DOES THE AIR QUALITY DETERIORATE DURING THE USE OF AIR FILTERS?

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ABSTRACT

Emissions from dust collected in air filters have been investigated using *in situ* and chamber measurements. Two air filters (class F6 and F8/9) were exposed to outdoor air for a period of six months, after which measurements were carried out during continuous and intermittent operation. Air samples were taken upstream and downstream of the filters and analysed for several substances, including VOCs, formaldehyde, microbial VOCs (MVOC), vital micro-organisms, ergosterol and endotoxin. Particles and fungus spores released while starting the fan were monitored using an optical particle counter and slit samplers.

No significant change of VOCs, aldehydes or MVOCs could be measured across the filters while in use. Particulate matter, including endotoxins, ergosterol and spores, was reduced. In the intermittent mode, a moderate and short-lived increase of particles was briefly measurable downstream of the filters after starting the fan. In the chamber experiments, the filters were found to be a source of various VOCs, such as aldehydes and MVOCs. Nevertheless, mycological examination of the filters did not show any active microbial growth.

This investigation does not indicate any deterioration of air quality due to outdoor dust in the air filters, even though they were occasionally dampened. The large amount of air passing through a filter in use obviously dilutes the gaseous emissions found in the chamber experiments to very low concentrations of minor importance. Finally, it should be stated that these filters were only moderately dirty and that this study does not include odour or other perceived air quality parameters.

INTRODUCTION

The supply air filters in a ventilation system are exposed to outdoor air, which is a mixture of various particles and gases such as soil, sand, bacteria, spores, volatile organic compounds, combustion gases etc. The filters reduce particulate matter and thus improve air quality. Under certain circumstances, the collected dust can cause an increase of unwanted substances in the air passing through the filters. Microbes might grow in filters, as nutrients, moisture and micro-organisms are often present on the used filter material [1, 2, 3, 4]. The metabolism of the microbes can produce volatile and particulate products. Fragmentation, mortality or new growth of spores can lead to substances that might be released into the supply air.

The presence of moisture seems to be the main condition that effects the growth of micro-organisms in filters [1, 2, 4, 5]. A relative humidity above 90 % seems to promote growth. Under most other conditions, microbes seem to die in the filters [2, 6]. Even new filter materials and their binders can serve as nutrients for microbial growth [7, 8, 9].

Filtration efficiency in terms of removing microbes depends on the filter class and the aerodynamic size of the microbes [10]. Elixman et. al. [11] show effective filtration of fungi. However, they noticed that, during certain days in the summer, the concentration downstream of the filters was higher than upstream. Their explanation is that fungi grow through the filter and sporulate on the downstream side.

Odour and volatile compounds from air filters have also been studied [5, 12, 13, 14, 15, 16, 17]. Pasanen et. al. [13] found that, after three months use, the air stream from filters smelled so much that every third person would find it unpleasant. They also found that coarse filters (EU3) smelled just as much as did more effective filters (EU6). The smell from the filters depended on the air velocity through the filters [14, 15] and the temperature [16]. Some studies [13, 16] on used air filters show that chemical measurements and perceived odour do not correlate. Schleibinger et. al. [17] measured MVOC emissions from used air filters *in situ*. They found increased levels of formaldehyde, acetaldehyde, and acetone, although all concentrations were low and comparable to normal outdoor levels. Further laboratory study showed emissions of the same compounds [5].

In our study we investigated used filters of two different classes operated *in situ*. We examined whether air quality is degraded because of the dust and microorganisms in the filters. The hypothesis is that a finer filter collects more dust and other fractions than a coarser one, and that this will effect the emissions. An assumption is that the micro-environment for growth is more suitable at lower or no flow through a filter, which is the case when ventilation systems operate intermittently. The study in its entirety is reported in [18] (in Swedish).

METHODS

Two glass fibre filters (F6 and F8/9, 610 x 610 mm) were exposed to outdoor air for six months (March to August 1997), and the measurements were made during August and September. Two different running conditions were studied, continuous and intermittent. The nominal airflow was 3400 m^3/h, which was reduced to 200 m^3/h at nights and weekends when in intermittent operating mode. In particular, the instant that the fan was started was studied for particle release. This was done using a HEPA filter upstream of the tested filter.

Table 1. Measurements and the methods used.

