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ASBESTOS FIBRES IN INDOOR AND OUTDOOR AIR

THE SITUATION IN QUEBEC

INSTITUT NATIONAL DE SANTÉ PUBLIQUE DU QUÉBEC

Québec

ASBESTOS FIBRES IN INDOOR AND OUTDOOR AIR

THE SITUATION IN QUEBEC

SUB-COMMITTEE ON EXPOSURE MEASUREMENT

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This report is presented to the *ministère de la Santé et des Services sociaux du Québec* by the *Comité aviseur sur l'amiante au Québec* sub-committee on exposure measurement.

Chapter 3 was written in 1998. It was then modified in 2001 with the addition of recent data from Quebec. The whole report was completed in 2001.

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INTRODUCTION

In 1997, in light of international developments with respect to asbestos, particularly after its banning in France and the ensuing controversy, the *ministère de la Santé et des Services sociaux* (MSSS) set up a *Comité aviseur sur l'amiante* (asbestos advisory committee). The aim of this committee was to make recommendations about appropriate measures to inform the public and to protect public health.

The mandate of the *Comité aviseur sur l'amiante* (exposure measurement) consisted in assessing the pertinence and the feasibility of assessing asbestos exposure in the general population, particularly in public buildings such as schools. The sub-committee that was created to carry out this task first analyzed the available existing data from all areas. As early as June 1997, the sub-committee identified schools as priority action areas. The sub-committee developed a protocol and environmental assessment tools intended for all school boards and for the *directions de santé publique* (DSP—public health departments) concerned. The work was carried out in close collaboration with Quebec's *ministère de l'Éducation* (MEQ—ministry of education), the *Commission de la santé et de la sécurité du travail* (CSST—a workers' compensation board) and the *Institut de recherché Robert-Sauvé en santé et en sécurité du travail* (IRSST—Occupational Health and Safety Research Institute Robert-Sauvé) under the auspices of the *ministère de la Santé et des Services sociaux* (MSSS—ministry of health and social services).

A program for the safe management of asbestos in schools was launched in the summer of 1997. A large part of the sub-committee's resources was mobilized for this program. In addition, resources were allocated to define a usable action criterion for managing the situation in the schools. At the same time, work continued on other relevant aspects: the criteria and standards in effect in Quebec, the sampling of asbestos fibres in ambient air, the situation in workplaces such as mines and processing plants, and finally, exposure levels in mining towns and in ambient air in general.

The present report sets out the committee's mandate on exposure measurement and the principal aspects of asbestos problems and issues at the environmental level. Then, it summarizes the current knowledge on population exposure in certain environments likely to contain asbestos fibres: public buildings, ambient air, and workplaces. Finally, it discusses the situation in Quebec. The committee then presents a series of recommendations to the MSSS with respect to this situation.

Advisory committee sub-committee on exposure measurement

General objective

Assess the pertinence and the feasibility of assessing asbestos exposure in the general population, particularly in public buildings such as schools. If necessary as a result of these findings, carry out this assessment in collaboration with the *directions de santé publique du Québec* (public health departments).

Specific objectives:

- Analyze available existing data, in Quebec and elsewhere: schools, public buildings, workplaces.
- Determine a sample of locations (schools, other buildings) likely to present a problem of asbestos exposure.
- Make personal visits to these locations to appraise the situation.
- If necessary, implement a strategy for environmental sampling of asbestos exposure in the places identified in the previous step.
- Obtain a list of affected school boards.
- Establish a definition of a school or public building in which there is an exposure risk.
- Evaluate the findings and determine the pertinence and the feasibility of carrying out a more thorough assessment of asbestos exposure in Quebec.

Asbestos and sources of exposure

The term "asbestos" applies to a group of fibrous silicate minerals. The term "fibre" applies to all inorganic and organic materials that have a length to diameter ratio greater than 3. Asbestos is one of the so-called natural fibres. Asbestos fibres are used commercially because of their excellent mechanical and thermal resistance as well as their great durability. The family of asbestos fibres is divided into two groups: serpentine fibres and amphibole fibres. Serpentines, whose only fibrous member is chrysotile (white asbestos), represent more than 90% of the asbestos produced in the world. Among the amphiboles, the most common types of fibres are crocidolite (blue asbestos), amosite (brown asbestos), tremolite, and actinolite. When manipulated or submitted to mechanical pressure, asbestos tends to fragment and release fibres into the air. The asbestos fibres contained in the mineral ore are not respirable unless they are released and dispersed in the air by extraction and processing procedures. Asbestos fibres can be inhaled when they are in suspension in the air.

Asbestos fibres released into the environment can contaminate air, soil, water, and food. Environmental contamination may come from natural or industrial sources. The natural erosion of the soil and rocks on the earth's crust represents a potential source of contamination. At certain locations on the planet, there are exploitable commercial deposits of asbestos ore, particularly in Quebec and in the former Soviet Union. The extraction, processing, and use of asbestos generate industrial contamination sources. Asbestos mines and mills are unquestionably the largest sources of contamination in the environment in general. Asbestos is used in the manufacture of hundreds of consumer products. The principal uses are related to the manufacture of brake pads, asbestos cement materials, and insulating materials.

Population exposure can occur in two types of environment, the workplace and the general environment. At work, the places most at risk are asbestos mines and mills, processing plants, construction sites, and buildings undergoing maintenance and repair. The processing industry is made up of several industries such as shipbuilding and repair, transportation equipment, fabrication of metal products, and adhesives.

