

Exposure to man-made mineral fibers at ten production plants in Sweden

by Staffan Krantz, MSc¹

An occupational environmental study has been performed in Sweden on the increased exposure to man-made mineral fiber (MMMF) dust, because of the rapid growth of MMMF production in the mid-1970s. The study was supported by the MMMF industry and the Swedish Work Environmental Fund. Ten factories were included covering the production of insulation wool (rock and glass), continuous-filament glass fibers, and special purpose fiber products. The special fiber products were earplugs (glass) and Inorphil (rock).

A pilot study at the factory producing continuous-filament glass fibers showed that no airborne respirable glass fibers were present. Therefore this factory was excluded from further investigation. At the remaining nine factories a careful characterization of the airborne dust was carried out on total dust levels, fiber levels, fiber size distributions, and the percentage of MMMF and Stanton fibers (S fibers). Both old and new factories were included.

Sampling strategy and measuring methods

The measurements were planned in cooperation with the local health and safety committees at each plant. The workplace was then divided into different occupational groups. This presentation will be limited to the following main groups: (i) process workers, (ii) maintenance workers, and (iii) cleaning workers.

So that the exposure within the different occupational groups would be representative, at least one person was included per group, per machine, and per production line.

Personal sampling was carried out with a small battery-operated pump and an open-face 37-mm filter cassette placed in the workers' breathing zone. The sampling period was normally two full shifts, and the sampling time varied between 2 and 8 h depending on the operation and fiber level. Approximately 75 % of the filters were Millipore AAWP used for total dust and fiber number determinations. The remaining 25 % were Nuclepore filters, also with a 0.8-mm pore size but used for scanning electron microscopy (SEM). Total dust was analyzed by a normal weighing procedure using a Mettler ME 22 balance, and the fiber counting was performed with phase contrast optical microscopy (PCOM) at a magnification of 500 times

according to special rules (2). A respirable fiber was considered to be a particle with an aspect ratio of at least 3:1 and a diameter equal to or less than 3 µm. Fibers shorter than 5 µm were not counted.

The fiber size distribution was determined from SEM micrographs. At least 100 fibers were measured, and all fiber sizes were included, even fibers shorter than 5 µm. To aid the visibility of short, thin fibers, a total magnification of 10 000 times was used. The size distribution was then calculated for fiber diameters and lengths and presented in diagrams. From these relationships the so-called S fibers (1) can be calculated. S fibers are fibers equal to or thinner than 1.5 µm and equal to or longer than 8 µm. These fibers are supposed to be of special toxicologic interest.

Energy dispersive X-ray analysis was used for the chemical characterization of the individual fibers visible in the SEM. The fibers were then grouped into the following categories: (i) MMMF, (ii) organic fibers, and (iii) other fibers, including those too thin to be analyzed, eg, <0.1 µm in diameter.

Results

In the study there were about 500 sampling sites, and 1 350 samples were taken. The mean (arithmetic) exposure to total dust levels and the PCOM fiber levels during rockwool and glasswool production are presented in table 1 for the different occupational groups.

There are only two different special fiber products included in this study, and neither of these used oil or binder for dust reduction. Table 2 shows the results for special purpose fiber production in terms of total dust and respirable fiber levels.

The fiber size distributions of the airborne dust during insulation rockwool and glasswool production are

Table 1. Total dust levels and respirable fiber levels given as the means for insulation wool production.

Occupational group	Total dust (mg/m ³)		Fiber level (fibers/ml)	
	Rock	Glass	Rock	Glass
Process workers	0.8	0.7	0.15	0.14
Maintenance workers	1.1	4.4	0.20	0.23
Cleaning workers	2.9	0.2	0.27	0.15
Mean (all groups) ^a	1.4	1.9	0.20	0.18
Total range	0.1–32	0.1–410	0.01–2.6	0.01–1.8

^a Also includes raw material handling.

¹ Division of Aerosols, National Institute of Occupational Health, Solna, Sweden.

Table 2. Total dust levels and respirable fiber levels given as the means for special purpose fiber production.

Occupational group	Total dust (mg/m ³)		Fiber level (fibers/ml)	
	Rock	Glass	Rock	Glass
Process workers	2.0	0.6	1.4	0.62
Maintenance workers	—	0.4	—	0.20
Cleaning workers	—	0.4	—	0.16
Mean (all groups) ^a	2.0	1.0	1.4	0.47
Total range	0.5—2.0	0.1—1.4	0.45—1.9	0.08—2.4

^a Also includes raw material handling.

Table 3. Median and nominal diameters of the airborne fibers in the product for different types of man-made mineral fibers.

Type of fiber	Median diameter (μm)		Nominal diameter (μm)
	Arithmetic mean	Range	
Insulation wool			
Rock	1.0	0.57—1.77	5—7
Glass	0.4	0.25—0.69	5—7
Special fibers			
Rock	0.5	0.29—0.71	4—5
Glass	0.2	0.13—0.28	2—3

Table 4. Percentage of Stanton fibers (S fibers) in different types of man-made mineral fiber dust.

