Fire insulations of ventilation equipment and shafts as a source of man-made mineral fibres

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SUMMARY

The sources of man-made mineral fibres (MMMFs) settled on furniture surfaces and in supply air were determined in an office building. The impact of renovation on indoor air and the perception of air quality by the occupants were studied. Renovation improved the air-tightness of the inner parts of structures. Settled MMMFs were collected with gelatine tape by pressure and deposition techniques. MMMFs in supply air were collected using the filter installed to the supply diffuser. Sources of MMMFs were determined by comparing the found fibres to the fibres of insulation materials in the building using SEM/EDS. Occupants’ perceptions of air quality and how it affected their wellbeing were collected using a questionnaire. The results showed that MMMFs originated mainly from fire insulations outside the main air ducts in shaft structures. The renovation improved indoor air quality and reduced the number complaints and symptoms of occupants. This study indicates that it is important to maintain the air-tightness of building preventing air leakage from shaft structures to indoor air.

INTRODUCTION

Man-made mineral fibres (MMMFs), which are also referred to as man-made vitreous fibres (MMVF), are amorphous silicates manufactured from glass, rock, or other mineral [1, 2]. The concentrations of man-made mineral fibres in indoor air and the sources of mineral fibres have been studied in Europe and in the United States since the 1980’s. Based on current knowledge, the sources of man-made mineral fibres can be thermal, sound, acoustical and fire protection insulations in building structures and ventilation equipments. Although MMMFs are not considered to have a carcinogenic effect [4], high levels have been related to symptoms experienced by occupants in particular irritation of the respiratory tracts, eyes and the skin. Exposure to fibres occurs mainly through surfaces [3].

The purpose of the study was 1) to identify the sources of MMMFs settled on furniture surfaces in the office building and 2) to assess the impact of renovation on the indoor air quality and on the experiences of occupants. This study is the part of comprehensive study that focuses on the condition of indoor air quality and climate of the building.

METHODS

A 8(9)-storey office building in which occupants perceived building-related symptoms was studied. The stone-structured building comprised of three sections connected to each other by an intermediate part. The study building had a mechanical air handling system. The main air ducts of ventilation units were located in vertical shafts located in the centre of the each building sections.
Man-made mineral fibres settled on room surfaces were sampled with gelatine tape (tape size 2 cm x 7 cm) by pressing the tape against surface or by allowing fibres deposit on the tape placed on the surface. The deposition time was one week. MMMFs were calculated with a light microscope. Two replicate samples were taken from each measurement point. The results were expressed as fibres/cm².

Man-made mineral fibres in supply air were collected using the polypropylene filter cloth that was attached to the supply diffuser. Mineral fibres were calculated using light microscopy. The samples were taken in different parts of the building complex, in the service areas of different ventilation units. Results were expressed as fibres/m³.

The sources of MMMFs were determined using scanning electron microscope with X-ray microanalysis (SEM/EDS). The sampled MMMFs were compared to the insulation materials of structures and ventilation equipments.

Complaints and symptoms experienced by occupants were collected using the Indoor Air Questionnaire (modified MM-40 questionnaire). Complaints and symptoms attributed to the building every week were reported from the past three months. The inquiry was conducted twice, before and after renovation in 2004 and in 2006, and in one part of building five times between years 2001 and 2006. The percentage of answered questionnaires ranged from 53 % to 60 % yielding 250 and 310 answers.

After determining the initial quality of the indoor air, the building was renovated. The feedthroughs of the vertical shafts and the manholes were sealed and an under pressure was created in the shafts. Old transfer air vents leading from rooms to the corridors were also sealed. The air-tightness of structures was checked with tracer gas, sulphur hexafluoride gas, and gas analyser after renovation.

In the statistical analysis the results were tested with the testing method of proportional sample (questionnaires) and with the $t$-test (mineral fibre concentrations).