In the general environment, the population may be exposed both indoors and outdoors. Detectable concentrations of asbestos fibres are found in the air in rural and even remote rural settings. In urban settings, the air is more contaminated due to the presence of certain diffuse sources, notably asbestos from brake pad wear. Near certain industrial sources such as asbestos mines and mills and industries manufacturing asbestos-based products, concentrations may be elevated.

The main sources of indoor air contamination are linked to the presence of friable asbestos materials such as the sprayed asbestos applied to the ceilings and walls of some public buildings up to the late 1970s. In public buildings and on ships, wrapped asbestos was used extensively to insulate pipes; places such as boiler rooms may be contaminated when these insulating materials deteriorate. Asbestos workers' clothing may be an important contamination source inside buildings and residences. Asbestos is also found in some construction materials such as insulating materials for boilers and pipes, floor and ceiling tiles, some paints, and some papers and textiles. However, in most cases these are non-friable materials.

1. TECHNIQUES FOR MEASURING EXPOSURE TO FIBRES

(Chantal Dion, André Dufresne and Guy Perrault)

The Regulation Respecting the Quality of the Work Environment (RQMT) specifies the time-weighted average exposure values (TWAEV) and the short-term exposure values (STEV) for several fibres—asbestos, natural mineral fibres, artificial vitrous mineral fibres, and organic fibres (1). The Safety Code for the Construction Industry calls for regular samplings in the work area of high exposure risk construction sites (2). In addition, the *ministère de la Santé et des Services Sociaux* (MSSS) recently adopted a management criterion in order to identify possible sources of fibre emission in the ambient air of public buildings, including schools (3).

Mixes of several fibres may be found in a single environment. It is important at the outset to characterize the fibrous phase in the samples of dust deposits, bulk materials, or insulating materials. The asbestos fibre content or the content of other regulated fibres is then estimated in order to guide the sampling strategy and the environmental surveillance protocol prescribed in the various regulations.

Samples of surface dust or bulk material should be representative of the environment. In the workplace, dust deposits are generally representative of workers' exposure to airborne particles, particularly if the sample is collected from high beams or furniture raised a few metres off the floor.

In the case of insulating materials, it is important to verify the homogeneity of the insulator throughout the room—it may be necessary to collect several samples from different locations—and to penetrate the entire thickness of the insulation to ascertain whether there are several consecutive layers.

After the fibrous material is characterized, usually by polarized light microscopy (PLM), samples of ambient air fibres may be taken. Depending on the goal of the intervention, the fibre concentration in air samples can be measured by phase-contrast optical microscopy (PCOM) or by transmission electron microscopy (TEM).

1.1. ANALYSES OF FIBRES IN DEPOSITED DUST OR BULK MATERIAL

Polarized light microscopy

Fibres in bulk samples are usually identified by polarized light microscopy (PLM), using traditional petrography or geology techniques. IRSST Method 244-2 describes the use of this technique to identify fibres in deposited dusts or bulk materials (4).

Principle of the method

The principle of the method consists in first carrying out a meticulous examination with a low-magnification stereomicroscope (10 to 60x) in order to verify the homogeneity of the sample, reveal the different components of the sample, and estimate the content. Placing the samples in appropriate refractive index liquids permits analysts to identify substances by studying their morphology and observing different optical properties such as dispersion staining, which is effective for rapid identification of asbestos fibres.

At times it may be difficult to mount representative samples of the product on microscope slides, due to the sometimes heterogeneous nature of the sample, and due to the widely varied particle size distributions for the different components of the mix. Fibres shorter than 5 µm and with a diameter less than 1 µm are difficult to detect with the dispersion staining lens. Usually, a portion of the fibres contained in insulating materials has dimensions greater than these limits.

Asbestos fibres heated to high temperatures undergo mineralogical transformations. Their optical properties may change, making fibre identification more difficult. The nature of the procedure used must therefore be specified when an analysis is requested so analysts can look for or identify products that alter or change the sample.

Expressing results

Quantification of the different components of the sometimes inhomogeneous mix is subjective, since it is based on a visual estimation by the analyst. Therefore, the method allows only a semi-quantitative determination of fibre content in the samples as observed visually by the analyst through comparison with reference preparations whose value is known. The results of the analyses are reported as a range of concentrations expressed in percentage (V/V) for the different fibrous components of the sample.

- ND (non-detected; no evidence after several samplings);
- Trace (a few fibres only: possible contamination of the sample);
- < 1%; 1 – 5%; 10 – 25%; 25 – 50%
- 50 – 75%; 75 – 90%; >90%.

From a practical point of view, more precise measurements of fibre content in bulk samples are not needed to guide a decision on how to manage existing asbestos or for choosing suitable protective equipment.

Quality control and quality assurance

IRSST Method 244-2 includes requirements for instrument calibration procedures and mounting solutions (4). Microscope slides, cover slips, and mounting solutions must be checked regularly for contamination. Quantitative analyses of the standard preparations must be carried out on a regular basis so as to document the precision of the analyst and the laboratory. Duplicate slides for at least 10 % of the samples analyzed are prepared and analyzed by the same analyst or another analyst from the same laboratory. These results must be recorded in a logbook.

All laboratories involved in the analysis of fibres in bulk samples should participate in an interlaboratory exchange program or quality control program like the National Voluntary Laboratory Accreditation Program (NVLAP) or that of the Research Triangle Institute (RTI). Each analyst should have complete formal training in polarized light microscopy and its application to crystalline materials. Due to the subjective nature of this method, frequent practice is essential in order to remain proficient in estimating fibre percentages.