Parameter:	**Method**
Particle concentration	Measurements by optical particle counters, OPC (> 0.3 μm).
Total dust	Sampling on 0.8 μm cellulose acetate filter, weighing on a micro balance.
Ergosterol and endotoxin	Total dust filters as above and pieces of the examined filters, analysed using a Limulus reagent method and GCMS.
Ozone	Diffusion sampler (15-20 days' exposure), analysed by ion chromatography
Microorganisms	BIAP slit sampler with agar dish, incubation and CFU counting. Optical microscope counting in the filter material.
VOC (C_6-C_{18})	Pumped and diffusive sampling on Tenax adsorbent tubes, analysed by thermal desorption on a GC/FID/MS system (non-polar capillary column).
MVOC (10 compounds[1)])	Pumped on Anasorb 747 adsorbent, analysed on GCMS (SIM). *Pegasus Lab*
Formaldehyde, acetaldehyde	Pumped and diffusive sampling on DNPH-cartridges (SepPak X-posure and GMD badges respectively), analysed by HPLC.

[1)] 1-octene-3-ol, 3-methyl-furan, 3-octanone, 2-hexanone, 2-heptanone, n-butanol, iso-butanol, 2-pentanol, 3-methyl-1-butanol, dimethyldisulphide. All ten substances are summed up to a MVOC total value in the results.

Afterwards, the entire filters were placed in climate chambers (1 m³) for volatile emission measurements and, finally, samples were cut out from the examined filters for analysis of microbial contents in the filter material.

RESULTS

Particles in air upstream and downstream of the filter

Table 2. Reduction (%) over the filters. (Ratio between upstream and downstream values.)

	Continuous		Intermittent	
	F6	F8/9	F6	F8/9
Particles 0.4 µm	20	75		
CFU of fungi	91	95	-	-
Total dust	47	65	35[1)]	76[1)]
Ergosterol	>76	>83	>82[1)]	>74[1)]
Free endotoxin	>98	>98	86[1)]	86[1)]
Total endotoxin	85	91	-	-

[1)] Unreliable values due to possible reverse flow due to fan breakdown.

No increase of any particulate matter could be seen downstream. However, when the fan was started in intermittent mode, a moderate and short-lived (< 15 sec) increase of particles was measurable downstream. The same pattern was measured for CFU. The release of particles and CFU at starting should be of minor importance in comparison to the normal penetration through the filters during continuous operation.

