STAMI
STATENS ARBEIDSMILJØINSTITUTT

Short report:

Asbestos measurements during removal of asbestos-containing building materials

This report is based on the full report in Norwegian: Asbestmålinger ved brann og rivning av asbestholdige byggematerialer– Delrapport 1: Asbestmålinger ved rivning av asbestholdige byggematerialer. STAMI report No 1 (2021),

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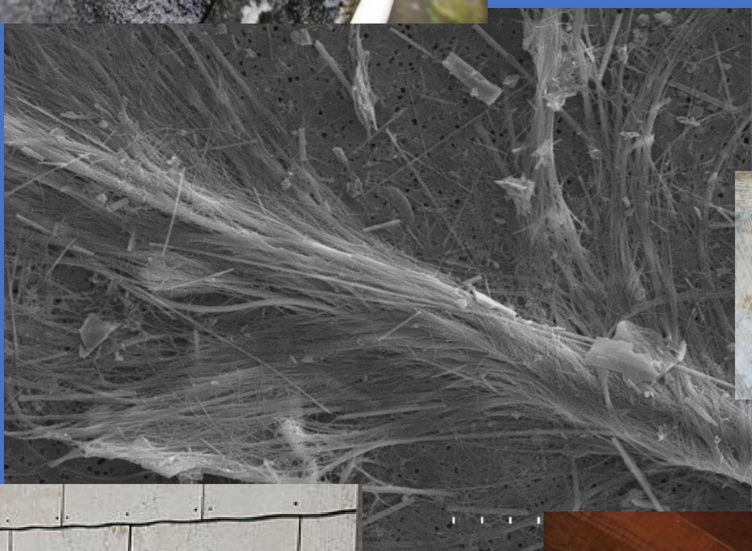
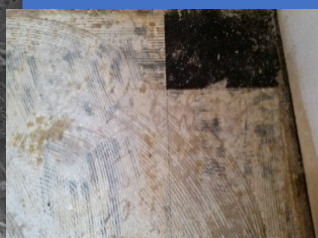
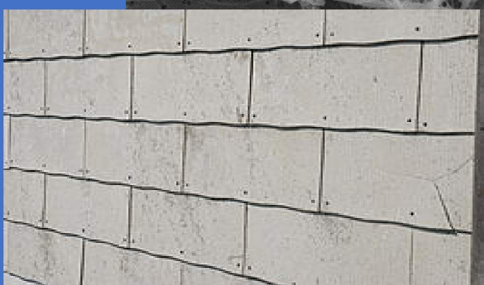






Content

Chapter 1: Summary

This is a short version of the Norwegian project report "Asbestmålinger ved brann og rivning av asbestholdige byggematerialer– Delrapport 1: Asbestmålinger ved rivning av asbestholdige byggematerialer". The Norwegian report can be found on: www.stami.no

It has been forbidden to use asbestos in building materials since 1985, but there are still a lot of asbestos-containing building materials left in private and public buildings. Many of these are now getting so old that they need to be renovated or demolished. An inadequate mapping of where in the buildings asbestos is located can result in inadequate removal of asbestos-containing material before work begins. It is, therefore, a risk that construction workers may be exposed to asbestos during this type of work.

This report describes the levels of asbestos fibres which can occur in the air at the workplace when working with asbestos-containing building materials. The measurements show that it is a potential for exposure if the correct protective equipment is not used.

Sampling of asbestos fibres was carried out with 'open-faced' antistatic sampling cassettes with either a 25 mm polycarbonate filter or 25 mm cellulose residue filter. Pumps specially designed for this project were used for sampling. The flow during sampling was 2 L/min, and the sampling continueduntil the end of the work or when the sampling had to be completed to avoid overloading the samples. Parallel samples were taken for fibre counting with phase-contrast microscope (PCM), scanning electron microscope (SEM), and transmission electron microscope (TEM).

Several of the measurements show levels of asbestos fibres above the occupational exposure limit values, although the work was carefully performed. Therefore, it is important to identify the possible occurrence of asbestos before starting work and that all asbestos-containing materials is removed correctly and safely. Especially when working with porous materials such as indoor ceiling and wall plates of asbestolux, a significant amount of fibre can be released into the air. Also, when handling exterior materials that have weathered and become porous due to age and wear, such as roof plates in eternit, a significant amount of fibres can be released. In indoor flooring materials, it appears that the asbestos fibres are firmly fixed in the matrix and, therefore, less fibres are released when working with these materials. However, the release of asbestos fibres into air cannot be excluded when working with these materials.

