#5625

Odor Emission from the Used Filters of Air-Handling Units

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ABSTRACT

It has been shown that an air-handling system can be a significant source of pollution that may actually increase the need for ventilation in a building. One specific source of odor generation is the air filter, where collected particles are accumulated. When the fresh air flows through the dirty filter, it becomes contaminated. To decrease the recontamination of the air, the dirty filter must be changed frequently. The contamination of air filters obviously depends on the filter type and on operational conditions such as outdoor air quality and airflow through the filter.

In this study, the dirty filters from air-handling units in ten office buildings were removed and installed in an air-handling unit in the laboratory one at a time, and their odor generation was measured by a trained panel.

The Standard ASTM butanol scale was used. The odor intensity of the air varied from 1 to 4.4 on a scale of 1 to 10. Measured values corresponded to an increase in perceived air quality from 0 to 6.2 decipols. In general, the filters with high odor generation had long been in use or were from a building located in a polluted area.

INTRODUCTION

The purpose of ventilation systems is to supply fresh, clean air to buildings and to remove the pollutants generated by human occupancy and building materials. Until recently, the major sources of pollutants were thought to be the outdoor air, building materials, and occupants and their activities. However, experiments in eight office buildings (Pejtersen et al. 1989) showed that the air-handling system itself can also be a source of pollutants. Dirty filters in the air-handling system were suspected of being one of the major sources.

The chief parameters affecting the odor generation of old, used filters are not clear. Our hypothesis was that odor generation must depend on the accumulation of dust on the filter and the quality of the dust. The hypothesis was tested by measuring the odor generation from filters in buildings in different localities at different times of operation.

METHOD

The Filters

Ten used filters from office buildings were taken to the laboratory, where their odor generation was measured in controlled conditions in an air-handling unit. The buildings from which the filters were taken are located in three types of surroundings with regard to air quality: the center of the capital city, Helsinki; a Helsinki suburb; and the city of Kuopio (70,000 inhabitants), 500 km north of Helsinki.

The dirty filters were taken from the office buildings when they were replaced with new ones according to a regular service schedule. The background data of the air-handling units from which the filters were taken are summarized in Table 1

Smoking was allowed in restricted areas and in individual offices in all the buildings; however, smoking frequency was not recorded. On average, 25% of Finnish office workers are smokers.

Filters were installed in the upstream of the humidifier and the cooling coil in the air-handling unit of building 15. Filters 1-7 were from the center of Helsinki, filters 8-11 from Kuopio, and filters 14-19 from the Helsinki suburb. The operation time and the replacement period were taken from the service records. Airflows were determined from the original design.

The filters were carefully transported to the laboratory, where they were placed one at a time in a standard air-handling unit with controlled temperature and airflow conditions. All the filter units were of standard size with a frame measuring 60 cm × 60 cm (2 × 2 ft).

The Odor Evaluation Method

Air samples were taken upstream and downstream of the filter. Outdoor air was used as a reference. The odor of the air samples was evaluated by a trained panel of 6-10 members. Judges were selected from laboratory personnel according to ASTM Standard STP 440. The panel was trained with odor of butanol-water mixtures. As a reference, the butanol ASTM Standard E-544 scale was used. A 10-point scale with water dilution of butanol concentrations of 10-5,120 ppm served as a reference.

The panelists evaluated the odor intensity on a scale from 1 to 10. They also evaluated the acceptability and freshness of the air samples. This was done with two 40-mm-long lines with unacceptable or stuffy air at one end and acceptable or fresh air at the other. Each panelist marked his/her evaluations of the sample air on the line. These marks were converted into numbers with a value of -1 for the unacceptable or stuffy end of the line and +1 for the acceptable or fresh end. The numerical value of the evaluation depended on the location of the mark on the scale. The panelists were trained at eight training sessions to evaluate odor

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TABLE 1
Data on the Tested Filters, the Air-Handling Units, and Buildings