Volatile compounds in air upstream and downstream of the filter

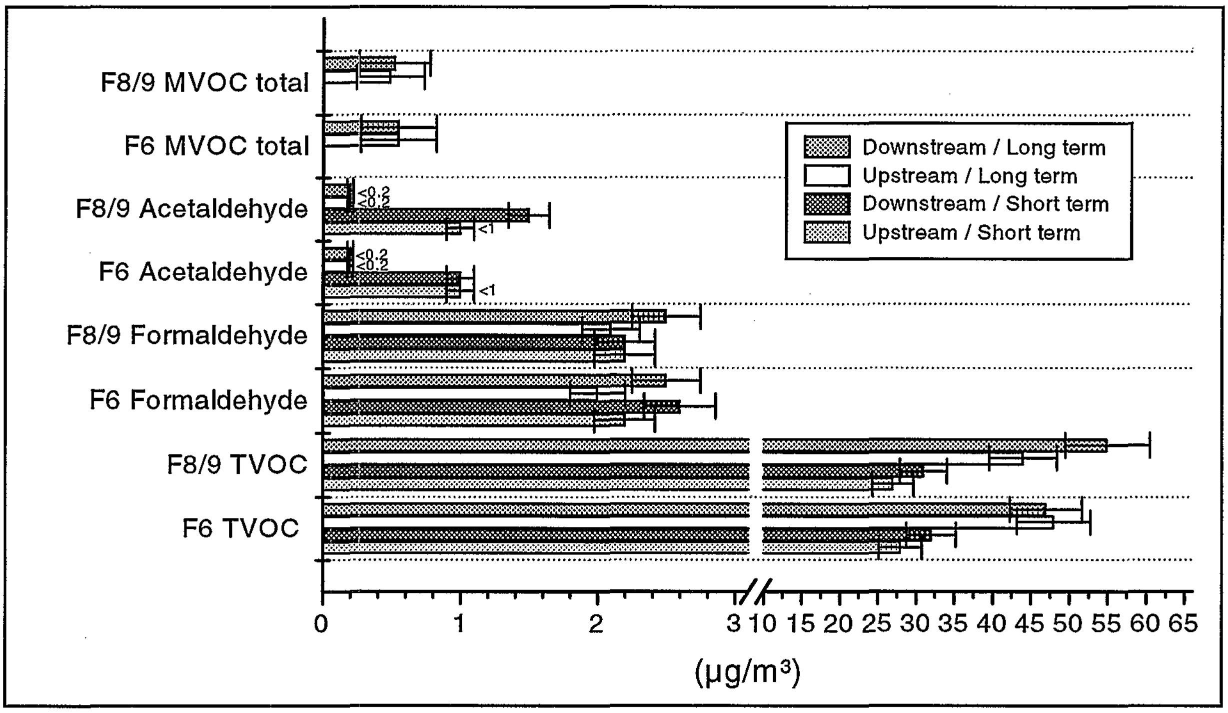

Figure 1. Volatile compounds up- and downstream of the filters during **continuous operation**. (Long-term values are sampled for several days and short-term values for a couple of hours).

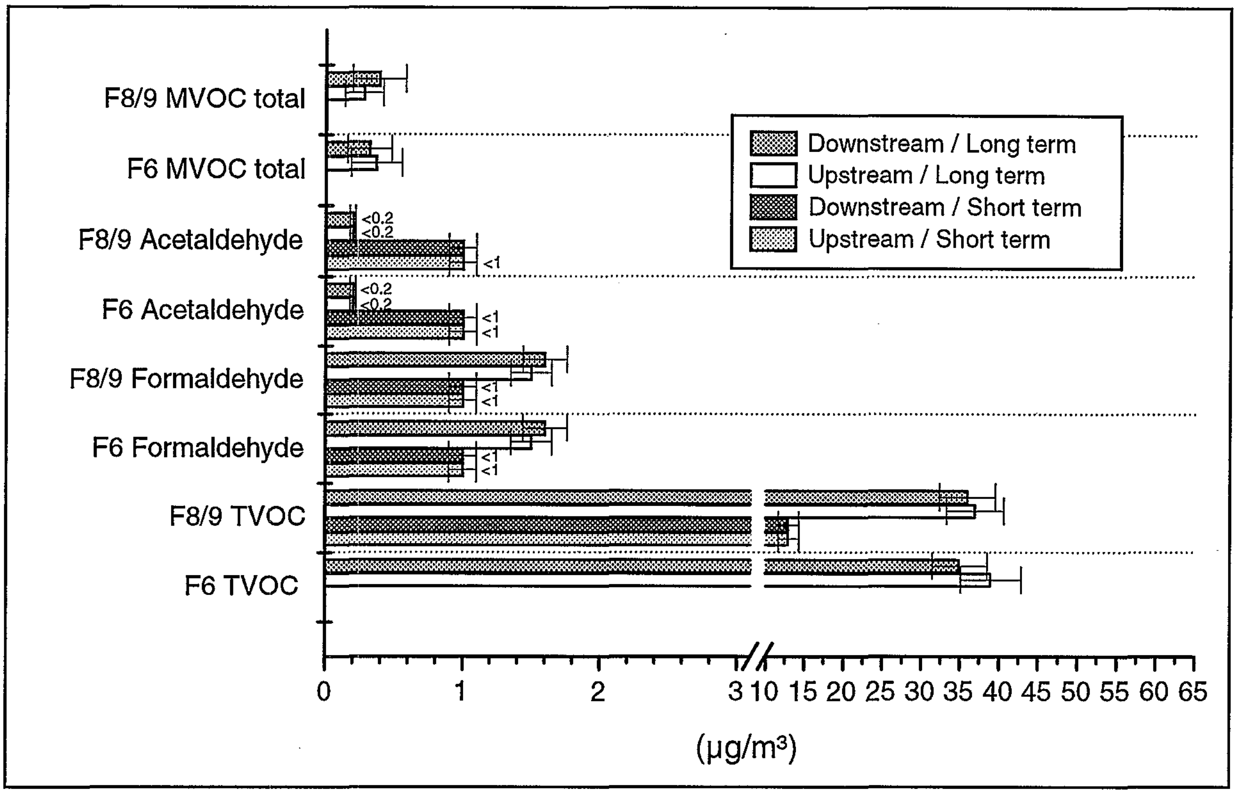

Figure 2. Volatile compounds up- and downstream of the filters during **intermittent operation.**

