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Assessment of occupational exposure to asbestos in energy and transport enterprises

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Abstract. Occupational exposure to asbestos in energy and transport enterprises was studied. For the assessment of occupational exposure to asbestos inspections of buildings, asbestos identification in material samples, and workplace measurements were included. The occurrence of asbestos in buildings from various time periods was studied using relevant acknowledged methods. The methods of polarized light and phase-contrast optical microscopy were used in the qualitative analysis of material samples and in the counting of asbestos fibres in air samples.

Key words: asbestos, identification, occupational exposure.

INTRODUCTION

The term “asbestos” is the generic name for a group of naturally occurring mineral silicates that have commercial value due to their fibrous morphology. Asbestos includes minerals of different origin. Fibrous hydrated magnesium silicate or chrysotile is the most common form of asbestos and belongs to the serpentines. Crocidolite (riebecite), amosite (grünerite), tremolite, actinolite, and antophyllite are members of the amphibole group of minerals, which form about 5% of all mined asbestos. They differ in chemical structure, resulting in different physical and biological properties. Crocidolite is a hydrated silicate of sodium and iron, amosite is a monoclinic silicate of iron and magnesium, anthophyllite is a magnesium iron silicate of low aluminium content, tremolite is a hydrated calcium magnesium silicate, and actinolite is a monoclinic calcium magnesium iron member of the amphibole group.

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Size and shape are the most important characteristics for defining the respirability of fibres. Chrysotile is often a tight tubular spiral, but it may fracture longitudinally into tiny fibrils. Crocidolite has long needle-like fibres, while amosite and antophyllite are rectangular. In general, long, thin, durable fibres are the most hazardous to health. Fibres shorter than 5 μm in length are not considered to present a health risk because of the ability of the body's natural defence mechanisms to deal effectively with contaminants of this size and nature. For workplace regulatory purposes a fibre has been defined most frequently as having an aspect ratio (ratio of fibre length to fibre diameter) of at least 3 : 1. It is known that 10 to 60% of the inhaled particles within the range 0.1 to 5.0 μm reach the lung. Exposure to asbestos is usually mixed because serpentines nearly always include a small amount of amphiboles, which are not purified after mining. Tremolite is thought to be especially important in this respect.

Commercial use of asbestos began in the mid-19th century. The special physical properties of asbestos that result in its widespread use are: insulation against heat, cold, and noise; incombustibility; good dielectric properties; great tensile strength; flexibility; and resistance to corrosion by alkalis and most acids. In addition, chrysotile asbestos is very easy to spin [1–4].

During the years 1962–95 the main user of asbestos in Estonia was Kunda Cement Factory where wavy roofing sheets were produced from a mixture of Portland cement and chrysotile asbestos (10–15%). About 1.4 million tonnes of roofing sheets were produced during this period, half of them were exported to the northwestern region of Russia.

The measurements (light and electronmicroscopy) for the determination of asbestos fibre concentrations in the roofing sheets department were carried out in 1991 by the Finnish Institute of Occupational Health. The concentration of asbestos fibres at normal process conditions varied between 0.52 and 8.6 fibres/cm^3. According to the questionnaire study carried out in the Estonian Institute of Experimental and Clinical Medicine about 20 000 tonnes of asbestos and asbestos-containing products were used at the beginning of the 1990s annually. Asbestos was used mostly in thermal insulation, textiles, friction and construction materials, and thousands of workers were exposed to asbestos [5–6].

All forms of asbestos have been classified as Class 1 "known human carcinogens" by the International Agency for Research on Cancer. The diseases caused by exposure to asbestos fibres include asbestosis, pleural fibrosis (with discrete or diffuse pleural thickening), benign pleural effusions, chronic bronchitis, chronic airflow limitation, malignant mesothelioma, respiratory track cancers, and gastrointestinal cancers. Respiratory tract cancers are the most common cancers associated with occupational asbestos exposure. When cancers occur, their period of latency averages about 25 years from the first asbestos exposure [7–9].

Malignant mesothelioma is an aggressive and rare tumour of the mesothelium, which arises in serosal cavities and is strongly related to asbestos exposure. The incidence of this tumour is still increasing because of the widespread use of asbestos over the past years and the long latency of this malignancy. The analyses in this field have demonstrated that the risk of lung cancer is similar for chrysotile, amosite, and crocidolite on a fibre exposure basis. Chrysotile and amosite appear to produce equal mesothelioma risks. The risk of mesothelioma is four to ten times greater for crocidolite [10–12].