Filter no	Year of construction or renovation	Age* (months)	EUROVENT** filter class	Face area (m^2)	Return air	Humidi- fication	Cooling	Operation hours per week	Air flow (m^3/s)	Distance of the air inlet from ground (m)
1	1989	6	EU 4	5,04	Y	N	N	112	13,6	5
2	1989	6	EU 5	1,44	N	N	N	71	2,5	27
7	1984	4	EU 5	0,72	Y	N	N	45	2,4	18
9	1985	6	EU 3	0,54	N	N	N	51	1,7	10
10	1983	6	EU 5	1,08	N	N	N	45	3,0	15
13	1976	6	EU 6	8,64	N	N	N	87	26,6	5
14	1988	12	EU 5	0,54	N	N	N	45	1,7	2
15	1974	4	EU 7	5,76	Y	Y	Y	168	15,3	16
17	1986	38	EU 5	1,10	Y	N	N	40	1,7	8
18	1973	12	EU 6	5,40	Y	N	N	55	17,5	30

*: age stands for the time that a used filter has been situated in the ventilation system until it was taken out and was studied in the laboratory.
**: EUROVENT is the European Association of Air Handling Equipment Manufacturers; corresponding ASHRAE Dust Spot Efficiency is by class EU 3 = ASHRAE 30...40%, EU 4,5 = ASHRAE 40...70; EU 6,7 = ASHRAE 70...90

intensity with a butanol scale. The same panelists also evaluated air quality in several offices, residences, and day-care centers.

The Air Samples

The panelists evaluated the odor intensity, acceptability, and freshness of the air from three sample locations. They did not know where the sample came from. Air samples were taken from the midpoint of the cross sections of the air-handling unit with the help of a small fan and aluminum-coated flexible hoses. One of the samples was taken just upstream of the filter, one downstream of the filter, and a third as a reference from the outdoor air (Figure 1). The outdoor air was heated to the same temperature as the samples from the air-handling unit. The airflow was controlled with a variable-speed fan. The sampled airflow had a speed of 1±0.1 m/s (200±20 ft/min) in the outlet. Its temperature was 21±2°C (70±3.6°F) and its relative humidity 22±6%. The mean air velocity in the cross section of the air-handling unit was 1±0.1 m/s (200±20 ft/min). During the test, the panelists were able to breath fresh air at an open window if they wished.

