Finnish Institute of Occupational Health

Asbestos risk management guidelines for mines

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FOREWORD AND THANKS

Exposure to asbestos may take place especially in renovation but also in the mining industry where awareness of asbestos-related risks is generally lower than in the construction industry. In recent years, high airborne asbestos fibre concentrations have been measured in many mines in connection with specialist services provided by the Finnish Institute of Occupational Health, and the asbestos problem has often come as a surprise to the mine personnel. Furthermore, the assessment of asbestos risks is clearly more challenging in mines than on construction sites so, to protect employees, there is an evident need for asbestos risk management guidelines for mines.

This report is intended for all parties in the mining industry: employers, employees and occupational health services. The purpose of this publication is to provide an in-depth view of how the occurrence of asbestos and employee exposure are assessed and how exposure is effectively prevented. A dedicated asbestos fibre management programme and work site guidelines for preventing exposure to asbestos must be prepared for each mine. This publication can be used as a basis for these mine-specific guidelines.

The report was created in connection with the HIME (Particles and noise in sustainable mining environment) project that was part of Tekes's (nowadays Business Finland) Green Mining programme and was carried out from 1 January 2013 to 31 October 2015. In addition to the Finnish Institute of Occupational Health, the project participants included the Finnish Meteorological Institute (co-ordinator), the National Institute for Health and Welfare and eight companies. The project was funded by research institutes, Business Finland and the participating companies. We would like to thank them all for their good co-operation and for making this publication possible.

This report is an updated translation of the original Finnish version, which was published in 2016.

Helsinki, Oulu and Tampere, June 2019

The authors

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1 BACKGROUND

1.1 Terminology

In this publication, "**asbestos**" refers to the fibrous silicates mentioned in the Government Decree 798/2015. These fibrous silicates are generally known as

-actinolite
-amosite (mineral name: grunerite)
-anthophyllite
-chrysotile
-crocidolite (mineral name: riebeckite)
-tremolite
-erionite

In bedrock and ground, asbestos occurs in fibres of variable thickness. An exceptionally high asbestos concentration in a bedrock area is called an **asbestos deposit**.

The minerals listed above also occur in forms other than fibres. In mineral extraction industry processes, asbestos tends to cleave into thin fibres (=asbestos fibres). The non-fibrous forms of the above-mentioned minerals may also produce fibrous pieces when they cleave.

Due to serious health effects caused by asbestos, the manufacturing, import, sales and use of asbestos and products to which asbestos is added by design are prohibited by Finland's current legislation, with few exceptions.

An **asbestos fibre** is a fibre consisting of asbestos. Its length-to-thickness ratio is at the minimum 3:1. Asbestos fibres with a thickness of 3 micrometres or less and a length of 5 micrometres or more cause a risk of cancer and pulmonary diseases when inhaled, regardless of whether they have been formed as a result of a geological process metamorphism or in an industrial process, such as in mining operations. When assessing an employee's exposure to asbestos, only the asbestos fibres that meet the above-mentioned fibre size criteria are taken into account.

A **fibrous mineral** is a mineral that occurs in a fibrous form in ground and bedrock. There are many different fibrous minerals and some of them, such as fluoro-edenite, have been

noted to have health effects similar to those of asbestos. As the health effects of all fibrous minerals are still not known exactly, the precautionary principle should be applied when considering their occurrence.

A **mineral fibre** is a fibre consisting of any mineral. Its length-to-thickness ratio is at the minimum 3:1.

"**Metamorphism**" refers to the change of bedrock caused by temperature, pressure and compressive and tractive forces. This changes the structural and mineral composition of rock. The formation process of all asbestos minerals requires metamorphism so knowing the bedrock's state of metamorphism is important for judging the occurrence of asbestos. In the Finnish bedrock, metamorphism is a common feature but there is regional variation in the intensity of metamorphism (=state of metamorphism).

"**Asbestos area**" refers to an area where an employee may be exposed to asbestos. The occurrence of asbestos fibres may be proved by earlier measurements or estimated to be possible on the basis of other factors. At least areas where the airborne asbestos fibre concentration exceeds 10% of the binding asbestos limit value are considered to be asbestos areas.

1.2 Occurrence of asbestos and other fibrous minerals in the Finnish bedrock

Rock types and geological formations containing fibrous minerals (see Table 1) are common in the Finnish bedrock and sometimes extensive. However, asbestos deposits are rare and, apart from the Paakkila anthophyllite area, they are small, local and associated with sills/dikes and shear zones. According to Aurola and Vesansalo (1954), there are three different forms in which asbestos occurs:

1) Cross-fibre asbestos, in which fibres are crosswise in the sill/dike, nearly at a right angle to the sill/dike wall.

2) Slip-fibre asbestos, in which fibres are in sill-/dike-like formations in shear zones.

3) Mass-fibre asbestos, in which bundles of fibres are mixed in mass-like rock.

Fibrous anthophyllite typically occurs in the mass-fibre form, rarely as slip fibres. Chrysotile is encountered in sills/dikes of varying width. Tremolite is clearly the most common form but usually it does not occur as thin fibres. Fibrous tremolite-actinolite is also sometimes called "sädekivi" in Finnish.

Image 1. *Anthophyllite from Paakkila (A–B), chrysotile (C) and green chromiferous tremolite from Outokumpu's tremolite-actinolite (D). Chrysotile in the image C is from Canada; however, it is a good example of how chrysotile occurs in a sill/dike.*

In mining operations, even small asbestos deposits may cause significant exposure to asbestos as the processing of fibrous rock releases more dust than the processing of non-fibrous rock. In this case, airborne asbestos concentrations may increase rapidly and exceed the binding limit value. Thin fibres also remain airborne for a long time. Typically, asbestos deposits are encountered in the same geological areas as the non-fibrous forms of the same minerals.

Other fibrous minerals (see Table 1) also occur in potential asbestos areas. In mafic formations, you can encounter cummingtonite, for instance, which belongs to the cummingtonite-series minerals, as does grunerite. A fibrous mineral that may be encountered in limestone deposits is wollastonite, but its occurrence is not usual, apart from the Lappeenranta wollastonite deposit. In addition, fibrous minerals are encountered in rock types in which asbestos is not known to occur; an example of this is richterite in carbonatites.

Table 1. Rock types/geological formations containing fibrous minerals and minerals that may be encountered in them.