In 1983 the European Union enforced a Council Directive on the protection of workers from the risks related to exposure to asbestos at work (83/477/EEC, amendment 91/382/EEC). The aim of this Directive is the protection of workers against risks to their health, including the prevention of risks arising or likely to arise from exposure to asbestos at work. It lays down limit values and other specific requirements [13, 14]. According to the Estonian Chemical Act (enforced on 01.01.1999) the limit value of asbestos in the workplace air (working zone) is 0.1 fibre/cm^3. In Estonia the determination of asbestos exposure levels was started in 1994–95 when the asbestos laboratory, which today has the competence according to EVS-EN ISO/IEC 17025:2000 to conduct tests in this field, was established at the Estonian Institute of Experimental and Clinical Medicine.

The aim of this research was to evaluate occupational exposure to asbestos in Estonian energy and transport enterprises. Earlier hygienic evaluation of air in power stations showed that all personnel could be assigned to the risk group of asbestos-related diseases development [15]. In the chemical industry, asbestos gaskets have been used extensively to prevent leakage between solid surfaces. Still, the exposure to asbestos fibres during gasket removal activities is well within the 8-h average exposure limit of 0.3 f/mL [16].

MATERIAL AND METHODS

For the assessment of occupational exposure to asbestos inspections of buildings, asbestos identification in material samples, and measurements at workplaces were performed. To determine the potential hazards, inspection of buildings was carried out by using relevant internationally acknowledged methods. It included a visual inspection of the buildings, bulk sampling of suspected asbestos-containing materials (ACM), evaluation of the ACM, and determination of the appropriate response actions [17]. The membrane filter technique and phase contrast optical microscopy (PCOM) were used for workplace assay, and expressed as fibres per cm^3 air (f/cm^3). The fibres having a maximum length >5 μm, diameter <3 μm, and a length:diameter ratio >3:1 were counted at magnification of 400. A Walton-Beckett gradicule type G22, matced to the microscope, was used for sizing the fibres. Membrane filters (mixed ester of cellulose) of 0.8 μm pore size with printed grids and battery-operated pumps were used for air sampling. All samples were taken under normal working conditions and without interfering the activities of the workers [18].

Asbestos in material samples was detected and identified by the optical microscope procedure known as dispersion staining. Dispersion staining is a technique of identifying substances microscopically by obtaining a characterizing colour optically. This was achieved by immersing the sample in a mounting liquid of similar refractive index but with a substantially different dispersion than the sample [19]. We used a Carl Zeiss Axioscop Pol Microscope equipped with a phase contrast condenser, a polarizer, an analyser, retardation plates, 360° graduated rotating stage, and gradicule. These methods are used in most European countries, including the Nordic countries, and the results are in every respect reliable and comparable [20].

A total of 32 industrial buildings were inspected, and 225 material samples (on average 7 samples from each object) were taken and analysed. Material samples were collected during the inspections from 21 energy (power plants, boiler houses) and 11 transport (bus, car, railway, etc.) enterprises, 146 and 79 samples respectively.

The exposure survey included 26 objects; 17 of them were energy and 9 transport enterprises. Altogether 137 air samples (52 personal and 85 static) were taken, on average 5 samples from each object. Personal samples were taken within the workers' breathing zone, static (area samples) in fixed locations at workplaces. Airborne fibre concentration measurements were taken mostly in various work situations, such as installation, demolition, maintenance, and various repair works. In addition, air samples were taken in normal working situations, where ACM were used for different purposes, but during the sampling period the working process was not directly connected with ACM. The objects for inspection were selected from different towns and regions of Estonia, most of them were from Tallinn, Tartu, Viljandi, Pärnu, Narva, Kunda, and from their vicinity. Of the inspected industrial buildings 62% were constructed in the 1950s–80s.