Although building materials often contain mainly one type of asbestos, the presence of several asbestos types, both amphibole and serpentines, are almost always found. The composition of the asbestos is dependent on where and when the materials were produced. In most material samples collected in this study, several types of asbestos were found.

The project has shown that there is a good consensus between PCM and SEM when asbestos fibres are the only type of fibre present, but that PCM seems to overestimate asbestos exposure when other types of fibres such as gypsum are present. TEM proved to be unsuitable for these samples in this project due to overload of the filters.

The proportion of thin fibres, with a diameter below 0.2 µm, in the workplace air varied by type of material but was found to be up to 40 % in some cases. When the proportion of amphibole in the material is high, such as in asbestolux, the proportion was lower and around 10 %. Consideration should thus be given to whether counting thin fibres should be done more frequently since this information may be important for assessing the health risks of asbestos exposure. The concentration of thin fibres should then be reported as a separate fraction and not included in the concentration of fibres with a diameter of 0.2 µm or thicker.

The study has received financial contributions from the fund of The Regional Safety Representatives - Building and Construction.

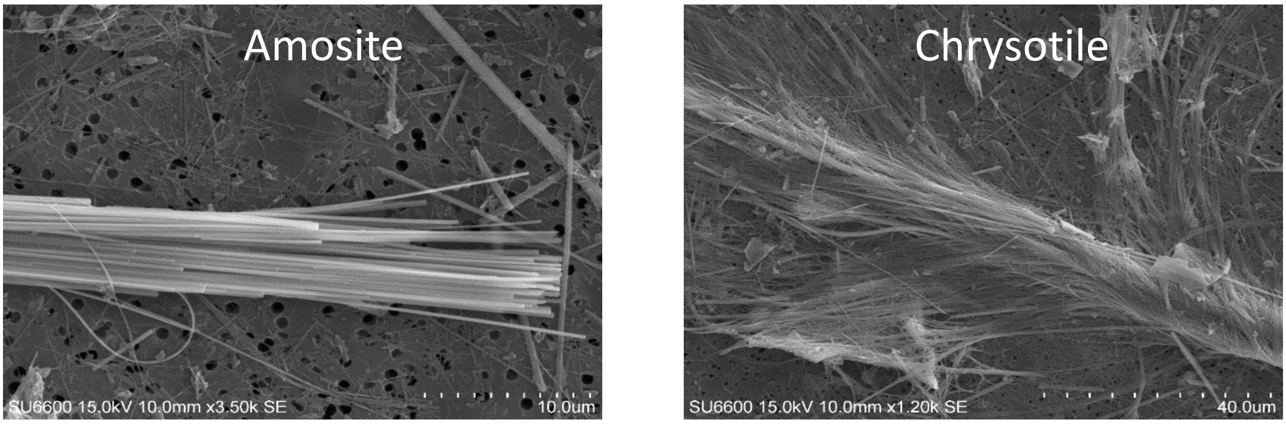
Main conclusions:

- A high proportion of asbestos fibres can be released into the air during asbestos removal. Therefore, it is important to identify possible asbestos deposits and to remove all asbestos containing materials before demolition or renovation work is started.
- Careful asbestos removal with additional measures such as vacuuming and the use of soap water can reduce the release of asbestos fibres into the air.
- Fibre concentration in air varied with material type. When working with brittle materials such as asbestolux and corroded roof plates, it was highest. Fibre concentration was lower during the removal of floor tiles.
- The proportion of thin fibres (with a diameter below 0.2 µm) depended on the type of material. In materials with chrysotile as the main component, the proportion was highest and up to 40 %.

- Some tasks, such as sawing and drilling, generate significant amounts of airborne fibres. This underlines the importance of proper protective equipment.
- Fibre counts using a scanning electron microscope or phase-contrast microscopy gave comparable results when asbestos fibre was the only fibre type present.

Chapter 2: Background

Asbestos is a group of minerals that occur naturally in the form of fibres. There are several different types of asbestos fibres that differ both morphologically and chemically. In general, the different forms of asbestos can be divided into two main groups depending on the morphology of the fibres: serpentine (softer fibres, e.g., chrysotile) and amphibole (stiffer fibres, e.g., crocidolite and amosite) (Figure 2.1).