Rock types/geological formations that may contain fibrous minerals	**Asbestos**	**Other fibrous minerals encountered in Finland**
limestone and skarn	tremolite, chrysotile	wollastonite
carbonatites		richterite
metamorphosed mafic layered intrusions, volcanic rocks and diabases	tremolite-actinolite, chrysotile, anthophyllite	cummingtonite
metamorphosed ophiolite complexes, including soapstone and talc schists, for instance	anthophyllite, chrysotile, tremolite-actinolite	cummingtonite
metamorphosed iron formations	amosite, crocidolite	
meteorite crater rocks	erionite	

1.3 Health effects caused by asbestos

All minerals that are called asbestos may cause asbestos-related diseases. The most common of these diseases is benign pleural thickening, or plaques. They are extrapulmonary, do not cause insufficient lung function and are not precursors of cancer.

They may be caused by relatively low exposure but are visible in X-rays only after decades have passed from the beginning of exposure. Only high exposure that lasts for years or decades may lead to pulmonary fibrosis (scarring), i.e. asbestosis. The most serious diseases caused by asbestos are lung cancer, laryngeal cancer and pleural cancer. There is no safe minimum limit for carcinogenic exposure and the risk of cancer increases with higher exposure. With all asbestos-related diseases, the latency period (the time elapsing from the beginning of exposure to the discovery of illness) is long, 10 years at the minimum but usually 20–40 years or even longer. Tobacco is a more significant cause of lung cancer than asbestos. In addition, smoking multiplies the risk of lung cancer caused by asbestos.

2 ASSESSMENT OF THE OCCURRENCE OF ASBESTOS

2.1 Asbestos and fibre survey

The occurrence of asbestos must be assessed before taking a mine into production. This assessment is called an asbestos and fibre survey and its results must be delivered to the occupational safety and health organization of the mine for utilization in the risk management process. The suitability requirements for the performer of the survey are a degree in geology and experience in fibrous minerals. The asbestos and fibre survey must cover the intended mining area in its entirety as well as both ore and gangue. If mining operations are later expanded to areas that are geologically different from the previously mined areas, the asbestos and fibre survey must be expanded to cover these areas, too.

The asbestos and fibre survey must cover the occurrence of asbestos, other fibrous minerals and their non-fibrous forms. The three parts of the survey – pre-survey, survey and crushing – are described in Image 2.

The survey begins with the literature study of the intended mining area (pre-survey, or part 1). Existing literature and maps are studied to see whether the area has any history indicating the occurrence of asbestos or whether the area features rock types that are typical of the occurrence of asbestos or other fibrous minerals. In addition, the state of metamorphism and the abundance of shear zones and sills/dikes are estimated.

During the survey, or part 2, a conventional geological bedrock survey is conducted in the area, with the primary focus on the observation and reporting of asbestos and other fibrous minerals. If fibrous minerals are found in the survey, their mineralogical composition are determined on the basis of thin sections. In addition to the survey, the occurrence of fibrous minerals is determined based on thin sections taken from core samples. If a gangue area turns out to be an asbestos deposit, mining in that area should be avoided as far as possible.

In part 3, crushing, a more detailed investigation is made to find out to what extent the fibrous minerals encountered in the earlier parts of the survey cleave into asbestos fibres or other mineral fibres. Drilling mud samples, for instance, are suitable for this purpose. In addition, the crushing pilot must include the determination of the concentrations in

which asbestos fibres or other mineral fibres occur in air in the crushing plant as well as the size of the fibres.

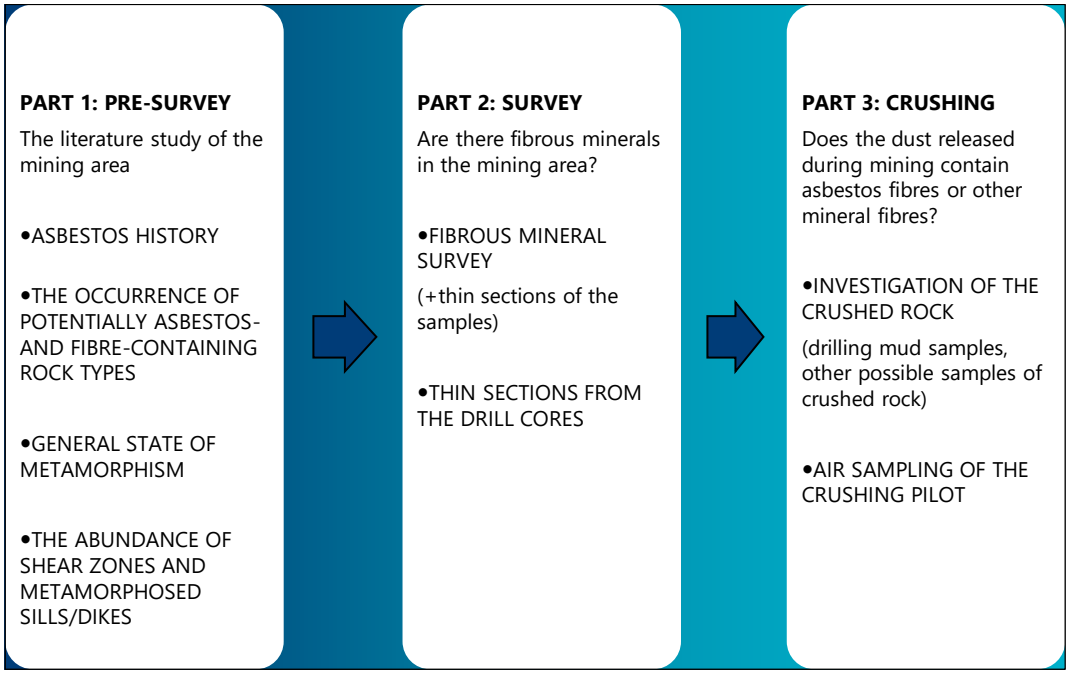

Image 2. *Parts 1–3 of the asbestos and fibre survey for the mining area.*

All parts (1–3) of the survey must be carried out even if the share of asbestos or other fibrous minerals in the bedrock seems low in part 2 from a geological point of view. The survey must be particularly thorough if the mining area is already known for its asbestos potential. Only if the surveys carried out in parts 1 and 2 indicate that asbestos or other fibrous minerals do not typically occur in the mining area, can part 3 be omitted. Even in this case, occupational hygiene measurements must be conducted after the beginning of production to verify that the airborne asbestos concentration at work sites does not exceed 10% of the binding limit value.