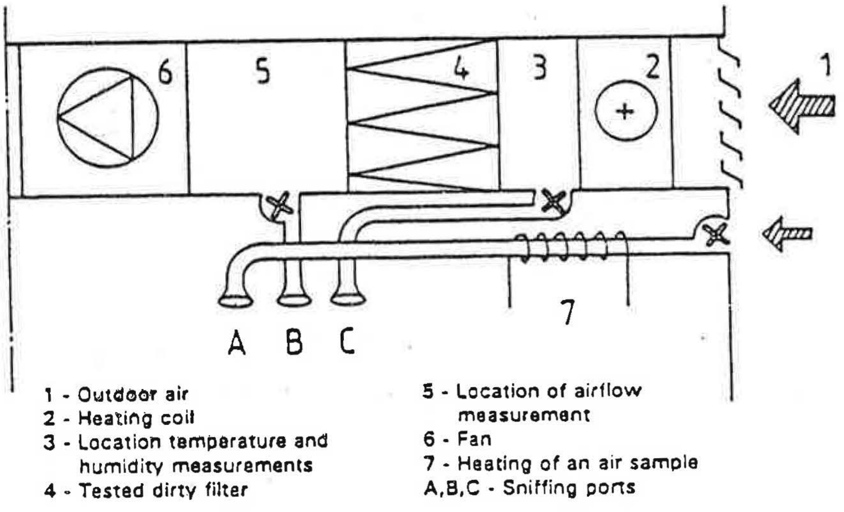

Figure 1 The experimental setup and the locations of the air samples

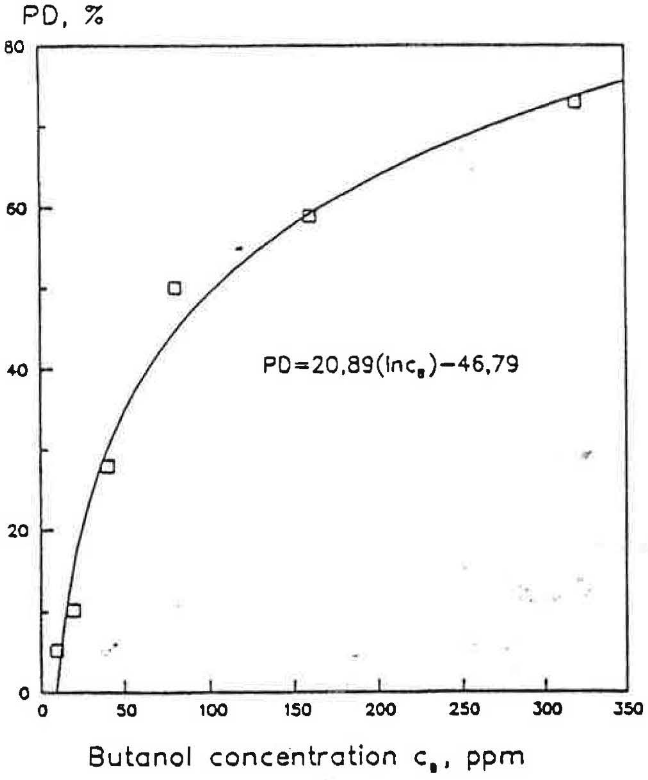

Figure 2 *The percentage of dissatisfied with butanol in various concentrations (summary of the results of 100 evaluations)*

Data Processing

The odor intensity evaluated on the butanol scale was converted to decipols using Equation (1) given by Fanger (1989).

$$C = 112\,(ln\,(PD) - 5.98)^{-4} \qquad (1)$$

where

C = perceived air quality, decipols
PD = percentage of dissatisfied

A hundred naive judges were asked to evaluate the acceptability of the odor of each point on the butanol scale (1-10). The percentage of dissatisfied (PD) was calculated for each point. The question put to the judges was formulated in a similar way (Fanger et al. 1983; Berg-Munch 1986): "Would you consider the odor acceptable if you had to work in a room with the same odor for eight hours a day?" The judges who did not accept the odor were considered to be dissatisfied. The conversion of the butanol scale to decipols is shown in Figure 2.

RESULTS

The perceived air quality of the outdoor air during all the tests was, on average, 0.15 decipols. The odor intensity upstream of the filter varied from 0.2 to 1.5 and downtown of the filter from 1.0 to 4.4 on the butanol scale. The average increase in perceived air quality (Figure 3) was 2.3 and ranged from 0 to 6.2 decipols. The variation between the filters was high. The freshness and acceptability of the air upstream and downstream of the filter are also indicated in Table 2.

The odor generation of the filters depended on the total air volume that had flowed through the filter and the location of the building from which the filter was taken. Three separate groups of data points can be seen when the perceived air quality is plotted against the total air volume through the filter. The highest odor generation was from the filters taken from the buildings in the center of Helsinki. The filters from the Helsinki suburb generated substantially less odor. The filters from Kuopio generated the least odor. Similar relationships were obtained when the decrease in the freshness and acceptability of the air samples upstream and downstream of the filter was plotted against the total air volume through the filter (Figures 4 and 5).

DISCUSSION

The odor generation of the used filters was strong and may be one of the major sources of pollutants in the air-handling systems. Although only ten filters were investigated, the results indicate a substantial difference in the odor generation of filters in buildings from different surroundings and with different ages. It appears the filter replacement period should also depend on the location of the building because this had such a major influence on the odor generation.

The filters taken to be tested were selected randomly, and they were made of different materials and had different removal efficiencies. This may also explain some of the results. Because of the design of the experiment, clean filters were not tested. The filter material itself may explain some of the results

The experiment showed that the butanol scale can be used to measure the odor intensity of air samples from air-handling systems. The results expressed on the butanol scale (1-10) were converted to decipol units with the help of naive judges. This makes comparison possible with other studies (Pejtersen et al. 1989;