Other methods of analysis

When an analyst does not detect fibres by PLM but suspects the presence of asbestos (e.g. in PVC tiles), the X-ray diffraction technique may be used to confirm the presence of sub-microscopic serpentine or amphibole minerals. This supplementary technique cannot differentiate between the fibres of the angular particles of a given mineral group. However, detection of these minerals suggests the presence of thin fibres that may be positively identified using another technique such as electron microscopy.

Electron microscopy may be necessary when the dust particles are too small for optical microscopy resolution. Fibre identification is based on the chemical composition obtained by energy dispersive X-ray analysis (EDRX). Fibres with a diameter greater than 0.05 μm may be observed by scanning electron microscopy while those with a diameter as small as 0.01 μm may be analyzed by transmission electron microscopy. The cost of analyses by electron microscopy is three to five times greater than the cost of analyses by optical microscopy and the samples to be analyzed must undergo multiple manipulations.

1.2. MEASUREMENTS OF AIRBORNE FIBRE CONCENTRATION (5)

Phase-contrast optical microscopy

Principle of the method

To evaluate fibre concentration in the atmosphere of a workstation and compare the results to the values prescribed in the Regulation Respecting the Quality of the Work Environment (RQMT), fibres are collected on a membrane filter and counted using phase-contrast optical microscopy (PCOM). A sampling pump is used to draw a known volume of air through a membrane filter to collect the fibres. A portion of the mixed cellulose ester (MCE) filter is then cleared and mounted on a glass slide for observation by microscope. The fibres on a measured area (field) of the filter are counted visually with the aid of a phase contrast optical microscope (with condenser), magnification at 400x.

Fibres longer than 5 μm, with a width less than 3 μm and a length-width (aspect) ratio higher than 3:1 are counted. Fibres with a width less than 0.25 μm are usually not detected by PCOM. This analytical method is applicable to the assessment of fibre concentration in the atmosphere of workstations for all natural or synthetic fibres, without restriction or distinction, whose refractive index is compatible with the mounting medium. This technique does not permit analysts to differentiate the various types of fibrous material normally found in the environment: asbestos fibres, natural or synthetic inorganic fibres, organic or plant fibres. Therefore, this type of method assumes prior knowledge of the preponderance of asbestos fibres over the other fibrous materials.

Sampling

IRSST Method 243-1 is very similar to the World Health Organization (WHO) method (Appendix 1). Sampling is done using a cassette fitted with an electrically conducting extension cowl containing a membrane of mixed cellulose esters (MCE), 25 mm in diameter with 0.8 to 1.2 μm pore size. The sampling flow rate varies between 0.5 to 2.5 L/min for measurement of a time-weighted average exposure value in industrial environments, and may go up to 16 L/min for measurement of the fibre concentration in environments with little dust such as public buildings.

The method's field of applicability suits densities varying from 100 to 1300 f/mm^2. Fibre densities from 25 to 100 f/mm^2, which are lower than optimum densities, may be taken into consideration to evaluate a worker's exposure, but the method's coefficient of variation at these densities is not known and may be higher. The field of applicability is a function of the volume sampled: the upper limit may be raised by using smaller sample volumes (flow rate or sampling time) and the lower limit may be dropped by using larger sample volumes.

Interferences

Any other airborne fibre may interfere if it possesses the geometric counting parameters described above. Heavy concentrations of non-fibrous particles may obscure fibres in the field of view and reduce the accuracy of the count.

Sources of variation

During sampling

During fibre analysis, several parameters can increase variability when determining a number concentration. In general, analysts have no control over samples. Results may be biased by samples that are not representative or that arrive at the laboratory in poor condition, by imprecise or insufficient sample volumes (flow rate or sampling time), as well as by poor distribution of fibres on the membrane. The sample volume should be set so as to meet the method's limits of applicability (100 to 1300 f/mm^2), an area where the variability of the analytical method is better known. These limits of applicability are a function of the sampling and may be met by appropriate sample volumes. Particular attention should be paid to the sampling material. Leakage is sometimes observed due to the cowl being poorly seated in the cassettes or lack of proper control at the time the sample is prepared; the perimeter of the membrane should be checked when mounting a sample to be counted so as to ensure there has been no loss of dust particles during the sampling.

In the laboratory

Samples should be prepared in conformity with the protocol described in the official method so as to avoid any contamination or loss of dusts on the membranes. The effective filter surface area should be precisely determined. The microscope should be adjusted following manufacturer's instructions for each day of operation and at the exact location where the counting will be done. Calibration of the counting surface (graticule of the microscope) should be carried out on a regular basis. When the microscope is moved, all these calibrations must be verified as required by Method 243-1 (6).

During analysis

Other sources of variation related to counting are directly attributable to the analyst. These variations are measurable parameters and are expressed in terms of coefficients of variation (CV). These values express the ability of an analyst (intracounter CV), analysts from the same laboratory (intralaboratory CV), and different laboratories (interlaboratory CV) to reproduce equivalent results. These variations are difficult to identify or correct but may be controlled or limited by quality control programs that aim to improve and maintain counting standards.

Accuracy and precision

When interpreting the result from a fibre count, it is necessary to ensure the accuracy or the reliability of this result. Is the reported value close to the reality? Is there a systematic difference between these two values? If two samples taken at the same time are counted by two different laboratories, will there be a difference and of what magnitude? It is impossible to know the real fibre concentration in the air. There are no absolute standards with which to compare results. Therefore, the method's accuracy cannot be determined except by comparison with averaged results from several experienced laboratories.