2.2 Continuous monitoring of the bedrock being mined

A one-off asbestos and fibre survey alone is not enough for the asbestos risk management. The monitoring of the occurrence of asbestos and other fibrous minerals must form a part of production safety work. It can be carried out by the mine's geologists monitoring the

mineralogical composition of the bedrock being mined. The reporting on the occurrence of asbestos and other fibrous minerals must be arranged so that information reaches mining workers before mining is begun.

Naturally, it must also be ensured that the mine's geologists have sufficient competence for identifying asbestos and other fibrous minerals. Furthermore, the personnel responsible for drilling and mining must be trained in the visual observation of fibrous mineral deposits in case no advance preparations have been made.

The continuous monitoring process of the bedrock being mined is described in Image 3. Attention must be paid to the occurrence of asbestos and other fibrous minerals when investigating the core samples of the mining area and in all routine surveys at the mining site (phase A). The non-fibrous forms of minerals with a chemical composition similar to asbestos must also be included within the scope of the monitoring, unless there is air sample evidence proving that they do not generate asbestos fibres during the process.

If asbestos or other fibrous minerals are observed in rock or it is already known that they may occur in certain rock type, samples of the rock material are collected for further investigation and information is reported onwards. Samples are screened by a light microscope, which makes it possible to take immediate measures to minimize exposure when asbestos fibres are encountered (phase B). Asbestos observations must be confirmed by SEM-EDS in a laboratory specializing in asbestos analytics.

If fibrous minerals are found in the samples, sampling must be continued with drilling mud samples while production hole drilling (phase C) to gather information about the impact of drilling on the cleavage of these fibrous minerals.

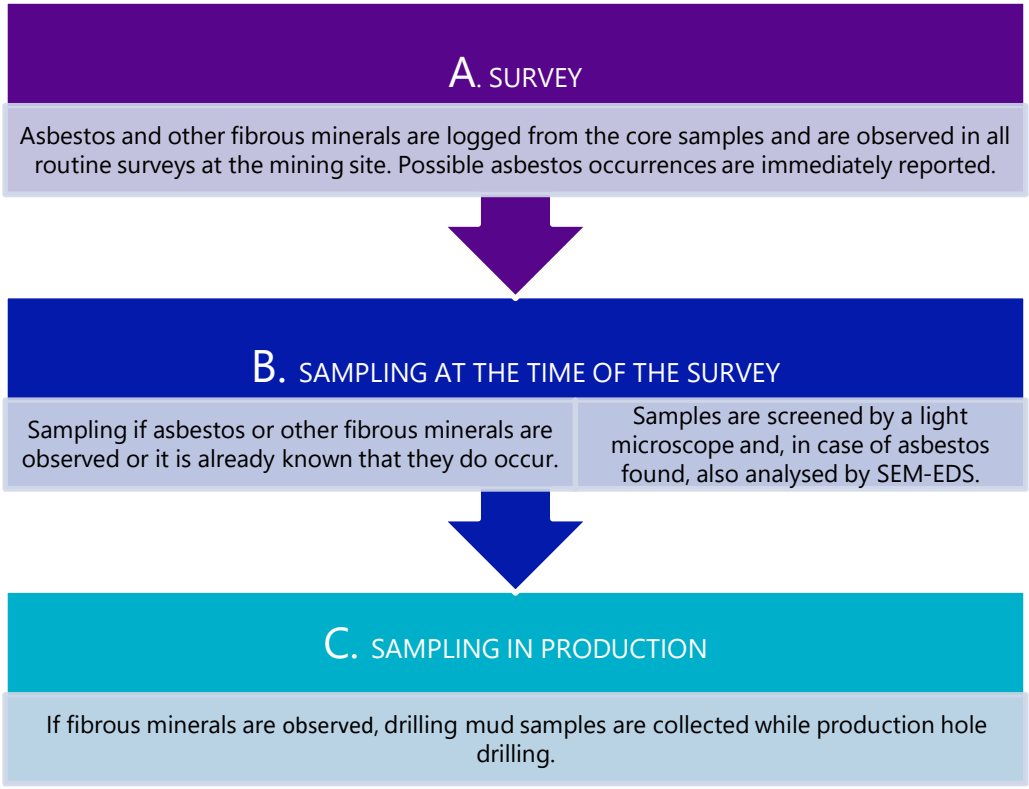

Image 3. *Continuous monitoring process of the bedrock being mined*

3 ASSESSMENT OF ASBESTOS EXPOSURE

3.1 Risk categorization

Without sufficient dust control measures and/or appropriate use of protective equipment, long-term exposure to asbestos may occur in mines. Long-term health effects are possible and, in case of serious health effects (including lung cancer), the health risk caused by exposure is significant. There is no safe minimum limit for carcinogenic exposure and the risk increases with higher exposure. Consequently, airborne asbestos concentrations must be kept as low as is technically and economically viable.

The binding asbestos limit value is 0.1 fibres in one cubic centimetre of air calculated as an 8-hour average concentration.

Table 2. Risk categorization and management and monitoring actions based on exposure levels.

Asbestos concentration	**Exposure level**	**Management and monitoring actions**
less than 10% of the limit value (< 0.01 f/cm^3)	non-significant exposure	• concentration follow-up measurements approximately every other year (especially if asbestos fibres have been observed in a measurement point in the mine) • concentration checking if processes or working conditions change
10–100% of the limit value (0.01–0.1 f/cm^3)	there is asbestos, health risk due to exposure exists	• management actions are taken to prevent exposure and the spreading of asbestos fibres • exposure, workplace airborne concentrations and occupational health monitoring is carried out • after the actions, the situation is reassessed

above the binding limit value (> 0.1 f/cm^3)	excessive exposure and health risk	• work in the area is discontinued until the exposure risk is under control • reasons for exceeding the limit value are determined • immediate management actions are taken to prevent exposure and the spreading of asbestos fibres • exposure, workplace airborne concentrations and occupational health monitoring is carried out • after the actions, the situation is reassessed

3.2 Occupational hygiene measurement strategy

Asbestos legislation obligates the employer to assess the risk of exposure to asbestos dust. In practice, exposure to asbestos can be assessed reliably only by measuring the amount of fibres in air at the workplace. The most advisable method is to conduct asbestos measurements as part of a more extensive dust risk management programme in the mining area. Alternatively, they can be conducted in connection with an occupational hygiene assessment.