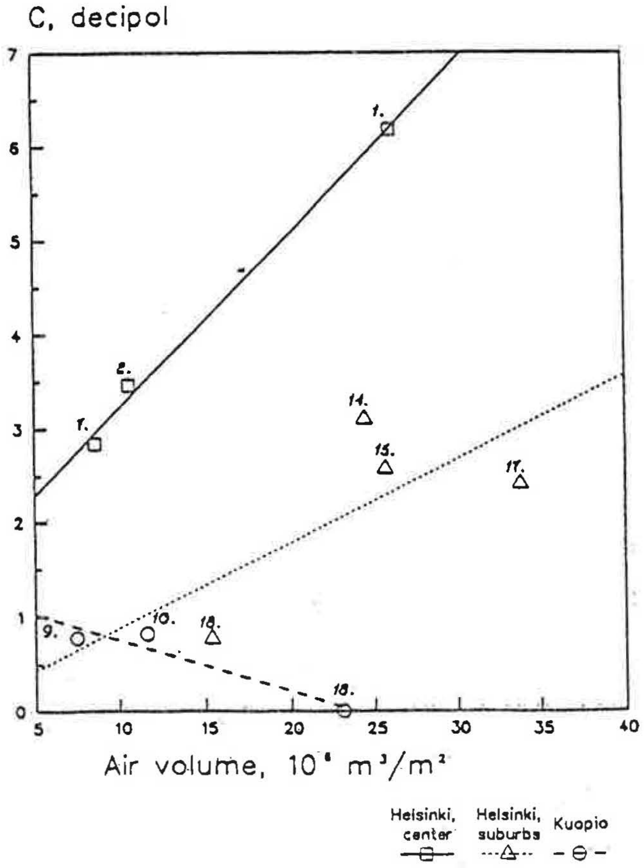

Figure 3 *The increase in perceived air quality caused by dirty filters taken from buildings in three surroundings*

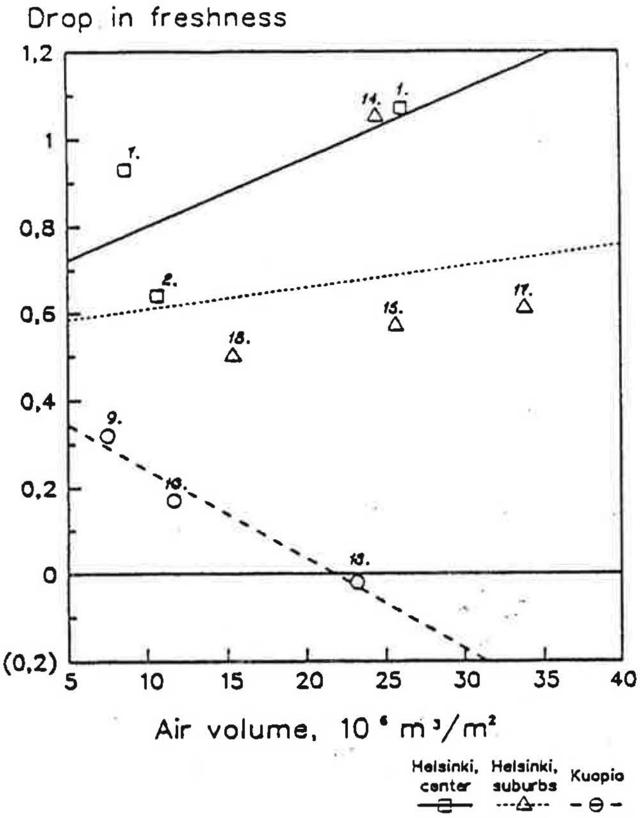

Figure 4 *The drop in freshness of air samples taken upstream and downstream of the dirty filters from buildings in three surroundings*

