#5997

Ventilation for Energy Efficiency and Optimum Indoor Air Quality
13th AIVC Conference, Nice, France
15-18 September 1992

Poster 19

The Composition and Location of Dust Settled in Supply Air Ducts.

P. Pasanen*, A. Nevalainen, J. Ruuskanen*, P. Kalliokoski***

*** University of Kuopio, Department of Environmental Sciences, P O Box 1627, SF-70211 Kuopio, Finland**
**** National Public Health Institute, Division of Environmental Health, P O Box 95, SF-70701 Kuopio, Finland**

ABSTRACT

The amounts, quality and factors affecting of dust accumulation in supply air ducts of eight nonindustrial buildings were studied. The average of surface density of dust settled in supply air ducts was 10.6 g/m^2 and the average of yearly accumulation rate was 3.5 g/m^2*year. The dust contained 82% of inorganic material, which agrees well with the composition of outdoor air dust in down town areas. In straight air duct the surface density of settled dust decreased as a function of distance from the air handling unit (AHU). The dust was mainly settled on the bottom of the duct and captured by the residues of lubricant oil used in manufacturing of ducts. In some cases soil depris was settled during the building construction period. The floor of the building did not affect the amount of settled dust. Fungal genera was similar to found in outdoor air and microbial growth in the air ducts was not observed in this study. The proportion of pollen grains was 70 mg/g of dust and it varied widely according to plants in surrounding environment. The results show that leakages between filter cassette and assembly frame were common in AHU of nonindustrial buildings.

1 INTRODUCTION

Outdoor air consists always suspended particles of which concentration varies widely even locally. Particulate impurities shall be removed from outdoor air before leading the air to the other parts of air handling unit (AHU). Filtration efficiency of air filters used in nonindustrial buildings is not good enough to prevent all the particles to pass through to heat exchangers, heat recovery unit and other components. This allows dust accumulation to inner surfaces of ventilation ducts. However, the production of high quality supply air provides a clean and odourless ventilation system. Impurities in the ventilation system decrease quality of supply air leading to dissatisfaction to indoor air quality or even health symptoms of the occupants. In several studies the building related illness is connected to the microbial growth in dirty ventilation system (1,2,3). If ventilation system is unclean and stuffy, maintenance of high indoor air quality demands higher ventilation rates that increase energy costs. On the other hand, the saving in filtration and maintenance costs will increase the costs of purifying the ventilation system.

The first purpose of our work was to determine amounts of dust accumulated in different parts of supply air ductwork in nonindustrial building. The other purpose also was to clarify the composition of the dust for evaluation the origin of dust.

2 MATERIAL AND METHODS

2.1 Research objects

Eight supply air duct systems in six mechanically ventilated office buildings were chosen for the study. Four of the ventilation systems were provided with recirculation air (objects 1-4). The maximum proportions of the recirculated air were from 39 to 68% of the total air flow and usually recirculation was used when temperature of the ambient air decreased below -10 °C. The age of the ventilation systems varied from 4 to 31 years. In the object number 5 (Table 1) the supply air ducts were partly cleaned with dry brush method three months before the sampling. Two of the objects, three and four, were equipped with humidifiers; during the heating season it was used yearly in object 3 and only in the first year of building in the object 4.

Table 1. Descriptions of the ventilation systems studied.

No	Age of building years	Age of duct years	Air flow capacity (m^3/s)	Filter change interval (months)	Filter efficiency (EU)
1	7	7	2.8	6	7
2	7	7	2.7	6	7
3	4	4	2.7	12	5
4	14	14	0.9	6	5
5	67	4	1.7	4	6
6	31	31	2.7	6	6
7	31	31	2.6	6	6
8	51	4	2.3	7	5

2.2 Sampling

A small amount of particles in supply air stream are settled on the bottom of an air duct. In a spherical duct, particles are mainly settled down on the surface which is rejected below the horizontal cross section. In a rectangular duct almost all of settled dust is settled on the bottom of a duct. For standardization of the sampling area to ducts with various diameters of spherical ducts dust samples were collected from an area which is rejected between the bottom line and the line on the widest level of the duct. The length (L) of sample area depended upon the limited space or on the amount of dust (Figure 1).