The fibre concentrations in air at the workplace are monitored systematically and measured regularly and whenever the situation so requires. Sampling must be representative and the performer of measurements must have sufficient professional qualifications and competence for collecting samples and interpreting and assessing results. Measurements are subject to the standard SFS-EN 689.

In the first round of measurements, the focus is on fixed measurement points that cover the entire production chain from ore mining to concentrate handling. As there often is rock in different phases in the ore production line, fixed measurement points provide a more comprehensive overview of the current situation. In addition, personal exposure measurements are conducted in the breathing zones of the employees that are most exposed to dust.

When asbestos concentration levels have been determined, the next focus area is exposure measurements. When determining exposure, measurements are primarily targeted at the employees subject to highest exposure and a day that is representative of normal production circumstances is selected as the measurement day. Exposure measurement is scheduled at a time that represents the worst or nearly worst stage

during the shift. Consequently, the actual average concentration over a long term is lower than the result for the measurement day. An opposite approach would produce an estimate of exposure that is too low. In practice, there are never enough measurement days for calculating the actual average.

Exposure measurements are complemented with room air samples from fixed measurement points, which are a better option for technical prevention measures. Fixed follow-up measurement points must be in a central location in each active working area that is significant for exposure. In room air measurements, dispersion caused by the employee's working practices and movements – that can be fairly significant – is eliminated and measurements give a better picture of the impact of prevention measures. Carefully selected fixed measurement points also provide information about the sufficiency of mine ventilation and local exhausts. The measurement results from fixed measurement points give useful information about concentration differences in the employee breathing zone and in room air. Often concentrations measured in the employee breathing zones are higher than those in room air as service and maintenance tasks, for instance, often require presence near the emission source.

Measurements are divided into measurement compartments and further into smaller measurement areas (see Image 4) which are then divided by position into groups where people are subject to similar exposure.

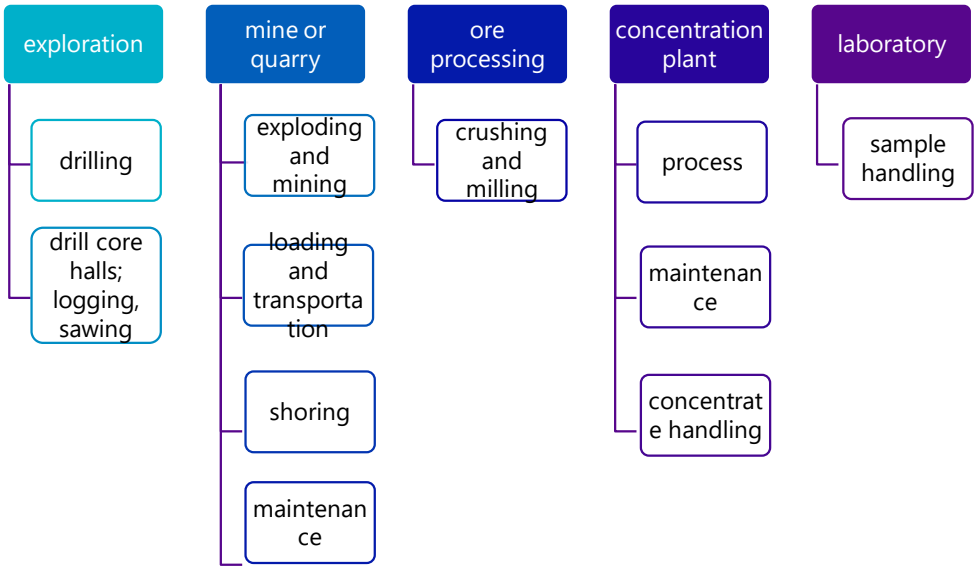

Image 4. *Area division for asbestos measurements.*

The assessment of asbestos exposure must be carried out again if changes that are significant for exposure have taken place in the work. Each employee who participates in measurements is provided with personal feedback and measurement results. The asbestos measurement results must also be reported by position and the reports must be available to all employees.

3.3 Measurement technology

When measuring exposure, the asbestos sample is collected from the employee's breathing zone with a portable sampling pump. At stationary sampling sites, samples are collected at 1.5 metres from the floor (at breathing height), see Image 5A. The collection time for an asbestos sample is 60–120 minutes. Due to the relatively short collection time, sampling in exposure measurement should focus on the work stage with the highest exposure. At stationary sampling sites that are in very dusty locations, it is recommended that several short (e.g. 10–20-minute) samples be collected instead of one long sample. To preserve the representativeness of sampling, it is recommended that several consecutive samples be collected from the same sampling point. The sampling pumps must be calibrated and regularly inspected.

Asbestos concentration is determined from the membrane filter of the collecting device by SEM-EDS, see Image 5B. If the samples are analysed in an external laboratory, the asbestos and fibre survey or another description of the fibrous minerals of the mining area and their composition should be attached to the analysis order.