Figur 2.1: SEM picture of amphibole fibre (amosite) and serpentine fibre (chrysotile). Photo: Torunn Kringlen Ervik, STAMI

Asbestos has been used for thousands of years, for example, in ceramics, but large-scale use of asbestos began in the 1880s when asbestos was used for heat and acid-resistant textiles and various insulation products. Throughout the 20th century, asbestos was used in a variety of products, including building materials, such as ceiling and wall cladding, floor mats, cement, and insulation.

It became apparent early on that working with asbestos could lead to negative health effects. Already in 1918, the first X-rays of the lungs of asbestos workers showed lung changes. Throughout the 1920s, several cases of pulmonary fibrosis (asbestosis) were described (Dodson and Hammar 2011). Cases of pulmonary fibrosis were eventually also described in persons working in the production of asbestos-containing products, workers in asbestos mines, and individuals using asbestos-containing products (Dodson and Hammar 2011). Also, the link between asbestos exposure and cancer has been known for a long time, both lung cancer and mesothelioma (Dodson and Hammar 2011, Markowitz 2015). Asbestos exposure is today considered the dominant cause of mesothelioma. It is difficult to create a dose-response curve for this cancer. However, it is assumed that relatively low exposure may entail an increased risk of disease (Markowitz 2015). Mesothelioma has a long latency (40 years) which makes it difficult to link exposure levels to disease (Lacourt et al. 2017).

Since 1985, it has been forbidden to use asbestos in building materials in Norway: However, it is estimated that more than a hundred people still die every year in Norway of cancer linked to asbestos exposure. Occupational exposure to asbestos is still an issue. Today, it is often described as the third wave of asbestos exposure (Landrigan 1991). Workers in asbestos mines and the production of asbestos-containing products comprised the first wave. Workers using the various materials made up the second wave, for example, housebuilders. Workers demolishing or renovating old houses with asbestos-containing building materials comprise the third wave.

Exposure to asbestos has traditionally been quantified by sampling air and filtering particulate matter including asbestos fibres onto a cellulose filter, which is then investigated in a microscope. Counting asbestos fibres in these samples is usually done using a phase-contrast microscope (PCM), which is a relatively inexpensive method. The disadvantage of this method is that it cannot detect fibres thinner than 0.2 µm or distinguish between asbestos and other fibre types. According to the World Health Organization (WHO), the fibres must be longer than 5 µm, have a diameter of less than 3 µm, and a ratio of length to thickness of more than 3:1 (World Health Organization. 1997).

It is assumed that the workers are well protected (respiratory mask and protective clothing) when asbestos is removed in accordance with the guidelines of the Norwegian Labour Inspectorate. Unfortunately, it happens that workers demolish asbestos-containing building materials without knowing that asbestos-containing materials exist in what they remove. Therefore, it is important that workers in the construction and demolition industry gain knowledge about asbestos, where it exists, how it is handled, protective measures, and possible health risks from exposure.

This project was initiated in cooperation with the regional safety delegates in building and construction. The study has received financial contributions from the fund of The Regional Safety Representatives - Building and Construction.

Chapter 3: Exposure when working with different asbestos containing materials

In this report, the results are arranged by the type of building material: indoor wall plates, indoor flooring, pipe insulation, outdoor wall and roof tiles.

3.1 Indoor walls

Figure 3.1: Removal of indoor asbestolux wall plates

Interior wall plates and ceiling plates, such as asbestolux, is often brittle and contain large amounts of amosite. The removal of indoor walls was done carefully to reduce the spread of fibres. Still, relatively high fibre concentrations were measured in the air when sanitising this type of material, and more than 90 % were amphibolic fibres and mainly amosite. Fibre counts from the personal sampling during indoor asbestolux removal are shown in Table 3.1.

Table 3.1: Air concentrations of asbestos fibers during removal of asbestolux wall plates.

Work operation	PCM (f/cm^3)
Removal of interior wall plates	1.4
Removal of interior wall plates	2.5
Removal of interior wall plates	4.7
Removal of interior wall plates	1.6
Removal of interior wall plates	2.5

3.2 Indoor floor

Figur 3.2: Removal of asbestos containing floor.

Vinyl flooring tiles with chrysotile is a matrix consisting of varying amounts of organic polymers, calcium carbonate or sulphate, mica minerals, cellulose, titanium dioxide (TiO_2), and/or quartz. In such flooring materials, the asbestos fibres are firmly bound in the floor matrix (Figure 3.3). The amount of asbestos varies between 5–30 % (Perez et al. 2018). Also, asbestos can be present in the matrix.