Fibre counting involves a subjective aspect that must be taken into consideration. The counting procedure used can result in significant differences in the counts produced by different analysts and, more particularly, by different laboratories. Proper training, and intra- and interlaboratory quality controls can minimize such differences. This means it is important to control certain parameters and to measure their variability. For the analysis, quality control is carried out on membranes. Microscope adjustments such as verification of the power of resolution and regular calibration of the graticule allow analysts to obtain more reproducible results. Analysts should document their precision by performing repeated counts of reference slides and thereby determine their intracounter coefficient of variation. Successive counts of these same membranes by other analysts from the laboratory allow evaluation of the intralaboratory coefficient of variation. Random counts on 10% of the samples already counted are also carried out. All new counters should be enrolled in a training program that compares their performance on a variety of samples.

Several factors can contribute to the poor precision of the method: the small portion of the filter surface that is examined (< 0.5 %) and the variable distribution of fibres on the surface (statistical variation); the use of different method specifications (systematic variation) and the differences in counts made by different analysts (subjective variation). Subjective and systematic variation can be reduced by harmonizing the methods used, properly training personnel, and participating in intra- and interlaboratory proficiency testing programs. Even when these variations are controlled, statistical variation remains a source of error that depends on the total number of fibres counted and the uniformity of fibre distribution on the filter.

The Poisson distribution takes into account variations of fibre counts resulting from the observation of randomly selected fields. Theoretically, according to the equation:

$$CV = 1/\sqrt{N}$$

where N is the number of fibres counted and CV, the coefficient of variation, for 100 fibres counted the CV is 10% while for 10 fibres counted, it is 32%.

In practice, the coefficient of variation associated with this method is higher due to subjective components of intra- and intercounter variations in a single laboratory. Thus, a CV of 22% is obtained when 100 fibres are counted, compared to 37% when only 10 fibres are counted. Interlaboratory coefficients of variation can be more than twice as great as intralaboratory CVs if quality controls are not followed. When the interlaboratory CV is not known, a value of 45% is realistic.

All laboratories engaged in counting fibres should participate in a wide-scale proficiency testing scheme (national or international) and regularly exchange samples taken in workplaces with other laboratories to compare the performance of their counters. Although these slide counts only allow us to compare results with other counting results and not with a reference value, these steps are essential.

Expressing results

The analysis report should satisfy the requirements of the requesting party and contain at least the following minimum data: identification of the requesting party and the sample analyzed; monitoring dates, date of intake and date the report is issued; parameters measured and units of measure; results. The report should also specify precision and limits of applicability. Intralaboratory and interlaboratory coefficients of variation should be reported with each series of results. Fibre concentrations (f/ml) in ambient air are calculated with the following equation:

$$C = \frac{E \times a}{(r \times t) \times 1000}$$

Where:

C = concentration (f/ml)
E = density (f/mm^2)
a = effective surface area of the filter (mm^2)
r = flow rate (L/min)
t = sampling duration (min)
1000 = conversion factor (mL/L).

Other analytical methods

When most of the fibres in the ambient air of public places are not asbestos, they have to be identified when measuring their concentration in the air. Many asbestos fibres in suspension in these ambient atmospheres have widths below the resolution limit of the optical microscope. Analytical techniques using either the scanning electron microscope or the transmission electron microscope are then required. Sampling techniques are similar for optical and electron methods. The high cost of the instruments, the prohibitive cost for their upkeep, and the numerous manipulations required to prepare samples all contribute to making these occasional analyses very expensive.

Scanning electron microscopy provides a specific analysis of airborne fibres. The filter is examined at a magnification of x2,000 and fibre characterization is obtained by analyzing chemical composition using EDXA or by analyzing morphology. The same counting criteria as in PCOM are applied but the detection limit for fibre width is 0.05 µm. A polycarbonate filter should be used with this equipment, which makes it impossible to use the same filter to do a count by PCOM and by SEM for comparative purposes.

Transmission electron microscopy (TEM) can operate at an enlargement of x10,000 and allows a specific energy dispersive x-ray analysis of fibres (EDXA).

Characterization is also accomplished by morphology, selected area electron diffraction (SAED), or energy analysis (EDXA).

The geometric parameters for a countable fibre are set at a length greater than 0.5 µm or at 5 µm as needed, with a length: width ratio greater than 3:1. The resolution limit is 0.01 µm. This method is recommended for measuring fibre concentration in the ambient air of buildings.

CONCLUSION

Phase contrast optical microscopy (PCOM) provides a good indication of workplace exposure when asbestos is the predominant type of fibre. In non-occupational environments where several types of fibres are present, transmission electron microscopy (TEM), which allows positive characterization of the types of fibres, should be used.

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2. PERMISSIBLE EXPOSURE STANDARDS AND CRITERIA IN THE WORKPLACE

(Guy Perrault, Chantal Dion and André Dufresne)

Over the years, many countries around the world have adopted permissible exposure values in the workplace with the goal of promoting the prevention of occupational diseases. Among the substances that have been subject to recommendations by organizations or by government regulations, asbestos is certainly the most affected and the most complex, especially since the term “asbestos” groups two families of natural substances: serpentines whose only fibrous member is chrysotile; and amphiboles, which include crocidolite, amosite, tremolite, anthophyllite and actinolite.

The standards and criteria range from banning (with exemptions) all forms of asbestos, to banning some amphiboles with controlled use of other forms, to controlled use of all forms of asbestos. These standards and criteria have changed continually over the years, adding technical and operational specifications that have created some very complex statutory instruments in various countries (1). It is practically impossible to report on an entire regulation or a code of practice by extracting only exposure standards and criteria. Nevertheless, the few general observations and examples that follow seem to us to be representative of asbestos exposure standards and criteria that are used around the world.