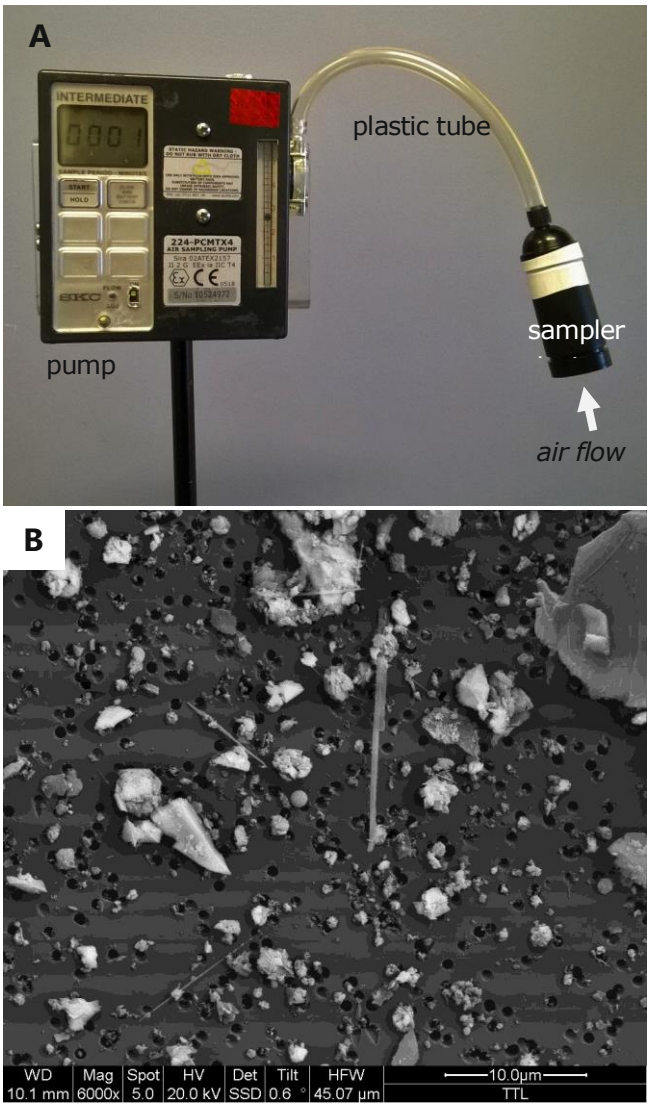

Image 5. *Air sampling at a stationary sampling site (A) and a SEM-EDS image of the air sample filter with plenty of mineral fibres among other dust (B). The image is magnified by 6,000.*

The laboratory analysing the sample must provide evidence of the reliability of the results. It is recommended that the laboratory in question is involved in international quality comparison.

4 REDUCING EXPOSURE

4.1 General prevention methods

Pursuant to legislation, mining work must be carried out so that the employees' work-related exposure to asbestos is kept to a minimum and is always below the limit value of 0.1 fibres per cubic centimetres.

To reduce exposure, the following measures must be taken:

1) the amount of asbestos used is limited to the lowest possible amount; mining in asbestos areas is avoided, if possible;

2) the number of employees exposed or likely to be exposed to asbestos dust is limited to the lowest possible figure; exposure area can only be accessed by persons for whom it is necessary for carrying out their work;

3) working methods are designed so that the release of asbestos dust into the air is avoided and, if this is not reasonably possible, dust is removed as close to its point of origin as possible;

4) the spreading of asbestos from the workplace to other locations with employees or their clothing or by other means is prevented; changing room facilities are arranged and the number of equipment and footwear washing places are increased;

5) machinery, air treatment devices, personal protective equipment and other equipment that prevent or reduce exposure sufficiently well are used, their condition is monitored regularly and their operation is inspected when necessary;

6) defective equipment is repaired or replaced before further use;

7) asbestos-containing material is stored and transported in suitable packaging;

8) it is ensured that all the buildings and equipment involved in the treatment of asbestos must be capable of being regularly and effectively cleaned and maintained.

The exposure of mining workers to asbestos fibres can be reduced according to the general dust control principles: the more dust concentrations can be decreased, the lower asbestos fibre exposure usually is. The primary method for carrying out dust control is to prevent the formation of dust, which requires the use of working methods that produce less dust. Another method of reducing the formation of dust is watering to bind the dust as near its point of origin as possible. When the formation of dust cannot be prevented, its spreading at the work site must be limited with the aid of enclosures and local exhausts that are complemented with general ventilation.

Furthermore, employee exposure is limited with regard to time and place and by restricting the working of other employees in the same premises. The spreading of dust outside the work site is restricted as far as possible by partitioning and negative pressurization.

Respiratory protective equipment must always be used when the employees' exposure to asbestos cannot be reduced sufficiently with technical dust control solutions. To ensure the effective selection and use of respiratory protective equipment, a respiratory protective equipment programme is launched at the workplace or it is ensured that all elements of the respiratory protective equipment programme are applied in addition to other safety activities. The respiratory protective equipment programme is presented in the standard SFS-EN 529:2006.

4.2 Mining machinery and vehicles

Exposure of the users of mining machinery and vehicles can be reduced by increasing cabin sealing and improving the incoming air filtering in the cabin. The incoming air filter of the cabin must also filter out fine dust. Filters must be replaced and maintained regularly to ensure effective operation. Cabins are regularly cleaned with wet techniques or with a vacuum cleaner equipped with a HEPA filter. Compressed air must not be used as a means of cleaning. When work is carried out in machines, the cabin doors and windows must be kept closed and eating, drinking and smoking in the cabin is prohibited. If the nature of the work requires consumption of liquid during work, dedicated equipment must be used to ensure that drinking is sufficiently hygienic.

Mining machinery and vehicles used in an asbestos area must be washed before maintenance or use in locations other than asbestos areas.

4.3 Examples of dust control and good practices for reducing exposure

Mining, loading, transportation, drilling:

- ventilation is appropriately scaled and sufficiently effective and exhaust air is directed into exhaust shafts
- rock being loaded and roads are watered, walls are washed with water
- only wet rock is loaded to prevent the formation of dust
- the ore transportation line system is equipped with effective dust removal and enclosed
- water is sprayed at the unloading point and in the crushing plant

- during drilling, work is carried out in the cabin as far as possible. In quarries, the prevailing wind direction is taken into account when placing machinery and the goal is to be upwind when working outside the cabin.

Sample handling:

- The sawing of drill cores is carried out in separate premises with wet techniques.
- Powdery samples are handled in fume hoods that have their own exhausts. The functioning of fume hoods is tested regularly.
- If fume hoods alone are not sufficient to prevent exposure, respiratory protective equipment is used when working.

4.4 Restricting the asbestos area

It must be ensured that the exposure area can only be accessed by employees for whom it is necessary for carrying out their work. The asbestos area must be outlined and indicated clearly with warning symbols. Warning signs and symbols must be easy to detect and read and they may not be remove before the asbestos concentrations have been determined to be low with measurements.

The warning and safety signs must indicate:

- asbestos hazard
- use of respiratory protective equipment and protective clothing
- smoking prohibition.

4.5 Personal protection and hygiene

All personal protective equipment must be CE-labelled, have type approval and be selected on the basis of the risk assessment. Occupational health services must ensure that the personal protective equipment is suitable for being used by the employee, considering the employee's physical condition and health. The employer and occupational health services must ensure that the required combinations of protective equipment are suitable for being used by the employee in the employee's work environment. The employee must be consulted about the suitability of the protective equipment for all tasks in which the employee must use it. If it is discovered that the protective equipment is partly ill-suited for its use, a survey must be launched at the workplace for acquiring better protective equipment. Guidelines for ensuring the suitability of respiratory protective equipment is in standard SFS-EN 529:2006 and for hearing protectors in SFS-EN 458:2005.