RESULTS

Man-made mineral fibres on surfaces

A significant decrease in settled man-made fibres ($p<0.001$) was observed after renovation of an office building (Table 1). The decrease in concentration levels had taken place in 2006 both as regards the number of samples exceeding the target maximum value of 0.20 fibres/cm² and as regards the average concentration level. In 2004 the variation of the MMMF concentrations was high ranging from <0.07 fibres/cm² to 100 fibres/cm². The high single concentrations may be due to the basic repairs of ventilation equipments in process simultaneously in part of the building and insufficient protection during work. This becomes evident in the check-up measurements carried out after the repairs in 2004 whereby equally high single concentrations were not observed.

<table>
<thead>
<tr>
<th></th>
<th>Pressure samples</th>
<th>Deposition samples</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2004</td>
<td>2006</td>
</tr>
<tr>
<td>Number of samples</td>
<td>137</td>
<td>80</td>
</tr>
<tr>
<td>Average fibres/cm²</td>
<td>4.27</td>
<td>0.07</td>
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<tr>
<td>Median, fibres/cm²</td>
<td>0.29</td>
<td>&lt;0.07</td>
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<tr>
<td>Minimum, fibres/cm²</td>
<td>&lt;0.07</td>
<td>&lt;0.07</td>
</tr>
<tr>
<td>Maximum, fibres/cm²</td>
<td>100</td>
<td>0.29</td>
</tr>
<tr>
<td>Samples exceeding target value of 0.20 fibres/cm², %</td>
<td>58</td>
<td>4</td>
</tr>
</tbody>
</table>

Man-made mineral fibres in supply air

In general, the mineral fibre concentrations in supply air were low. The MMMF concentrations varied from <1 fibre/m³ to 21.4 fibres/m³. It was found that the MMMF concentrations were below the target value of 1.0 fibre/m³ suggested by Finnish Institute of Occupational Health [5] in 80 % of samples.

Sources of man-made mineral fibres

X-ray microanalysis of settled man-made mineral fibres showed that MMMFs originated mainly from the fire insulations outside the main air ducts of the vertical shafts. Some fibres originated from the insulation materials of partition walls and from old transfer air vents in 2004, but not after renovation in 2006. MMMFs in supply air and on furniture surfaces originated from the same source i.e. the fire insulations outside main air ducts of vertical shafts.

Indoor Air Questionnaire

In general, the amount of building related symptoms and environmental complaints decreased after renovation (Figures 1 and 2). No exceptional amount of building-related symptoms (above 20 %) and environmental complaints (above 40 %) emerged in autumn 2005 or in the spring months of winter 2006. The amount of reported eye irritation symptoms and dry air perception diminished significantly (p<0.05) in the winter spring months (in 2006 compared to 2004). Similarly, the dry skin symptoms and dry air perception diminished significantly (p<0.001) in autumn (in 2005 compared to 2001). In late winter in 2006 more symptoms were reported than in autumn 2005. In winter time indoor air is dry in Finnish buildings and may increase the perception of dry air.
Figure 1. Building related symptoms in the study area of the building. After the inquiry of 02/2004 the comprehensive measures were made in the building.

Figure 2. Environmental complaints in study area of the building. After the inquiry of 02/2004 the comprehensive measures were made in the building.
DISCUSSION

These results showed that man-made mineral fibres found in dust settled on furniture surfaces and in supply air originated mainly from the fire insulation materials outside the main air ducts of the vertical shafts and also to a lesser extent from the insulations of the partition walls and from transfer air vents. This study indicated importance of renovation for indoor air quality. The indoor air quality improved, and, complaints and symptoms experienced by occupants decreased as the emissions of MMMFs decreased.

Thus the renovation work of sealing the inner parts of the structures towards the shaft structures, can be considered useful. The present study does not provide adequate evidence to conclude the reasons for symptoms and complaints. The symptoms and complaints may have been caused by mineral fibres, or they may also be related to the migration of the air into indoor air through non-airtight structural components. The air flowing through the structures contains various impurities originating from building materials or for example from microbes attached to the inner walls of shaft structures. The joints between the indoor spaces of the building and the shaft structures were non-tight and air flowed towards indoor spaces from the shaft structures. Buildings with mechanical ventilation system have mainly negative pressure. Based on this research results it is important in buildings with mechanical ventilation system to maintain the air-tightness of the inner parts of structures e.g. towards shaft and air conduit structures.

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REFERENCES