2.1. CURRENT SITUATION

In humans, the carcinogenicity of all forms of asbestos is generally acknowledged, although some researchers have recently challenged the evaluation of the carcinogenicity of chrysotile (2).

Countries such as Finland, France, Germany, Italy, Holland, and Sweden have banned asbestos. In the United States, the 1989 ban was revoked in 1991. Other countries have been able to prohibit the use of one or several amphiboles or all forms of asbestos but it is very difficult to index all of this information.

Appendix 2 offers an overview of the evolution of standards in various countries and under certain organizations (Regulations of Quebec; American Conference for Governmental Industrial Hygienists (ACGIH); Occupation Safety and Health Administration (OSHA); Health and Safety Commission (HSC)).

Quebec is an example of the trend toward banning two amphiboles, amosite and crocidolite, with controlled use of other forms. Of course, we must reiterate that the few standards and criteria mentioned here are entrenched in statutory instruments that detail numerous requirements and prevention techniques such as ventilation, safety equipment, and health standards. Although scientific data are common to all countries, regulatory practices vary. The American organizations ACGIH and OSHA are examples of the coexistence of recommendations made by occupational organizations and government regulations, while the British example clearly shows each organization choosing to introduce its own specifications regarding safe usage in order to better protect its workers. It should also be noted that British law awards permits that confer on employers and workers who have met specific knowledge and performance requirements the right to perform certain jobs.

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3. PUBLIC BUILDINGS

(Benoît Lévesque and Henri Prud'Homme)

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Asbestos fibres possess special physical and chemical properties. They do not burn and are very resistant, both from a mechanical and a chemical perspective. For these reasons, they have a number of uses in industry and construction.

In Quebec, sales to local buyers of chrysotile asbestos produced in Quebec increased gradually until the beginning of the 1980s, reaching 45,490 tons per year. Sales then dropped dramatically until 1986 (30,200 tons/year). Subsequently, following American manoeuvrings to ban the product, they decreased to 11,030 tons, and in 1994, sales stood at 4,486 tons. A significant proportion of these sales as well as some quantities of amosite and crocidolite were used in the construction and renovation of a number of buildings, mainly between 1950 and 1980 (2).

Several types of asbestos-based products were used in construction and can be found in existing public buildings. One of these products is asbestos cement, an extremely versatile material still highly valued for various uses, but there are numerous other products from flooring and textiles to bulkheads and fire doors (3).

More precisely, asbestos-containing materials (ACM) in public buildings can be classified into three categories: miscellaneous products (floor and ceiling tiles, acoustic plaster, cement tiles, etc.), insulation for pipes, boilers and tanks, and sprayed surface treatments (3). This last process, used from 1935 to the 1970s (4), and now formally banned in Quebec (5), involved the bonding of fibres with a binder and subsequent air-forced spray application for the purposes of fire control and improved acoustical insulation of structures.

Sprayed asbestos and asbestos insulation products are both constituted of materials that are generally friable and that can be pulverized or decomposed into very small particles by simple hand pressure (3). Under these conditions, the materials are more susceptible to fibre release in ambient air when damaged or merely touched. Consequently, insulating materials, especially sprayed asbestos materials, because they were often installed in locations that are highly frequented, were the main impetus for the programs set up in the United States at the beginning of the 1980s to assess and limit asbestos exposure in public buildings (6).

From 1979 to 1990, the Environmental Protection Agency (EPA) produced seven different reports on the issue of asbestos in public buildings, the last two published in 1985 (Purple Book) and 1990 (Green Book). These represent the organization's current official policies on the matter (3,7). Also, the U.S. Congress adopted the Asbestos Hazard Emergency Response Act (AHERA) in 1987 to require administrators of elementary and secondary schools to implement ACM operations and maintenance programs in their institutions (7). In 1990, the US Congress mandated a group of experts under the auspices of the Health Effects Institute - Asbestos Research (HEI-AR) to report on ACM in public buildings (4). Ontario also examined the issue in its 1984 Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario (8). Finally, following the report by the *Institut national de la santé et de la recherche médicale* (1), France recently enacted a regulation focused mainly on control of sprayed asbestos and asbestos insulation in public buildings (9).

The intent in the present report is to broadly review the data from the literature on asbestos exposure in public buildings and the resulting health risks. The report will also examine control measures and provide an update on the situation in Quebec.

3.1. EXPOSURE AND HEALTH RISKS

Three population groups may be exposed to different degrees of asbestos present in public buildings: building occupants, who are at little risk of being in contact with or disturbing existing asbestos (professors, students, office workers); cleaning and maintenance workers who are more likely to disturb ACM as they do their work; and building workers who during construction, renovation, or repair work may be regularly in contact with ACM.

Measurement methods

Before looking specifically at asbestos exposure levels in public buildings, we should quickly review measurement methods.

Several techniques have been developed to measure asbestos fibres in ambient air. The standard method in the workplace is phase contrast optical microscopy (PCOM). This analytical method, first used in the 1960s (10), has been improved over the years. As a result, the protocol has gradually been standardized (4). PCOM allows analysts to calculate the number of fibres of a diameter (d) less than 3 micrometres, a length (l) greater than 5 micrometres, and a l:d ratio greater than 3. However, its inability to distinguish asbestos fibres from other types of fibres, and its limited power of resolution make it an unsuitable method in environments presumed to have low contamination such as public buildings (1,4).