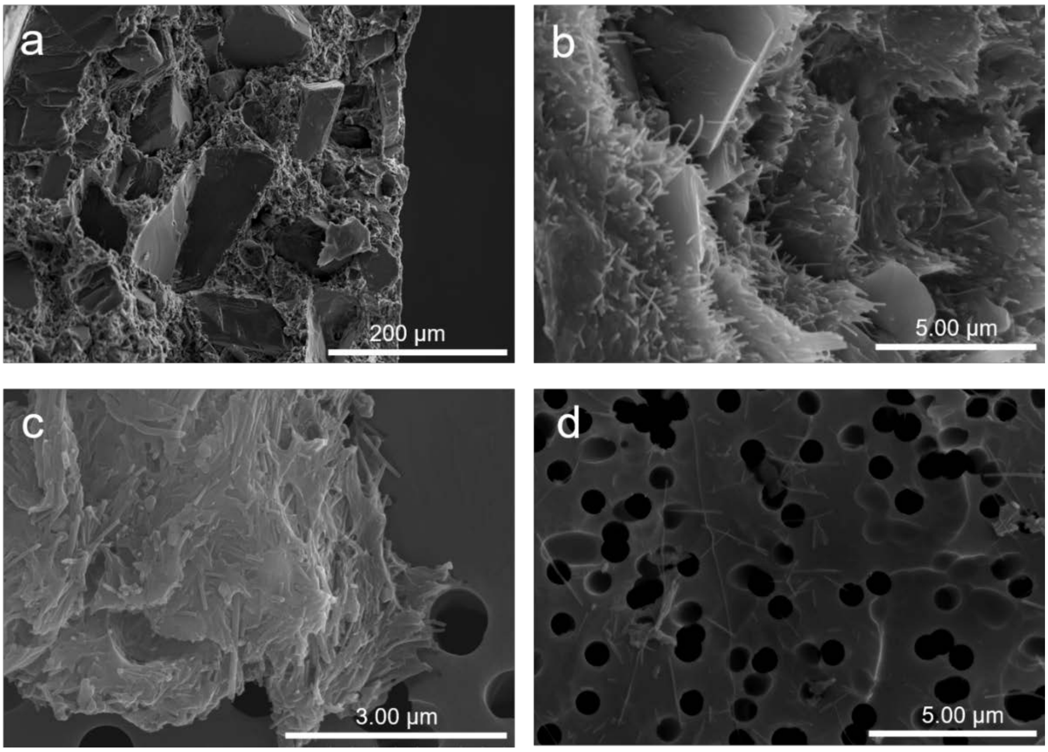


Figure 3.3: **A** Cross-section of a floor tile **B** Enlarged view of A shows asbestos fibers protruding from the edge **C** large dust particle with embedded dust fibers **D** Released fibers (most are < 5 µm).

A challenge when quantifying asbestos during floor removal is that dust and particles from other building materials settle on the floor and swirl up during removal of the floor. If it is very dusty, the main challenge is that the filters might quickly become overloaded and thus cannot be counted. For example, gypsum fibres may remain on the surface of the floor, and these fibres might be misinterpreted as asbestos fibres and counted with PCM. With PCM, the fibre concentration is above the limit value for all samples, while the SEM samples have less than four fibres per filter and are, therefore, below the detection limit. When examining material samples, gypsum fibres and other particles were found on the surface of the floor samples.

Table 3.2: Air concentrations of asbestos during removal of asbestos containing floor.

Work operation	PCM (f/cm^3)
Removal of floor - griding	0.2
Removal of floor tiles	0.4
Removal of floor tiles	0.3
Removal of corc floor	2.0
Removal of corc floor	1.6
Floor packing	1.3
Floor packing	2.1

3.3 Pipe insulation

Figure 3.5: Removal of a pipe section with asbestos insulation.

The pipe section, if containing asbestos, is wrapped in plastic before being removed as a whole piece, without covering the whole room as is done in other indoor asbestos removals.

For pipe asbestos removal, it is assumed that asbestos fibres are not released since the pipe section in question is wrapped in plastic before dismantling. Air sampling conducted during this work still showed 0.1 asbestos fibres, when counted with PCM. However, an asbestos fibre concentration of 0.02 fibre/cm^3 was determined by SEM. Other fibre types, such as gypsum, where found and might explain discrepancy between PCM and SEM.