Type of fiber	S fiber (%)	
	Mean	Range
Insulation wool		
Rock	42	27—63
Glass	27	11—51
Special fibers		
Rock	25	20—29
Glass	24	14—34

Table 5. Levels of man-made mineral fibers (MMMF) in the fibrous airborne dust. (NA = not analyzed)

Occupational group	Insulation wool ^a		Special fibers ^a	
	Rock	Glass	Rock	Glass
Process workers	High	High	High	High
Maintenance workers	Low	Low-high	NA	NA
Cleaning workers	High	NA	NA	NA

^a High = 75—100 % MMMF, medium = 30—75 % MMMF, low = 0—30 % MMMF.

presented in figure 1. The shadowed areas show the span between the distributions with the minimum and maximum median lengths (on the left) and minimum and maximum median diameter (on the right). All together there were about 50 samples analyzed for fiber size distribution.

The median diameters of the airborne fibers were, in all cases, much smaller, by almost one order of magnitude, than the nominal diameters of the products (table 3). Table 4 shows the percentage of S fibers in the airborne dust. Table 5 shows the percentage of

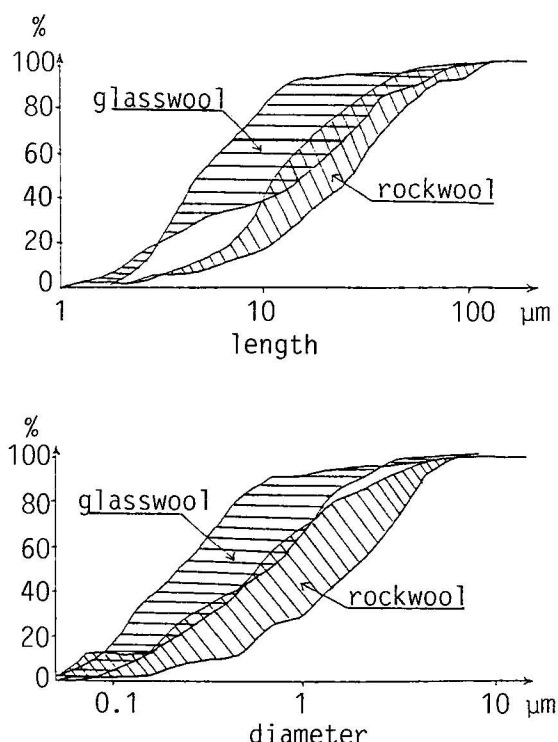


Figure 1. Length and diameter distributions for airborne glasswool and rockwool fibers.

MMMF in the fibrous dust for the different occupational groups.

Discussion

According to the mean values presented in table 1 for all the groups, rockwool and glasswool insulation is equally dusty in terms of total dust and fiber dust concentrations, 1.4 mg/m³ against 1.9 mg/m³ and 0.20 fiber/ml against 0.18 fiber/ml. Higher levels were found among the maintenance and cleaning personnel, in some cases very high individual total dust levels, ie, >30 mg/m³. The highest fiber level measured among the process workers was 0.55 fibers/ml, and according to the chemical analysis the proportion of MMMF was high. High fiber levels of >1 fibers/ml were only found in maintenance work and raw material handling, where fibers other than MMMF were predominant. No significant difference was detected between the old and new plants in terms of fiber levels.

During the production of special purpose fiber products, higher individual fiber levels were measured during process work, ie, 1.9 fibers/ml for rockwool and 2.4 fibers/ml for glasswool. The mean level was 1.4 fibers/ml for rockwool and 0.47 fibers/ml for glasswool. The main reason for these higher values was the absence of dust-reducing oil and binder in combination with manual handling.

As can be seen from the size distributions (figure 1), airborne rockwool fibers are longer and thicker than glasswool fibers. For special purpose fiber production the distributions for both rockwool and glasswool shift towards thinner and shorter fibers.

According to table 3 the maximum median diameter for airborne insulation rockwool fibers was below 2 μm , and for the other fiber types it was below 1 μm . When these values are compared with the nominal fiber diameter of the product (table 3), it is obvious that it is the fine (thin) fibers in the product that become airborne. In addition the respirable fraction of the airborne fibers varied between 73 and 94 % in the entire study; in other words most of the airborne fibrous dust was respirable.

Rockwool production gave the highest S fiber value in the airborne fibrous dust, in spite of a smaller fraction of thin fibers (< 1.5 μm), 60 % against 85 % for the other fiber types. This finding can only be explained by the higher fraction of longer (> 8 μm) fibers for rockwool, 90 % against 50 % for glasswool and 30 % for special fibers. A new insulation rockwool plant showed the same S fiber percentage as insula-

tion glasswool because of fewer longer fibers present in the air. Special purpose fibers had somewhat lower S fiber values than insulation glasswool because the airborne special fibers were shorter.

The chemical analysis of the airborne fibers (table 5) showed that the proportion of MMMF was high for work close to the production process. Low MMMF fractions existed mainly in service work, which did not take place in the immediate vicinity of the production process.

References

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