4.5.1 Respiratory protective equipment

Respiratory protective equipment must be used always when working in an asbestos area. The minimum requirement for employees working in an asbestos area is a class FFP3 filtering half mask. This is recommended only for a very short-term use under low asbestos concentrations. A more recommended option is to use a half mask that is equipped with separate P3 particle filters. A half-face mask equipped with separate particle filters usually fits better than a filtering half mask. In longer-term work, it is recommended that a filter respirator equipped with a fan and a particle filter is used.

A sufficiently effective respirator is selected on the basis of its actual protection factors that can be found in SFS-EN 529: 2006, Annex C. Attention must be paid to the identification of correct protective equipment classifications. In respirators with a fan, type approvals are granted to the entire equipment combination: filters, the mask and the fan. However, non-approved combinations are commonly used. The effectiveness of equipment that has not been approved as a combination cannot be known and such combination is not considered personal protective equipment.

The nominal protection factor is derived from the requirements used in the type approval of protective equipment. These requirements are presented in the harmonized standard for each protective equipment type. The assigned protection factor is an expert estimate of the effectiveness of protective equipment. According to the definition, the assigned protection factor is achieved for 95 per cent of users when the user has been trained, the leakage test has been carried out, the protective equipment is appropriately chosen and correctly used and the protective equipment is in working order. Assigned protection factors vary by country.

When selecting respiratory protective equipment, one must also take into account the variation and potential unpredictability of asbestos concentrations at the workplace as well as the fact that even when adhering to the best protective equipment use practices, it is difficult to manage exposure of all employees with respiratory protective equipment. Consequently, it is advisable to anticipate potential exposure in accordance with precautionary principles when selecting protective equipment and not use the statutory limit values but values that are 50 per cent lower, for instance.

Table 3. Protection factors of respiratory protective equipment

	Standard, type/class	Nominal protection factor	Assigned protection factor
Filter respirators without a fan	EN 149 FFP3	50	20
	EN 140 Half-face mask + P3	48	30
	EN 136 Full-face mask + P3	1,000	500
Filter respirators with a fan	EN 12941 TH2	50	20
	EN 12941 TH3	500	200
	EN 12942 TM3	2,000	1,000

When using respiratory protective equipment, it must be ensured, on an employee by employee basis, that the mask sits tightly and that it is compatible with other protective equipment, such as a helmet, hearing protectors and safety spectacles. Asbestos removal requires regular, annual personal leakage testing of full-face or half masks. This requirement should also be expanded to mining work involving asbestos. In addition, when starting to use protective equipment, the employee must ensure with respiration that the equipment does not leak.

Only clean personal protective equipment that is in good condition should be used. When asbestos concentrations are near or above the limit value, all reusable personal protective equipment must be cleaned before the beginning of the next shift.

Table 4 contains an example: the risk categories used in a mine and corresponding protection requirements. Premises are categorized according to measured asbestos concentrations and the doors are marked with the colours indicated in the table.

Table 4. Risk categories defined in a mine and corresponding protective equipment rules

Risk category	Protective equipment used
significant risk:	
asbestos concentration over 0.05 f/cm^3	respiratory protective equipment: class TH2P filter respirator with a fan short-term use; filtering half mask (FFP3) or half mask with a particle filter (P3)
asbestos concentration over 2.0 f/cm^3	respiratory protective equipment: class TM3P filter respirator equipped with a fan and a full-face mask type 5 chemical and dust protection suit worn over normal workwear, dust protection gloves
potential risk:	
asbestos concentration over 0.05–0.01 f/cm^3	respiratory protective equipment: class TH2P filter respirator with a fan short-term use; filtering half mask (FFP3) or half mask with a particle filter (P3) normal workwear, gloves that protect from dust
insignificant risk:	
asbestos concentration under 0.01 f/cm^3	no special requirements

4.5.2 Protective clothing, personal hygiene

The employer must provide the employee with suitable work and protective clothing that protects the employee from dust and fibres and supervise the appropriate use, inspection and cleaning of the clothing.

When asbestos concentrations are near or above the limit value, disposable dust-permeable and dust-resistant hooded overalls must be used in work that exposes the employee to asbestos. These clothes are classified as type 5 chemical protection clothing and meet the requirements of the standard EN 13982-1. Hooded overalls reduce the spreading of fibres with clothing and hair. As the use of overalls increases thermal stress and makes other protective equipment more difficult to select and use, the primary approach is always to improve working

conditions so that overalls are not needed. Necessary breaks and consumption of liquid must be considered. The gloves used must be dust protection gloves. Footwear used must be such that it can be easily cleaned with water.

Respiratory protective equipment is usually worn under all other equipment and clothing to ensure its effectiveness until all other protective equipment and clothing is taken off. Hooded protective clothing may decrease the effectiveness of ear-muff hearing protectors and complicate the use of two-way radios. There should be appropriate premises and equipment for cleaning the miner's helmet and re-usable respiratory protective equipment. Attention must be paid to the flammability of protective clothing. This is a property that is tested in protective clothing and described in more detail in the usage instructions.

Mines, quarries and concentration plants must have changing rooms in connection with the asbestos work area, in a location that prevents recontamination. Protective clothing must be cleaned/changed before moving to asbestos-free areas. Disposable clothes are also cleaned with a vacuum cleaner or dust is bound by moistening the clothes before taking them off as this stage is critical for the effectiveness of the overall protection: when clothes are taken off, no dust may spread to the surroundings.

Changing room facilities must be comprised of three linked compartments:

- "dirty area" for washing hands and face and for vacuum-cleaning/taking off clothes
- shower rooms for washing up (including hair) at the end of the shift
- "clean area" for storing and changing into clean clothes/non-workwear, non-workwear must always be kept separate from dirty protective clothing

Before meals, coffee breaks and smoking, asbestos-contaminated clothes are changed or cleaned with a vacuum cleaner. Footwear is cleaned with water. Hands and face are washed.