3.4 Outdoor walls and roof

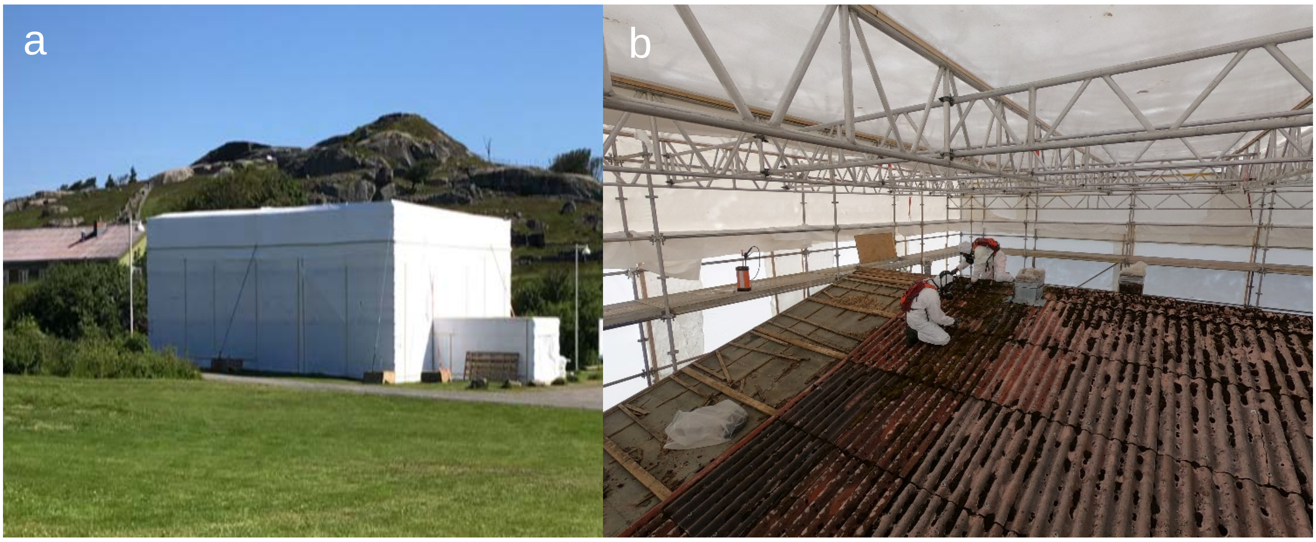


Figure 3.6: A The enclosed object from outside **B** inside of the enclosure during removal of roof

When performing asbestos removal of outdoor walls and roof, the sanitation area is usually not covered in plastic, but those who carry out the work have proper protective equipment. In this project, measurements have been made by sanitation on roofs and walls without a plastic cover and the sanitation of exterior walls and ceilings in an experiment in which the house was covered in plastic (Figure 3.6).

The results from the enclosed asbestos removal are shown in Table 3.3. The asbestos removal in an enclosed area provided the possibility of testing whether different working methods had an effect on the release of asbestos fibres from the building material. The colours in Table 3.3 distinguish the different working methods, where green shows careful removal with additional measures such as vacuuming and the use of soap as a binder. The white fields show the fibre concentration when asbestos removal is conducted without additional measures. This should, therefore, be considered as normal asbestos removal. The red fields show samples from removal where the work is carried out carelessly. The fiber concentrations measured by careful work (green) are below the limit value, while work performed in the usual way (white) and careless (red) results in fibre concentrations above the occupational limit value. The proportion of small fibres counted by SEM (< 0.2 μm) ranged from 20–40 %.

