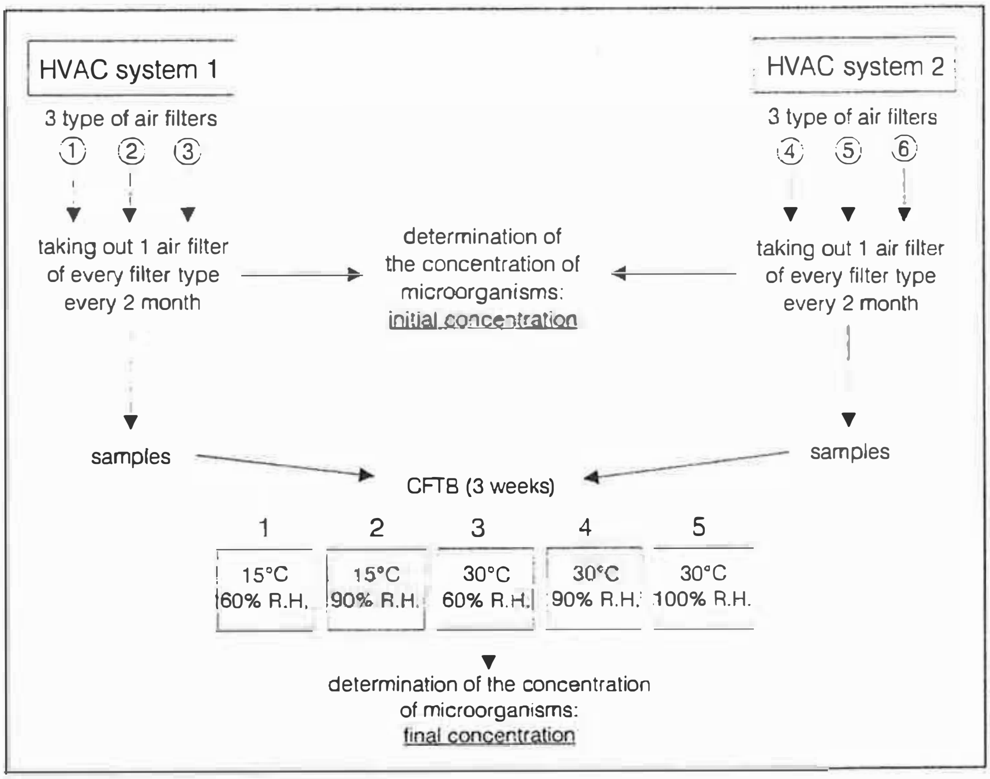


Figure 1: Scheme of the procedure

RESULTS

Exemplary for the variety of results, figures 2-5 show the percentual increase/growth (positive R-values) resp. the percentual decrease/dying (negative R-values) of molds on the air filter samples during the three weeks´ test in the LSH.

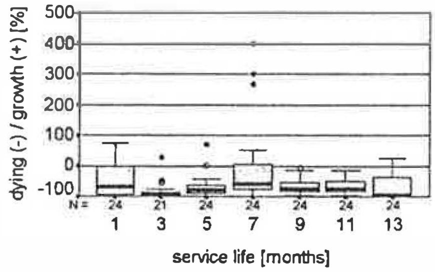
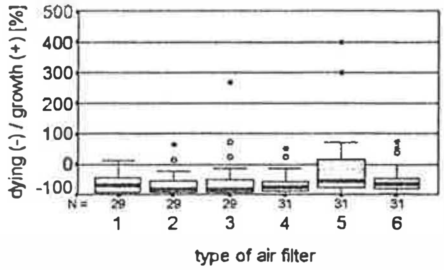


Figure 2



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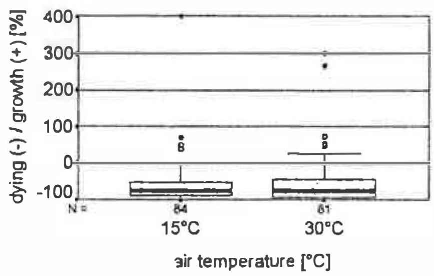