In rectangular duct the sample was collected from the bottom of the duct. The dust settled on the surface of the duct was loosened by crosswise movements of plastic nozzle as long as the galvanized steel seemed to be clean. The ventilation was turned off during the sampling.

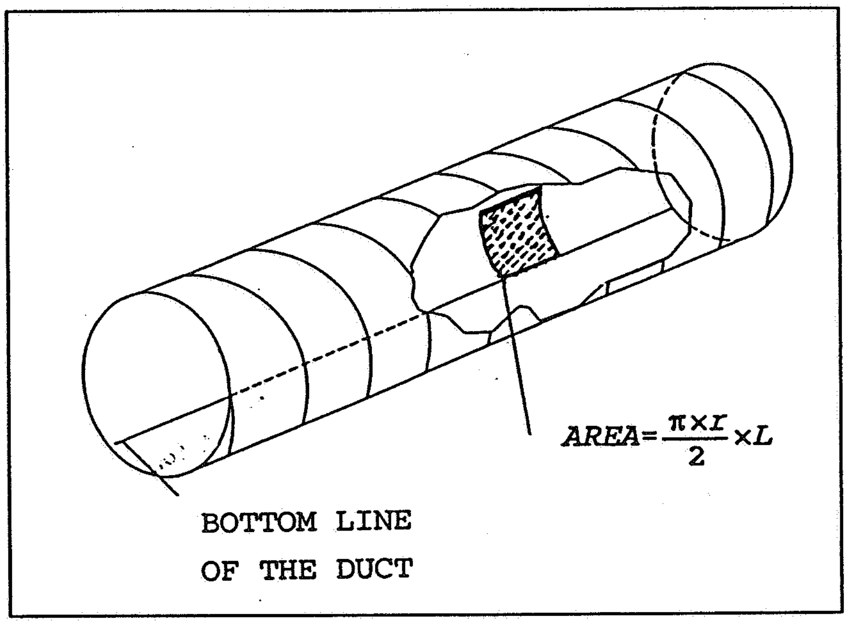

Figure 1. A schematic picture of the standardized sampling area in a spherical duct. L is the length of the sampling area.

For studying the behaviour of the dust in air ducts the samples were collected at the identical sites in different floors of the building. Both the vertical and horizontal distances were measured. The air flow rate in he sampling point was calculated from the information of the measuring data.

2.3 Analysis

Surface density (g/m^2) and yearly accumulation rate (g/m^2*year) of dust accumulated on the inner surface of supply air duct were determined. For comparison outdoor air dust sample was collected on EU7 classified ventilation filter during nine months. The proportion of the inorganic material of dust was determined as annealing lost by annealing the dried (105°C) sample at 550°C. The material loss indicates the proportion of organic and inorganic carbon (soot) particles.

The amount of different types of pollen were determined by using Bürker's method (4): A homogenized dust sample was divided to two parallel 20 mg portions which were mixed with 1 ml 20% Gelvatol mounting liquid (5). The pollen grains were counted by light microscope. Different types of pollen were divided to four classes according their mass: *Picea* 111 ng, *Pinus* 37 ng, *Betula* 1.4 ng and *Poacae* c. 20 ng (6).

Viable fungal spore counts and bacteria in the dust were determined by cultivation method on malt extract agar and on trypton-glucose-yeast extract agar, respectively.

3 RESULTS AND DISCUSSION

The average of surface density was 10.6 g/m^2 (n=44, ranged 1.2 to 58.3 g/m^2). The yearly accumulation rate of dust was 3.5 g/m^2*year (1.2-8.3 g/m^2*year). The yearly accumulation had a slight negative correlation with both horizontal and vertical distances between sampling site and air handling unit. The decrease in the amount of settled dust was observed especially in the main air duct on the top, at the same floor with AHU. This was observed also in our previous study when surface densities along the main air duct were measured and the AHU consisted coarse (EU2) filters. Any single factor, as horizontal or vertical distances from AHU, the height of the air intake from ground level or air flow rate measured in the sampling site had no statistically significant influence on the dust accumulation rate on the duct surface. The average of surface density of dust was about twice and the yearly accumulation rate five times higher than observed in the Danish study, respectively (7).