RESULTS

Chrysotile asbestos in the form of asbestos cement, thermal insulations, textiles, gaskets, and other technical products was found in 67.6% of all material samples (Table 1). About 76% of the material samples taken in the energy and 52% in the transport enterprises included ACM. In addition to chrysotile asbestos some insulation materials contained tremolite as well. In the energy enterprises asbestos was mainly found in thermal insulation materials, where different types of asbestos cement mixtures, paper, and textile products (cardboard, cord, rope, cloth, etc.) were used. The content of asbestos in insulation materials varied between 10 and 100%. In the transport enterprises asbestos was found mainly in technical products (friction and gasket materials, safety screens, machine accessories, etc). Air-borne levels of asbestos fibres were from <0.01 to 2.1 f/cm^3 at workplaces in both personal and area measurements. During the assessment the occupational exposure limit value was exceeded in 12% of all collected samples. In the energy enterprises the highest concentrations were measured during demolition of thermal insulation and in the transport enterprises during renewal (grinding) of vehicle brakes (Table 2).

Table 1. Results of identification of asbestos in material samples

Type of enterprise, *n*	Insulation materials		Construction materials		Other	
	Samples, *n*	ACM, *n* (%)	Samples, *n*	ACM, *n* (%)	Samples, *n*	ACM, *n* (%)
Energy, 21	96	81 (84.4)	23	13 (56.5)	27	17 (62.9)
Transport, 11	27	11 (40.7)	14	9 (64.3)	38	21 (55.3)
Total, 32	123	92 (74.8)	37	22 (59.5)	65	38 (58.5)

Table 2. Concentration of airborne fibres (f/cm^3) at workplaces

Type of enterprise, *n*	Personal measurements			Static measurements		
	Samples, *n*	Mean ±SD	Range	Samples, *n*	Mean ±SD	Range
Energy, 17	33	0.29 ± 0.11	0.009–0.49	59	0.16 ± 0.19	0.008–2.10
Transport, 9	19	0.16 ± 0.12	0.008–0.38	26	0.07 ± 0.06	0.008–0.26

CONCLUSIONS

The use of asbestos (chrysotile) is widely spread in construction and thermal insulation materials, also in transport equipment and other industrial products. In the inspected objects, built mainly in the 1950s–80s, comparatively large amounts of asbestos cement wavy roofing sheets were used, which were produced in Kunda for about 30 years. It was the main roofing material as alternative materials were in short supply at that time, and the population was not informed about health risks caused by asbestos. Exposure levels varied with the use of ACM depending on the duration of the exposure and amounts of ACM handled during the job activity. In general, personal sample fibre concentrations were greater than area sample fibre concentrations. Area sample fibre concentrations had a larger variability than personal measurements. During the normal use of asbestos cement products there was a limited release of fibres because of the strong binding of cement. Most dangerous were friable thermal insulation materials where asbestos fibres readily release. The asbestos used in the buildings today will constitute thousands of tonnes of extremely stable waste in the future. The occurrence of ACM should be inspected before the renovation or demolition of all types of buildings: industrial, public, and residential. The exposure levels should be monitored at workplaces and in the environment because all stages in the use and handling of ACM may release asbestos fibres that pose a risk either to the workers or, through the general environment, to the entire population. The possible effects of long-time exposure to asbestos deserve more attention. All persons who have been exposed to asbestos in the past and who are still working should be monitored through the occupational health service. Primary prevention carried out today can reduce the disease incidence in the future. Asbestos is indisputably a major health risk.

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Asbestiohu hindamine energia- ja transpordiettevõtetes

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Uuriti asbesti kasutamist ja hinnati sellest tulenevat ohtu energia- ja transpordiettevõtetes. Kokku võeti ja analüüsiti 225 materjaliproovi, millest 67,6% sisaldas krüsotiilasbesti. Mõnedes isolatsioonimaterjalides leiti lisaks krüsotiilasbestile ka tremoliiti. Asbestikiudude hulk töökeskkonna õhus oli <0,01–2,1 kiudu/cm^3 ning põhiliselt sõltus see kasutatud materjalidest, nende liigist ja kogusest ning käitlemisviisist. Asbestikiudude sisaldus ületas lubatud piirnormi ligi 12% õhuproovides. Töös kasutati rahvusvaheliselt tunnustatud metoodikaid ning uuringud tehti Eksperimentaalse ja Kliinilise Meditsiini Instituudi asbestilaboris, mille on akrediteerinud Eesti Akrediteerimiskeskus (reg nr L033) ja mis vastab standardile EVS-EN ISO/IEC 17025:2000.