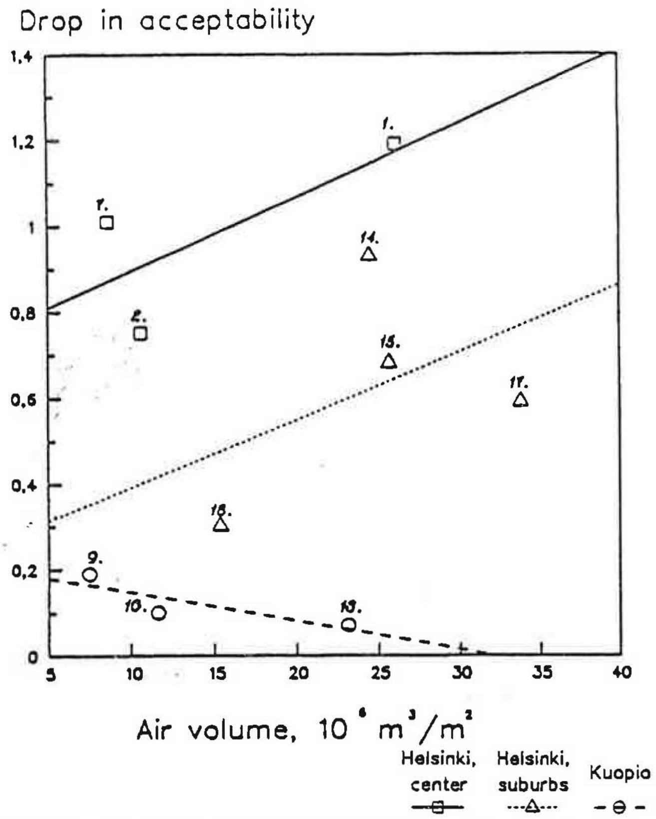

Figure 5 *The drop in acceptability of air samples taken upstream and downstream of the dirty filters in buildings in three surroundings*

TABLE 2
Odor Intensity (1...10), Freshness (-1...+1), and Acceptability (-1...+1) on the Butanol Scale

Number of filter	Before filter			After filter		
	Odor intensity	Freshness	Acceptability	Odor intensity	Freshness	Acceptability
1	0.8	+0.65	+0.75	4.4	-0.42	-0.44
2	1.2	+0.23	+0.44	3.5	-0.41	-0.31
7	0.5	+0.56	+0.64	3.1	-0.29	-0.37
9	0.8	+0.60	+0.67	1.8	+0.28	+0.48
10	1.5	+0.40	+0.46	1.9	+0.23	+0.36
13	0.8	+0.52	+0.68	1.0	+0.54	+0.61
14	0.5	+0.83	+0.80	3.3	-0.22	-0.13
15	0.2	+0.70	+0.87	3.0	+0.13	+0.19
17	1.5	+0.24	+0.44	3.2	-0.37	-0.15
18	1.0	+0.64	+0.76	1.9	+0.14	+0.46

Bluyessen 1990) The freshness and acceptability of the air also appear to be good indicators of air quality.

The test method seems to work well and can also be used to evaluate the odor generation of other components in air-handling systems. The odor generation of the used filters was high, up to 220 olfs. This kind of odor generation is obviously much higher than that experienced in the buildings. The reasons for this discrepancy may be found in the sorption of long ductwork in the real buildings or from the fact that during transportation of the dirty filters to the laboratory, the structure on the filter surface may have changed, thereby creating more surface area of accumulated dirt for odor generation.

The reason for the large variation between the filters may lie in the outdoor air concentration of suspended particles. Unfortunately, the outdoor air concentrations were not recorded in the location of the buildings. The average dust concentration in Helsinki during 1989 was 44-121 g/m^3, depending on the location, and in Kuopio it was 22-70 g/m^3, also depending on the location. The difference in the dust concentration does not necessarily explain the differences in odor generation between the filters. It is not only the concentration of the particles but also the chemical composition of the dust. The difference may also be explained by climatic conditions. Helsinki has a coastal climate, while Kuopio is 500 km from the coast and has a colder and drier climate.

CONCLUSIONS

The experiment showed that a trained panel using a butanol scale easily detected the dirty filters and was also able to evaluate the odor generation of the filters. The results obtained with the butanol scale can be converted to decipols with the help of percentages of dissatisfied on two scales. The results showed that not only the dust accumulation on the filters but also the location of the building must be considered when determining the replacement period of filters. The odor generation of the filters in the laboratory test was higher than may be expected from the odor of the supply air. This may be due to sorption effects in the air distribution system.

ACKNOWLEDGMENT

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