The proportion of inorganic material in dust was 82%. This agrees well with the result of our previous study, where the proportion was 80% (8). The corresponding proportion of dust sample was 81% collected in the down town area. The results showed that the dust accumulated in ventilation systems was originated from outdoor air which may indicate frame leakages between the filter cassette and assembly frame. The frame leakages of air conditioning filters is observed to be common particularly AHU with coarse filters (9). Soil depris during building construction period was observed in ducts of few objects.

In all randomly selected objects were EU5 classified or more efficient air filters therefore the effect of filter efficiency to dustiness of air ducts could not be examined regard to filtering efficiency. In our previous studies we found that filtration efficiency affected dirtiness of ducts; the coarser the filter more dust accumulated. The differences in accumulated dust are more clearly seen between the coarse filters (EU2-EU4) because of the higher differences in filtering efficiency (by weighting test). The relative dust accumulation into straight air duct by using filters with different efficiencies is presented in Figure 2. The results were calculated to the atmospheric aerosols and both the sedimentation and diffusion losses are taken account of calculation. Filtration efficiency has a significant effect on dust accumulation in supply air ducts. For example, dust accumulation rate into ventilation ducts equipped with EU7 classified filters is about three times slower than into ducts which are equipped with EU3 filters.

The average proportion of total pollen was 71 mg/g, of which about 90% was originated from coniferous trees (*Pinus, Picea*). Plants in the surrounding environment of the building affect the composition of pollen found in the ventilation ducts. The objects studied were equipped with fine filters, filter classification EU5 or better, which should be able to separate particles sized as large as analyzed pollen grains were, over 10μm. It is obvious that in the systems studied there have been or had been frame leakages or ventilation was used periodically without filters.

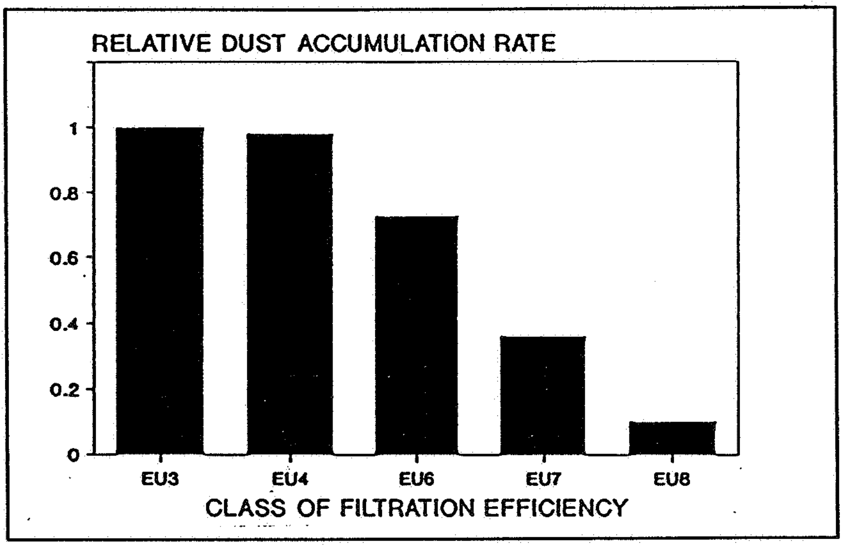

Figure 2. Relative rate of dust accumulation in supply air ducts by using filters with different filtration efficiency.

The average counts of viable fungal spores in the dust of air ducts was moderate low, 990 CFU/g (range 180-2340 CFU/g). That means about one spore per square centimetre. The result agree well with spore counts, obtained with similar method, in Danish study, 1100-1200 cfu/g (7). The fungal genera found in the dust was similar to outdoor air genera in Finland (10). This indicates that fungal growth has not occurred inside the ventilation system. The average counts of viable bacteria in the dust was 1980 CFU/g (from detection limit to 10000 CFU/g). For the sake of comparison the bacteria count levels found in house dust has ranged from 10^4 to 10^{10} CFU/g. Occupants and pets are the major bacterial sources in house dust (11).