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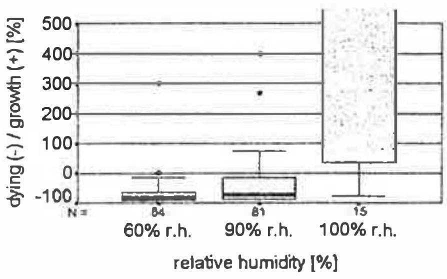

Figure 5

Figure 2 - 5: Influence of service life (fig. 2), filter medium (fig. 3), air temperature (fig. 4) and relative air humidity (fig. 5) on the behavior (dying/growth) of microorganisms on air filters.

Figure 2 shows the influence of service life of the air filters on the behavior of molds on the filter samples. The highest decrease (approx. -90% (median)) of molds occurred on air filters with a service life of 3 and 13 month. The lowest decrease/dying was observed on air filter samples with a service life of 7 months (approx. -60 % (median)).

As figure 3 shows, the behavior of molds is only insignificantly influenced by the filter media itself. Only the glass fiber cell filter (type 5) showed an average reduction of approx. -53 % (median), which means a slight survival resp. growth enhancing influence in comparism to the other filter media.

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Figure 4 shows no influence of air temperature on the behavior of molds on air filters at 15°C and 30°C (59°F or 86°F). As it can be seen at both tested temperatures 74% (median) of the "naturally" collected molds on the air filters died.

In contrast to that, relative air humidity showed a strong influence on the behavior of the molds on the air filters (figure 5). At 60% R.H. 80 % (median) of the molds died on the filter samples. At 90 % R.H. nearly 70% (median) died and in some cases growth occurred on the filter samples. At 100% R.H. strong growth (approx. 2,000% (median)) of molds could be observed on all filters. Table 1 gives a summary of all results obtained at the LSH for the microbial behaviour on air filters .

Table 1: Reaction of microorganisms on air filters on the variation of different parameters

	temperature ↑	rel. humudity ↑	service life ↑	type of air filter
	(15°C - 30°C)	(60%-90%-100% R.H.)	(1-13 months)	(type 1-6)
bacteria and yeasts	↓	↑	-	-
molds	-	↑	-	(5)
yeasts	-	↑	-	-

↑ = increase, ↓ = decrease, - = no influence

As it can be seen, neither the air temperature and the service life of the air filters nor the type of filter media had a strong influence on the behavior of microorganisms on the air filters. Surprisingly more bacteria died at 30°C (86°F) than at 15°C (59°F) on the air filter samples. The relative humidity proved to be the only parameter to have a strong influence on bacteria as well as on molds and yeasts. Within an increase of R.H. more microorganisms were able to survive or to grow on the air filters.

DISCUSSION

As expected, microbial growth increases with increasing relative air humidity (2). 90% R.H. seem to be a boundary condition for the growth of microorganisms, so that relative humidity has to be kept below 90% in order to avoid microbial growth on air filters in HVAC systems.

These results cannot confirm the conclusions out of the study of Elixmann et al. (4), who found that molds are able to grow on air filters in HVAC systems when the relative humidity of the supply air exceeds 70% R.H.. On the contrary the results of the presented study are supported by the results of Kemp et al. (5), who found microbial growth on glass fiber pocket filters challenged continously with outdoor air for one year when the relative humidity of the air was adjusted at 90% R.H..

According to Rüden et al. (6) the behavior of microorganisms on air filters is not influenced by the service life of the air filters.

The observed effect of air temperature (i.e. more bacteria die at 30°C (86°F) than at 15°C (59°F)) may be explained by the adaptation of the collected bacteria to lower outdoor temperatures.

ACKNOWLEDGMENTS

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AN AIR HANDLING
The Factor 4 in Air

Ing. Ben Bronsema -
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Abstract

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Introduction

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Bethesda MD
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