A second method, used primarily in Europe, particularly in Germany and Switzerland (1), is scanning electron microscopy (SEM). When combined with fibre chemistry analysis, SEM allows analysts to roughly distinguish asbestos fibres from other fibrous materials. However, these high-magnification instruments require a compromise between image resolution and the signal (4). Thus, both in terms of quality of measurements and identification of fibres, the technique is not suitable for public buildings.

In public buildings, the recommended method is transmission electron microscopy (TEM) (1,4). This method allows exact identification of asbestos fibres and is sensitive enough for measurements in a low contamination environment. Two different procedures are used, direct-transfer methods, and indirect methods that involve dispersal of the original filter in a liquid suspension (4).

For quantification of chrysotile fibres longer than 5 micrometres, it seems that direct and indirect methods produce nearly equivalent results. However, for fibre mixes such as those found in public buildings, the relative suitability of the two methods has not been determined. Moreover, over the years and in various published studies, analytical protocols have often varied, both at the sampling stage and in laboratory analysis, greatly limiting the possibilities of comparison (11).

Occupants

Exposure

In 1990, following an exhaustive review of the literature on the subject and a qualitative evaluation of studies by a panel of experts, HEI-AR surveyed all the reports on asbestos concentrations in the ambient air of public buildings measured by TEM and likely to reflect occupants' exposure. All results were indexed for fibres longer than 5 micrometres (4).

Two Canadian studies (8,12), two British studies (13,14), and two American studies (15,16), one of which recorded measurements taken in support of legal disputes (16), were included in the analysis. Three unpublished investigations were also added, one of which had been carried out in support of litigation. In total, the resulting databank of the non-litigation studies represented 1,377 samples in 198 different buildings. Mean concentrations by building type were respectively 0.00051 f/ml, 0.00019 f/ml, and 0.00020 f/ml in schools (n=48), residences (n=96), and other types of public and commercial buildings (n=54) (4). For all buildings, the mean was 0.00027 f/ml with a 95th percentile of 0.0014 f/ml. In litigation cases, the average values for 171 schools, 10 residences, and 50 other types of buildings were respectively 0.00011 f/ml, below the detection limit, and 0.00006 f/ml (4). Based on these data and on the fact that outdoor air concentrations are 0.00001 f/ml and 0.0001 f/ml in rural and urban environments, respectively, HEI-AR experts, in keeping with the latest EPA report on the matter at that time (7), concluded that ACM in good condition and undisturbed are not very likely to generate exposures higher than those prevalent in outdoor air.

In Quebec, available data are scarce. In March 1979, as a result of the controversy in the United States over the presence of ACM in schools, the *Bureau de l'amiante* (asbestos board) notified the *ministère de l'Éducation du Québec* (MEQ—ministry of education) that certain forms of asbestos used in schools built between 1945 and 1975 could be dangerous to occupants' health (17). At the time, they were referring to sprayed asbestos, that is, unsealed asbestos that is easily damaged (17). After receiving this warning, the MEQ inventoried the schools likely to contain asbestos. It is very difficult to know now how this inventory was done. In any case, at the time, approximately one hundred schools were identified, and approximately thirty were singled out as requiring special treatment (17).

Over the years, the issue resurfaced periodically, notably in the Laurentians (18) and the Quebec City regions (19). Quite recently, in 1996 and 1997, badly deteriorated sprayed asbestos was identified in educational institutions (20,21,22). Some of these cases caused a considerable stir in the media. However, very few objective measurements of ambient air were taken. In cases where such measurements were taken, PCOM was usually used. As we have already stated, this technique does not have the desired precision to evaluate exposure in public buildings. For example, the case of a high school in the Gaspé region, where asbestos fibres were measured by PCOM and TEM, eloquently demonstrates the possible disparities between results obtained by the two methods. Measurements made on the same samples from this school showed concentrations varying from 0.02 to 0.26 f/ml of asbestos in PCOM and from undetected to 0.035 f/ml of asbestos in TEM (22). In this instance, the higher results measured by PCOM are probably due to contamination of the environment by fibres other than asbestos. Nevertheless, a figure of 0.035 f/ml of amosite asbestos measured by TEM (as documented in this case) in a classroom is a higher concentration than concentrations enumerated by HEI based on studies carried out in the 1970s and 1980s.

Besides the case mentioned above, the only quantification data by TEM of asbestos fibres in Quebec's public buildings were collected from 1990 to 1997 by Dr. André Dufresne of McGill University's Department of Occupational Health.[1] It is important to remember that the samples were taken in buildings where damaged ACM problems were suspected. Thirty-nine samplings were taken in 10 schools in the Montreal area. In total, 30% of the measurements showed concentrations higher than 0.025 f/ml of fibres longer than 5 micrometres, the baseline established in France to signify that control measures should be put in place in the presence of ACM (9), and 38% were higher than 0.01 f/ml, the action criterion with respect to asbestos concentrations in the ambient air of public buildings adopted by the *ministère de la Santé et des Services sociaux du Québec* (MSSS) (23). The highest value was 0.3 f/ml. All samples higher than 0.025 f/ml were from three schools and involved exceptional situations (considerable physical contact with surfaces, lack of hygiene, etc.). Dr. Dufresne also measured asbestos fibre concentrations in fifteen air samples collected in six public buildings other than schools. All results were below 0.025 f/ml (24). Taken together, the values determined by Dr. Dufresne were higher than those recorded by HEI in situations where damaged ACMs were suspected. As in the Gaspé region school, the age of the ACM may be a factor since McGill University data are more recent than those found in the existing literature.