4 CONCLUSIONS

The amounts of settled dust on supply air ducts were low. Thus the dust has no significant effects on air flow rates in supply air ducts. The dust found in the ducts had comparable composition with outdoor air dust. Relatively large amounts of pollen grains in the air ducts indicate that frame leakages between filter cassette and assembly frame is obvious. Both the fungal spore and bacteria count levels were moderate low compared with the levels in other indoor dust samples. The genera of fungal spores were similar those to found in outdoor air. It supports the conclusion about the frame leakages. In properly maintained HVAC system the settled dust on supply air ducts has an unremarkable significance to indoor air quality. If surfaces are moistened due to water condensation or by other reason the dust accumulated inside HVAC system offers an opportunity to microbial growth, and, thus, indoor air problems will arise.

No significant differences was observed between the dust accumulation levels in supply air ducts in different floors of the building. The quality of a particulate air filter had a significant effect on an accumulation rate of depris inside HVAC system. The coarser the filter is the more depris is accumulated in main air ducts.

ACKNOWLEDGEMENTS

This work was funded by a grant by of Ministry of Environment of Finland. We thank Jussi Teijonsalo from Helsinki University of Technology, HVAC-Laboratory for his flow rate measurements in the field. We tank The Finnish Aerobiology Group for the counting of pollen grains.

REFERENCES

1. MOREY,P. and SHATTUCK, D.
"Role of ventilation in the causation of building-associated illness"
Problem buildings: Building Associated Illness and Sick Building Syndrome. 1989, Philadelphia, USA, Hanley and Belfus Inc. pp625-643.

2. MOREY, P. and WILLIAMS, C.
"Is porous insulation inside an HVAC system compatible with a healthy building"
Proceedings of Healthy Buildings, ASHRAE, USA, 1991, pp128-135.

3. TAMBLYN, R. et al.
"A comparison of two methods of evaluating the relationship between fungal spores and respiratory symptoms among office workers in mechanically ventilated buildings"
Proceedings of Healthy Buildings, ASHRAE, USA, 1991, pp136-141.

4. BAKER, F.J., SILVERTON, R.E. and LUCKCOCK E.D.
"Introduction to Medical Laboratory Technology"
1955, London. Butterworth & Co. p330.

5. KÄPYLÄ, M.
" Adhesives and mounting media aerobiological sampling"
Grana, 28, 1989, pp215-218.

6. STANLEY, R.G. AND LINSKENS, H.F.
"Pollen: biology, biochemistry, and management"
1974, Berlin, Heidelberg, Germany. Springer-Verlag. p307.

7. VALBJØRN, O., NIELSEN, J.B., GRAVESEN S. and MØLHAVE, L.
"Dust in ventilation ducts"
Proceedings of the fifth Indoor Air Quality and Climate, 3, 1990, pp361-364.

8. LAATIKAINEN, T., PASANEN, P., KORHONEN, L., NEVALAINEN A. and RUUSKANEN, J.
"Methods for Evaluating Dust Accumulation in Ventilation Ducts"
Proceedings of Healthy Buildings, ASHRAE, USA, 1991, pp379-382.

9. PASANEN, P. et al.
"Criteria for changing ventilation filters"
Proceedings of Healthy Buildings, ASHRAE, USA, 1991, pp383-385.

10. PASANEN, A-L., REPONEN, T., KALLIOKOSKI, P. and NEVALAINEN, A.
"Seasonal variation of fungal spore levels in indoor and outdoor air in the subarctic climate"
Proceedings of the fifth Indoor Air Quality and Climate, 2, 1990, pp39-44.

11. van BRONSWIJK, J.E.M.H.
"House dust biology for allergists, acarologists and mycologists"
1981, Zoelmond, The Netherlands. NIB Publishers, p316.