No specific compounds of MVOCs and VOCs emerged from the pattern of the total values (Figures 1 and 2). An expected reduction of ozone was found during intermittent operation, but not during continuous operation. This might be due to longer dwell time when the flow is low. However, no newly formed substances were detected due to ozone reduction.

Chamber experiments

The chamber experiments found the filters to be a source of various VOCs. Aldehydes such as hexanal and nonanal dominated, but alcohols (1-butanol, iso-butanol, 3-methyl-1-butanol, 2-ethyl-1-hexanol), ketones (2-butanone), hydrocarbons (heptane, bensene, toluene) and other substances were found as well. A slightly increase of formaldehyde was measured, in addition to the presence of acetone. Furthermore, the filters were a source of various MVOCs, particularly isobutanol, n-butanol and 3-methyl-furane. Considerably more MVOCs were measured in the F8/9 filter chamber than in the F6 chamber. We noticed a striking odour from the filters after opening the climate chambers.

Microbial contents in the filter material

Optical microscopy of the filter material showed spores in abundance on the upstream side and rare occurrences on the downstream side of both filters. Hyphae were found only on the upstream side, and only as fragments. This indicates no fungi growth on the filters. The dust in the filters contained high amounts of ergosterol and endotoxins.

DISCUSSION

No significant change of VOCs, aldehydes or MVOCs could be measured across the filters while in use, and the downstream levels are comparable to normal outdoor findings. No fungal growth could be found either, which seems logical in conjunction with the MVOC results. In a recent field study, Möritz et. al. [19] showed a mean survival time of microorganisms deposited on air filters of one to three days. This means that air filters are not a good environment for microbial growth, except when the relative humidity is high. However, the filters in our chamber experiments were found to be a source of various VOCs. These emissions can originate either from desorption, biological degradation or chemical reactions in the filter. As an example of the latter, hexanal and nonanal are oxidation products from fatty acids in the dust. Butanoles might be a result of biological degradation or biological activity. Theoretically, if the calculated source strength from the filters were the same *in situ* as in the chambers, the passing air flow would dilute the emissions to very low and hardly measurable values (e.g. hexanal and nonanal increase $< 0.02\ \mu g/m^3$).

The filters examined did effectively reduce particulate matter. Fragmentation of the dust could be expected in the filters, and these fragments might be released downstream. Our measurements of fungi and bacteria fragments (ergosterol and endotoxin) showed no abnormal concentration of these substances: instead, we found a reduction across the filters during both the running conditions. The release of particles measured by OPC while starting the fan was low and short-lived. It does not appear as if particle loosening causes any deterioration of the air quality. Another study shows that used low filtration class filters release lots of particles and more than finer filters [20]. Synthetic filters release more particles than do glass fibre filters of the same class. Low filtration class filters (≤ F5) are often made of coarse fibres and have a relatively open structure, which is also the case for synthetic filters of finer classes (≥ F7). The tested filters in our study were glass fibre filters of fine classes (F6 and F8/9), which might explain their ability to retain the particles.

Möritz [21] studied release of endotoxin from used filters over several years and found a reduction over the filter during the first years. On the other hand, the reduction decreased over time, and finally the filters started to raise the concentration of endotoxin across the filter i.e. negative filtration efficiency. Our measurements were made after six months' use, and the reduction of endotoxin correlates with Möritz' findings. Möritz [21] also found that coarse filters started to release endotoxin earlier than did fine filters. His recommendation is to change prefilters every one to two years, and main filters every third year, due to endotoxin release.

Our conclusion is that moderately dirty filters do not degrade air quality. However, this study does not include odour or other perceived air quality parameters, which should be taken into consideration. No difference in deterioration of the air quality between the two filters can be seen from our results, but other studies [20, 21] indicate differences between coarse and fine filters in respect of release of particulates. Air filters are not a favourable environment for microorganisms, although high relative humidity and water must be avoided in filters.

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