Health risks

Asbestos exposure occurs mainly by inhalation, so it is not surprising that resulting effects occur mainly in the respiratory system. These effects have been documented in animals (25) and have also been documented in humans from data collected among individuals exposed to high concentrations in the workplace (25). In this context, it has been clearly demonstrated that asbestos causes a form of fibrosis of the lung and the pleura (asbestosis) during prolonged exposure to high concentrations, but it is also an etiologic factor in lung cancer, mesothelioma (cancer of the pleura and peritoneum), and possibly neoplasia in other sites (larynx, colon, rectum) (1,4). It is on the basis of this evidence that the International Agency for Research on Cancer (IARC) classified asbestos in Group 1, that is, a proven human carcinogen (26). However, regarding the particular problem of ambient air contamination in public buildings, exposure levels are relatively low. Consequently, the only pathologies linked to asbestos that are of concern to occupants are lung cancer and mesothelioma (4).

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[1] Since this report appeared in 1998, the IRSST carried out a study in 17 educational institutions. This study is discussed in the final paragraph of section 3.4

Some evidence demonstrates that lung cancer and mesothelioma risk secondary to asbestos exposure increase with fibre length. Thus, in animals, fibres longer than 5 micrometres have been clearly shown to produce an increased number of tumours. Shorter fibres are relatively inactive (4). As well, mesotheliomas occur more frequently following exposure to thinner rather than thicker fibres (4). Finally several studies suggest that amphiboles are more likely than chrysotile to cause mesothelioma (25). However, this is strongly contested (27), and the hypothesis of a risk specific to one type of fibre is not yet proven (4). For lung cancer, no difference has been shown with respect to type of fibre (4).

As we indicated earlier, the carcinogenicity of asbestos on the lungs and pleura has already been demonstrated. It was clearly proven in a case study of highly exposed workers (4). However, the same evidence does not currently exist for lower dose exposures associated with environmental contamination, particularly in public buildings, and it is doubtful that a link can be proven, due to the important methodological limitations inherent to epidemiological studies of etiologic factors. Consequently, risk is evaluated on the basis of analytical models using data collected among workers. Certainly, it is dangerous to extrapolate from results gathered on subjects highly exposed at work to populations subjected to much lower concentrations in an entirely different context.

In addition, the construction of such models involves making assumptions to take into account, for example, latency period, the effect of age, and the existence or non-existence of a threshold. Therefore, it is understood that results must be interpreted with the awareness that numerous uncertainties exist (23,28). A recent correlation study conducted in Quebec among women in two mining towns seems to show that the EPA dose-response model overestimates lung cancer risk by a factor of at least 10 (29). All the same, these models provide an interesting quantitative indication of the possible health impact of environmental exposure to asbestos.

As we have already stated, in 1988, Congress mandated HEI-AR to examine asbestos issues in public and commercial buildings (4). HEI-AR reviewed all asbestos risk assessments, synthesized them, and applied the results directly to building contamination. HEI-AR estimated that a six-year exposure from age 5 to age 11 (180 days/year, 5 hours/day) occurring in a highly contaminated school—according to the data taken from the literature, that is, ambient air concentrations of 0.005 mixed fibres longer than 5 micrometres/ml—produced a risk of death from lung cancer or mesothelioma of approximately 30 cases per million exposed persons (30x10^{-6}). Again according to HEI-AR estimates, a teacher exposed for twenty years to 0.005 mixed fibres longer than 5 micrometres/ml from age 25 to age 40 (200 days/year, 8 hours/day) would incur a risk on the order of 80 per 10^{-6} (4). It is worth mentioning here that, although this subject is highly controversial, most environmental protection organizations estimate that a risk higher than 1 x 10^{6} should not be accepted when exposure to human carcinogens is involved (30). EPA considers that an environmental exposure that generates excess lifetime risks on the order of from 1 x 10^{-4} to 1 per 10^{-6} should, within the limits of possibility, be subject to public health protection measures (30).

Hughes and Weill performed this same exercise using the model of the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario (8), weighting for type of asbestos. Their risk estimate for a nine-year-old child exposed to 0.003 mixed fibres longer than 5 micrometres/ml over six years is 15 x 10^{-6} and 4.5 x 10^{-6} for chrysotile (31). The results are therefore on the same order of magnitude as those obtained by the HEI-AR model. Interestingly, the authors transposed the risks calculated secondarily to asbestos exposure into annual mortality rate from the end of exposure at age 15 up to 75 years of age. An annual rate of 15 x 10^{-6} for an exposure to 0.003 mixed fibres longer than 5 micrometres/ml is equal to an average annual rate of 0.025 deaths per million exposed persons (0.25 x 10^{-6}). In comparison, the same rate is 1,200 x 10^{-6} for tobacco-related deaths, 15 x 10^{-6} for cycling accident deaths between the ages of 10 and 14, 15 x 10^{-6} for deaths caused by inhalation or ingestion of foreign objects and finally, 10 x 10^{-6} for fatalities due to injuries incurred while playing football in secondary school in the U.S. between 1970 and 1980 (31).

Workers

As they work, maintenance workers cause the resuspension of settled asbestos debris and dusts and can occasionally come into contact with ACM while performing certain tasks. As early as 1971, Lumley, Harries and O'Kelly provided evidence that brushing a surface covered with sprayed crocidolite could result in an airborne concentration of 11.9 f/ml (32) documented by PCOM. Sawyer showed that dusting books in a library contaminated by chrysotile debris from the ceiling could generate concentrations measured by PCOM of 15.5 f/ml (33). Unfortunately, until 1991, no solid study was conducted to verify the effect of cleaning activities on workers' exposure in public buildings (4), and we found no record of any since then. However, a study conducted among 120 public school janitors in the U.S. showed a 33% prevalence of pleural plaques documented by pulmonary radiography (a good indication of asbestos exposure) compared with 1.8% among 717 workers from a Boston university with no known asbestos exposure (34).