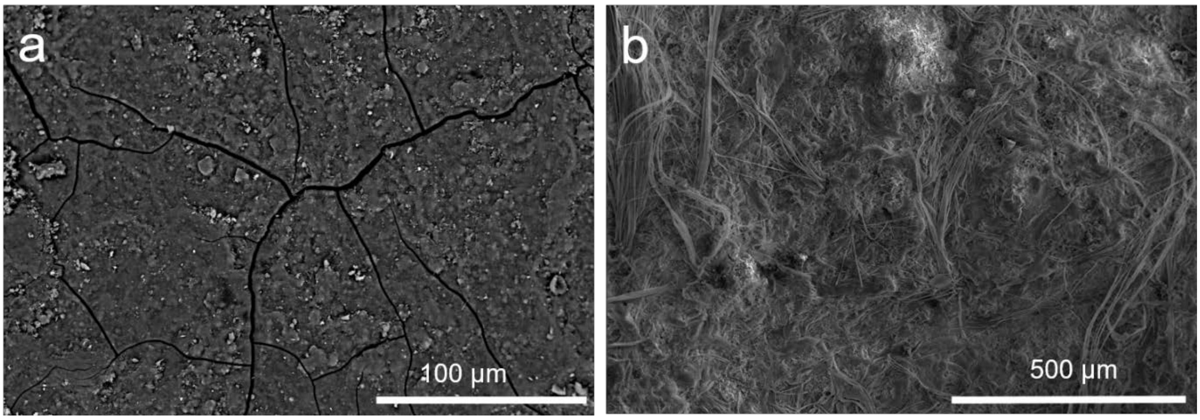
Table 3.3: Air concentrations of asbestos fibers during removal of eternity wall and roof. The removal work were classified as: careful work (green) regular (white) and careless (red).

Work operation	PCM (f/cm³)
With plastic cover	
Removal of eternit wall plates	0.03
Removal of eternit wall plates	0.04
Removal of eternit wall plates	0.2
Removal of eternit wall plates	0.3
Removal of eternit wall plates	0.2
Without plastic cover	
Removal of eternit wall plates	0.01
Removal of eternit wall plates	0.04

Work operation	PCM (f/cm³)
With plastic cover	
Removal of eternit roof plates	0.1
Removal of eternit roof plates	0.1
Removal of roofing felt	0.2
Removal of roofing felt	0.2
Removal of eternit roof plates	0.1
Removal of eternit roof plates	0.1
Removal of eternit roof plates	0.4
Removal of eternit roof plates	0.6
Removal of eternit roof plates	0.3
Removal of eternit roof plates	0.3
Removal of eternit roof plates	0.2

Asbestos cement is a mixture of cement and asbestos fibres. The most common type of asbestos cement is eternit, which was widely used as outdoor wall covering. Chrysotile, amosite and crocidolite are frequently found in asbestos cement, but chrysotile is the most commonly used. All three asbestos fibre types were found in the material samples from the exterior walls. No asbestos fibres were found in the wall felt.

Samples were collected during asbestos removal of various types of roofing: both asbestos slate and corrugated eternit. During the asbestos removal, loose material found under the roof plates was collected. Asbestos fibres were observed in these material samples. The corrugated eternit, which was probably mounted in the 1960s, was clearly weathered as the surface layer had corroded away on large parts of the roof. Where the surface had corroded away, the cement had also begun to disintegrate, and asbestos fibres were visible (Figure 3.7) (Ervik et al. 2021).



Figur 3.7: A surface of a roof eternite tile with an intact surface coating **B** surface of a roof eternit tile where the surface coating as erroded resulting in the fibers being exposed

Chapter 4: Short-term measurements during different work operations

During the project, measurements of asbestos fibres were done during drilling and sawing in asbestos-containing building materials (Figure 4.1). This was done to investigate the exposure during minor work tasks such as drilling a hole in the outer wall. These operations are short, but a craftsman may have to perform many such short-term operations on asbestos-containing materials.