At the end of the shift, clothes are placed in dirty laundry and employees take a shower and wash their hair. Workwear and protective clothing must be left at the workplace after the shift to avoid the spreading of asbestos fibres to employees' homes. Disposable clothes are disposed of.

The employee must use and maintain the provided workwear and protective clothing carefully and according to the instructions. If the employer does not dispose of or clean workwear and protective clothing, they are washed at an external facility that is equipped for such cleaning. In this case, they must be taken to the facility in closed containers.

Eating, drinking and smoking in the exposure area is prohibited. Employees must be provided with a place where they can eat or drink without being exposed to asbestos dust. Strenuous work may require special arrangements for consumption of liquid.

5 NOTIFICATION TO AUTHORITIES

Pursuant to legislation, the employer must inform, in writing, the occupational safety and health authority of activities involving exposure to asbestos. The notification must contain at least the following information:

1) workplace details;

2) characteristics and amount of asbestos-containing materials;

3) nature of activities; and

4) asbestos-containing products that are being handled.

If the activity-related information change in a manner that is material from the point of view of asbestos exposure or occupational safety and health enforcement, the employer must submit a new notification.

6 MONITORING OF ASBESTOS EXPOSURE AND HEALTH

6.1 Monitoring of asbestos exposure

The higher the earlier concentrations are, the more frequently asbestos concentrations should be measured. In addition, asbestos concentrations must be measured whenever processes or working conditions have changed materially. Measurements should be carried out even if concentrations had been less than 10% of the limit value in the earlier measurements because the composition of the rock being mined may change as mining proceeds. In such cases, monitoring should take place every other year, for instance, at least if asbestos fibres have been previously observed in certain measurement points or if mining involves rock types that generally contain asbestos minerals.

6.2 Monitoring of the health of persons exposed to asbestos

Pursuant to the Occupational Health Care Act, persons who are exposed at work to factors or substances that cause a particular risk of illness must undergo a medical examination at the beginning of the work and at regular intervals during the duration of the work. Some exposure agents that collect in the body, such as asbestos and quartz, may cause diseases even after exposure. Occupational health care activities are planned on the basis of workplace investigations. The investigation assesses work and the significance that stress factors and resources as well as health risks and harms caused by the work environment and the work community have for health and work ability. One of the issues that the investigation pays attention to is that everyone uses their protective equipment. Occupational health services always comment if protective equipment is not used as required as the use of protective equipment is part of the prevention of work-related diseases. It may be that protective equipment is not used due to the employee's health requirements or physical condition, which are issues that occupational health services should look into. Factors that may restrict the use of personal protective equipment include pulmonary and heart diseases and hearing loss (SFS-EN 529: 2006). In connection with the workplace investigation, it is ensured that there is enough protective equipment available and that its maintenance runs smoothly.

When work that subjects employees to exposure begins, an initial examination is carried out to determine the employee's suitability for the work. The purpose of periodic medical examinations is to monitor exposure, motivate the employee to use safe working methods and to identify problems or diseases caused by exposure agents as early as possible. When work that subjects employees to exposure ends, there is a final examination where the employee's

health is examined, the overall degree of exposure is assessed and it is decided whether there is a need to continue medical examinations.

Medical examination guidelines for persons exposed to asbestos and other factors causing a particular risk of illness can be found in the so-called New Blue Book (Karvala et al. 2019). For employees exposed to asbestos, the examination is usually conducted at three-year intervals, and it aims to ensure the employee's capability to work using protective equipment. In other words, the goal is to prevent exposure. In mining industry, it is most important to ensure with repeated monitoring that employees are not exposed to asbestos. In case of only occasional asbestos exposure conditions, medical examinations are of little importance. The most common health effect of asbestos exposure is pleural plaques, which in practice do not cause symptoms or disadvantages. Therefore, taken also long latency period of asbestos diseases into account, there is no need for repeated x-rays or spirometries. However, of asbestos exposure incidents, the circumstances of exposure (working time, results of measurements) should be documented in the medical records. This information would be useful in possible case of later suspicion of an asbestos disease. In mining industry work, medical examinations based on e.g. exposure to quartz must be considered. The use of personal protective equipment causes stress, which is taken into account in the assessment of a person's suitability for the work. Employees must be able to use their personal protective equipment in all tasks that require this. The Government Decision on the Selection and Use of Personal Protective Equipment (1407/1193) defines that ergonomic requirements and the employee's health must be taken into account in the selection of protective equipment.

The register of workers exposed to carcinogenic substances and processes at work, the so-called ASA register is statutory. The employer reports, by calendar year, all workers who have been exposed to carcinogenic substances, including asbestos, at work during the previous year.

Employees must be motivated to reduce or quit smoking as smoking multiplies the risk of cancer caused by asbestos.

7 PROVISION OF INFORMATION

The employer must inform employees, contractors and their representatives of:

- airborne asbestos concentration at the workplace
- results of measurements and assessments related to the employees' exposure to asbestos dust and the significance of these results
- measurement results that exceed the limit value and the reasons that caused the exceeding of the limit value
- actions taken in emergencies
- health supervision methods

8 EMPLOYEE TRAINING

Before permitting access to an asbestos area, it must be ensured and supervised that the employees have received training and instructions on asbestos-related health and safety issues. Training must cover everyone working in the asbestos area. In addition to training, short safety briefings, for instance, are a good forum for individual issues that are for information only. Refresher training and discussions with supervisors and occupational health services keep employees up to date and offer an opportunity to review exposure monitoring results, for instance.

Employees must be provided with training and guidance in the following topics:

- characteristics of asbestos and its health risks, the additional risk caused by smoking
- asbestos exposure limit values and monitoring
- occurrence of asbestos at the workplace
- factors that influence exposure to asbestos and preventive measures to reduce exposure
- safe working methods and protective equipment, good practices
- protection measures and activities related to ensuring them
- selection of respiratory protective equipment, its correct use and ensuring that it is in working order
- cleaning, maintenance and storage of respiratory protective equipment
- use and cleaning of protective clothing and other personal protective equipment
- personal hygiene in the prevention of exposure
- cleaning of equipment
- emergency procedure
- medical examinations

9 RESPIRATORY PROTECTIVE EQUIPMENT PROGRAMME

To ensure the safe and correct use of respiratory protective equipment, a respiratory protective equipment programme is prepared for the workplace. The goal of the programme is to train and motivate the personnel in using respiratory protective equipment. More information about the programme can be found in the standard SFS-EN 529 (Respiratory protective devices. Recommendations for selection, use, care and maintenance. Guidance document). Information about a more comprehensive programme encompassing all protective equipment can be found in the Control Approaches related to personal protective equipment, www.ttl.fi/malliratkaisut (in Finnish). The Control Approaches contain information for the management, occupational safety personnel, occupational health services and employees.