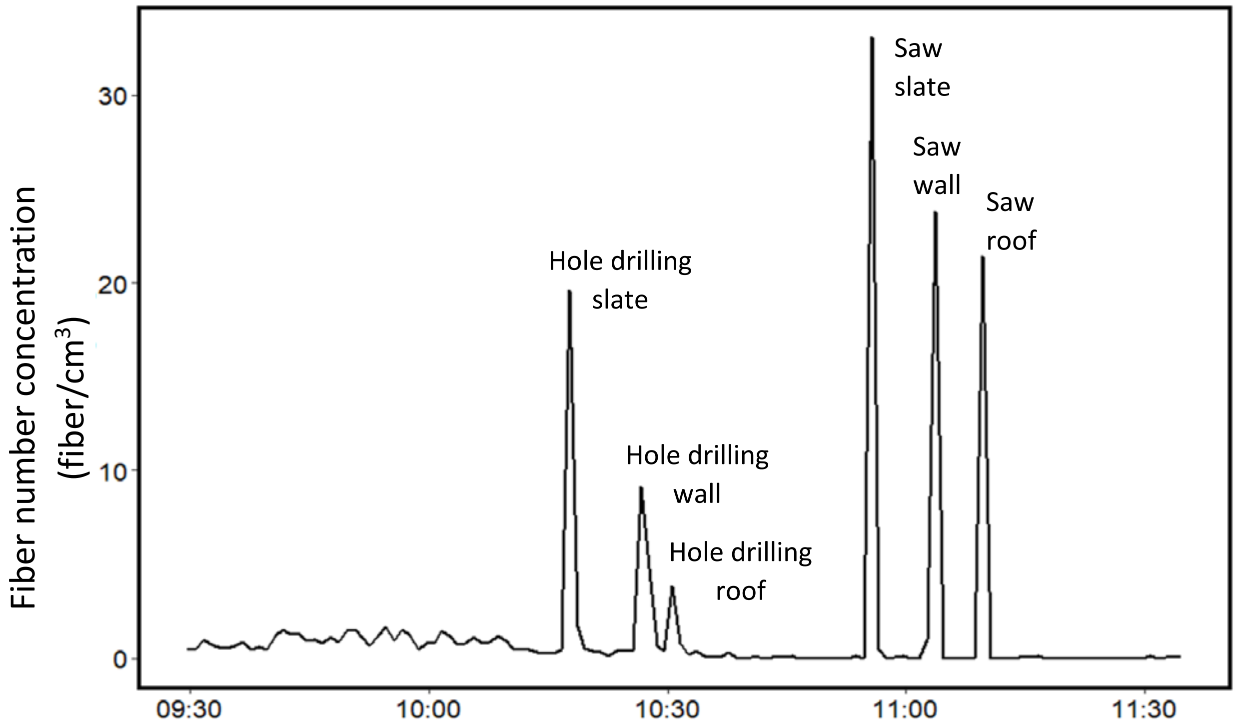


Figure 4,1: Fiber concentration measured with a real-time fiber monitor (TSI) during short-term work.

Drilling in the ceiling and wall seemed to generate more dust on the filters than sawing. The A significant amount of fibre is released during these operations. Even if the work is performed only for a short time, the sum of such short-term work operations over a long working life will lead to significant exposure to asbestos fibres.

Chapter 5: Weathering of the Asbestos Cement Ceiling

Around one of the asbestos removal sites, material samples were collected from moss on the roof, the soil under the gutter, as well as a water sample in which water was poured over the roof to simulate rain. The purpose was to investigate whether the asbestos fibres from the roof were mobile (Ervik et al. 2021).

In places where the surface cover had eroded, exposed asbestos fibers could clearly be seen with SEM (Figure 3.7). Surveys of samples taken from soil under gutters and simulated rain showed that asbestos fibres were released in both samples. The results show that the weathered asbestos cement roof had free asbestos fibres that can be mobilised by, for example, rain. However, no asbestos fibres were detected in air samples taken in the area in relatively calm wind conditions. The removal of moss on the roof resulted in asbestos fibres becoming visible on the roof's surface. Therefore, they have a greater opportunity to be mobilised and possibly become airborne. On the basis of these results, it is recommended that when removing moss and cleaning old asbestos cement roofs, personal protective equipment should be used. Caution should also be exercised when working on old asbestos cement roofs.

Chapter 6: Discussion

When assessing the findings in this project, it is important to point out that the measurements have been carried out outside the protective equipment. This means that they do not reflect the exposure of those who carry out asbestos removal while using protective equipment. However, the asbestos measurements show the potential for exposure if the removal is not carried out correctly, which may occur if no mapping of asbestos-containing building materials has been carried out before starting renovation. All measurements for indoor removal of walls and floors are carried out in enclosed areas where fans provide negative pressure to limit the spread of asbestos fibres. This implies that the measurements can underestimate fibre concentration, especially the stationary samples.

The proportion of fibres thinner than 0.2 µm depended on the type of material and the type of asbestos minerals in the material. Chrysotile has thin fibrils, down to 0.02–0.03 µm in diameter. Therefore, materials with an abundance of chrysotile will have a high proportion of fibres thinner than 0.2 µm. In our opinion, these should also be counted and specified as a separate fraction, as described in the standard for counting with SEM (ISO 14966:2019).

In samples taken outside the enclosed asbestos removal area or inside houses during ongoing external asbestos removal, only low amounts of asbestos fibres were found. This suggests that the measures taken to limit the spread of asbestos fibres appear to be working.

When sanitising internal wall plates of asbestolux, a large quantity of asbestos fibres were released into the air, even if care was taken not to break or damage the plates during the removal. This is probably because this type of material is brittle and crumbles easily, even with careful handling. Previously, asbestolux was used in many buildings; therefore, it is important to map whether this type of material is present before renovation or demolition work starts.