A personal protective equipment (PPE) programme should contain the following equipment-related matters:

- assessment of usage needs and selection of equipment
- usage specifications
- personal suitability
- safe and correct use
- service and maintenance
- putting on and taking off of the PPE
- supervision of use and maintenance
- leakage testing, protective equipment with mask
- guidance and training

10 EMERGENCY PROCEDURE

A plan is prepared for emergencies that lead to unusually high exposure. The employer must inform the employees as quickly as possible of an unexpected hazard or accident that causes unusual exposure.

In working areas where measurements show concentrations above the limit value, immediate measures must be taken to control the situation and decrease the concentrations. Access to the area must be supervised and the employer must place visible warning signs that indicate that the airborne asbestos concentration may exceed the binding asbestos limit value. Only work that is necessary for decreasing the airborne asbestos concentration at the workplace may be carried out in the area and no work may be carried out without appropriate and sufficiently effective respiratory protective equipment and other personal protective equipment.

After measures have been taken, measurements must be carried out to verify that the airborne asbestos concentration does not exceed the limit value.

11 LEGISLATION

Pursuant to the Occupational Safety and Health Act (738/2002), the employer shall systematically and adequately analyse the hazards at the workplace and assess the risks they cause. When the hazards and risk factors caused by the work, the working premises, other aspects of the work environment and the working conditions cannot be eliminated, their consequences to the employees' safety and health must be assessed. If the assessment of risks shows that the work may cause a particular risk of injury or illness, such work shall be done only by an employee who is competent and personally suitable for it or by another employee under the direct supervision of such an employee. Access to the danger area by other persons shall be prevented by appropriate measures.

The Occupational Health Care Act (1383/2001**; as amended by** 51/2006) and the related Government Decrees (1485/2001 and 708/2013) provide binding instructions on medical examinations in occupational health care in work that presents a special risk of illness. Pursuant to this act, the employer shall arrange occupational health care and there shall be a written occupational health care action plan that shall be based on the investigation of health problems and risks (workplace investigation). The health risks that the employees are subjected to must be investigated in co-operation with the personnel. On the basis of the workplace investigation, occupational health services make suggestions for improving working conditions. Occupational health services monitor the effect of occupational safety and health measures taken and other changes and provide advice and guidance on occupational diseases and their prevention.

The Government Decree on Chemical Agents at Work (715/2001) requires that the nature and degree of exposure be determined so that safety and health risks can be assessed reliably and necessary prevention measures can be taken. The decree requires that a measurement of atmospheric contaminants be carried out when the employees' exposure cannot be reliably assessed in any other manner. In practice, exposure to asbestos can be assessed reliably only by measuring the amount of fibres in air at the workplace with room air concentration measurement and by measuring the employees' personal exposure with breathing zone measurements.

The Decree of the Ministry of Social Affairs and Health's Decree on Concentrations Known to be Harmful (538/2018) defines that the binding asbestos limit is 0.1 fibres in one cubic centimetre of air calculated as an 8-hour average concentration.

the Government Decree 798/2015 obligates the employer to monitor and ensure, with measurements carried out at regular intervals, that the limit value of 0.1 fibres in one cubic centimetre of air calculated as an 8-hour average concentration is not exceeded.

The International Agency for Research on Cancer, IARC, classifies asbestos into group 1, Carcinogenic to humans. The EU classification for asbestos is 1 (CLP classification: group 1A).

The Government Decree on the Prevention of Work-Related Cancer Risks, 716/2000**, as amended by** 245/2002, defines that carcinogen means a substance or preparation which meets the criteria for carcinogens of group 1 or 2 in accordance with the Decision of the Ministry of Social Affairs and Health on the criteria for classification of chemicals and the labelling of chemicals (979/1997) and its annexes.

In any activity likely to involve a risk of exposure to carcinogens, the nature, degree and duration of employees' exposure and any risk to the health and safety of employees shall be assessed and the necessary measures shall be taken. Upon request, the employer must submit the assessment mentioned in this section and the information it is based on to the occupational safety and health authority.

The register of workers exposed to carcinogenic substances at work (ASA register) 717/2001

Employers are under an obligation to submit an annual notification of the basic workplace information and their workers exposed to carcinogenic substances to the ASA register. Every March, the occupational safety officer (unless otherwise agreed at the workplace) reports to the register all workers who have been exposed to carcinogenic substances for a significant share of their working time (at least 20 working days) during the previous calendar year or whose exposure has been determined with occupational hygiene measurements. Guidelines and forms can be found at www.tyosuojelu.fi/web/en/home. Exposure can be continuous or take place during several work periods. Significant one-off exposure in an accident, for instance, also requires the submitting of a notification. A worker is considered to have been exposed for a significant share of their working time if they are exposed for a minimum of 2–4 hours per day. If a carcinogenic substance is only used in a closed system and there is no exposure, a notification is not needed. Notifications to the ASA register must be based on a thorough risk assessment carried out at the workplace pursuant to the Government Decree.

The Government Decision on the Selection and Use of Personal Protective Equipment (1407/1993) regulates that personal protective equipment must be selected and acquired on the basis of the assessment of risks at the workplace. Personal protective equipment must be sufficiently effective and suitable for employees and work. When multiple pieces of protective equipment are used simultaneously, the combination must be suitable for the intended use and all of its components must be sufficiently effective. It must be assessed that protective equipment do not risk the employee's health and ergonomics and health must be taken into account in the selection of protective equipment.

The Act on Occupational Safety and Health Enforcement and Cooperation on Occupational Safety and Health at Workplaces (44/2006), Section 48**, obligation to give a prior notice**:

The employer or other person responsible for the activity shall notify the occupational safety and health authority of asbestos work, other than temporary construction work, and other comparable work causing special risk of accident or harm to health, and of the nature and duration of the work. Further provisions on the work or activity to be notified, the content of the notification, notification time and other procedures may be issued by Government Decree.

12 REFERENCES

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