With indoor asbestos floor removal, some fibres were observed with PCM, but with SEM, it was found that most of these fibres were gypsum fibres and not asbestos. All SEM counts of asbestos fibres at indoor floor cleaning were below the detection limit. It was a challenge with these field measurements that the removal work was very dusty, and that the samples were quickly overloaded. Most of this dust is probably from previous work on the ceiling and walls, which had been removed before work on the floor was started. In fracture edges on floor coverings, small fibres were observed sticking out of the matrix. It is conceivable that these may break off and be released during the removal of the floor, but this was not confirmed in the field measurements. Also, in the dust from floor removal, asbestos fibres were found bound in larger particles from the flooring material, but very few free fibres were found.

During removal of a pipe segment with asbestos insulation, the fibre levels in the air were at the occupational limit value (0.1 fibre/cm^3) when counted with PCM. The fibre monitor also measured concentration at the same level (average 0.1 fibre/cm^3). This was somewhat surprising when, during the pipe removal, where the pipe segments were wrapped in plastic before removal, asbestos fibres are not expected to be released. It is unclear whether the detected fibres were fibres released from the plastic packaging or fibres already present in settled dust swirled up during work. However, the fibres found in the air samples were of the same type as the material samples. For samples collected during pipe removal, counting with SEM gave a concentration of asbestos at about a fifth of PCM and fibre monitor. The fact that the concentration of fibres was five times higher at PCM or the fibre monitor than SEM is probably due to the presence of other fibre types than asbestos, such as fibreglass and gypsum fibre.

For the sanitation of outdoor wall and roof plates, fibre quantification with PCM, fibre monitor, and SEM provided comparable concentrations. Asbestos fibre concentration is 20–40% higher if fibres thinner than 0.2 µm are included. The sampling was carried out both by normal sanitation without embedding the sanitation area and at sanitation where the entire sanitation area was enclosed. As expected, the levels of asbestos fibres were higher in the working atmosphere at the built-in sanitation; when sanitising without embedding, the air levels may vary depending on weather conditions.

During outdoor asbestos removal, asbestos levels were generally low when removing wall plates and roof eternit. However, higher levels were measured when removing old corrugated cement eternit, probably because the material had begun to deteriorate, exposing the asbestos fibres exposed on the surface (Ervik et al. 2021). An important observation is that the highest fibre concentrations in the air during roof removal were not during the removal of the roof plates themselves but during the removal of the roofing felt under the roof plates.

As demonstrated during the measurements in this report, the way the work is carried out has an impact on how many asbestos fibres are released during asbestos removal. A careful removal in which materials are loosened and carefully laid down and the use of soap as a binder resulted in the lowest release of asbestos fibre compared to a careless removal. Based on the measurements done in controlled encapsulated conditions, it is clear that working carefully has an effect. Therefore, to reduce the spread of fibres during sanitation, it should be considered to work as carefully as practically possible.

The sampling conducted during shorter work operations such as sawing and drilling in eternit roofs and wall plates showed that significant levels of fibres were released. Therefore, proper protective equipment is essential, even during shorter work operations, and especially if many of these short work tasks are performed.

Chapter 7: Conclusion

The measurements during removal of various asbestos-containing building materials show that exposure to asbestos fibres can become high, even during careful removal, especially during removal of porous materials indoors (as shown for asbestolux). Also, even during shorter work operations such as sawing and drilling, relatively large quantities of asbestos fibres can be released. Therefore, it is important that asbestos removal is always carried out with appropriate protective equipment and that measures are taken to limit the spread of dust.

One challenge is that it is not always known whether there are asbestos-containing products in the wall or ceiling being removed. Therefore, it is important that all buildings that may include asbestos-containing materials are thoroughly inspected before renovation work starts.

This report also shows that the levels of asbestos fibres counted with PCM or SEM were comparable for most material types, except floor tiles, where counting with PCM was probably affected by large amounts of gypsum fibres at the sanitation site. SEM with the possibility to identify asbestos fibres should be considered to reduce counting error.

The proportion of thin fibres (< 0.2 µm) in the air depended on the material. When working on materials that contained a lot of chrysotile, the proportion of thin fibres was up to 40 %. When the material contained amphibole asbestos types, the proportion was lower. The proportion of thin fibres should be specified when counting with SEM is used (according to ISO 14966:2019).

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