For maintenance activities such as the upkeep of boilers and air exchange systems, the repair and replacement of asbestos-insulated pipes, valve replacement, and the installation of telecommunications cables, in 1992 Price, Crump and Baird reviewed existing data obtained by PCOM and estimated the median value and the 90th percentile of exposure at 0.002 f/ml and 0.02 f/ml per year for workers involved in these kinds of activities. The databank that was used pooled 1,227 air samples collected during regular maintenance activities in public buildings (35).

More recently, in 1994, Kinney, Satterfield and Shaikh published the results of a surveillance of maintenance activities carried out as part of a surveillance program of work involving ACM in a large office building in Washington. Samples were taken near the work area over a period of five years and mainly represent the exposure of workers and occupants who were in proximity to the work but not involved in the work themselves. In all, 916 samples were taken by PCOM during the performance of 213 maintenance and renovation tasks, while taking steps to limit contamination of the environment. In the work zones, mean concentrations were 0.007 f/ml; they decreased to 0.004 f/ml outside these zones. Tasks that generated the highest levels were repairing damaged ceilings (0.01 f/ml) and above-ceiling repair work (0.009 f/ml). Finally, certain specific activities contaminated ambient air considerably more. For example, above-ceiling repair work produced fibre concentrations from 0.013 to 0.451 f/ml. A total of 162 samples was also taken by TEM in cases where high concentrations were suspected and the results were recorded in structures (any fibre and/or network of fibres) greater than 5 micrometres/ml. On average, concentrations were 0.014 f/ml. The authors concluded that the ACM operations and maintenance program was instrumental in limiting contamination but that some tasks could nevertheless generate high levels of asbestos in ambient air (36).

Corn, McArthur and Dellarco also investigated sampling data from five public buildings (4 commercial buildings and 1 hospital) as part of an operations and maintenance program. Some 500 samples were obtained using personal monitors and samples taken in the workplace. Analyses were performed by PCOM. Contamination was controlled with simple procedures such as vaporization of ceiling tiles with water, use of a very efficient particle aspirator in the work area, and use of meticulous work methods. Personal exposures in one of the buildings during electrical/plumbing work, cable running, and HVAC work ranged respectively from 0.000 to 0.035 f/ml, 0.001 to 0.288 f/ml, and 0.000 to 0.077 f/ml. Taking account of the time spent on performing these tasks, the 8-hour time-weighted averages (TWAs) for these three types of work were respectively 0.015 f/ml, 0.017 f/ml, and 0.02 f/ml. The authors concluded that it is possible with simple measures to limit workers' asbestos exposure to well below the U.S. Occupational Safety and Health Administration (OSHA) standard of 0.1 f/ml for a daily period of 8 hours per day, 5 days a week during work involving ACM in public buildings (37).

While it is possible to control asbestos contamination of ambient air during work involving ACM, it is clear that without appropriate protection measures exposure can be greater. In a study conducted in eleven buildings where renovation work was done and in three other buildings where sprayed asbestos was removed, Paik, Walcott and Brogan demonstrated elevated exposures for workers, documented by PCOM. The mean exposure of sheet-metal workers, carpenters, and electricians was 0.19 f/ml. During removal work using dry methods, average concentration was 16.4 f/ml. This was reduced to 0.5 f/ml when wet methods were used (38). Burdett, Jaffrey and Rood conducted a study in two buildings where sprayed asbestos was removed. In one of these, concentrations of fibres longer than 5 micrometres measured by TEM in the work area ranged from 10 to 30 f/ml (39).

In Quebec, there is little data available on exposure of workers involved in maintenance, renovation, or control and removal of asbestos in public buildings. The "Regulation Respecting the Quality of the Work Environment" stipulates that work liable to generate asbestos dust must be carried out in accordance with provisions in section 3.23 of the "Safety Code for the Construction Industry" (2), which prescribes measures to be taken to protect workers and the environment. But workers still have to be aware they are handling ACM.

During the investigation of a sprayed asbestos problem in the ceilings of second-floor classrooms in a school in the Quebec City area, it was learned that after water damage had occurred a few years earlier, similar coatings had been removed with no precautions to protect workers and avoid fibre dispersal in the school during the work. (21). In such conditions, the resulting contamination can last a long time, and several weeks or even months may pass before a return to background level (39). Equally troubling is the fact that during work on ACM in a Montreal area building, McGill University's Dr. Dufresne documented by TEM concentrations of 10 to 30 fibres longer than 5 micrometres/ml, 40% of which were amosite (24). No measures had been put in place to protect workers or the occupants who continued their regular activities.

It might be thought that cases such as those mentioned in the preceding paragraph are simply exceptions. However, recent data on occupational diseases indicate that Quebec's construction industry workers have been exposed to asbestos. After reviewing mesothelioma cases compensated by the *Commission de la santé et de la sécurité du travail* (CSST) from 1967 to 1990, Bégin et al. noted a larger increase of cases in the construction industry than in the mining and processing industries. Over the last four years of the study, 33% of the cases occurred among building industry workers (40). In addition, still according to the CSST data, but between 1991 and 1995, of 135 asbestosis cases recognized by occupational pulmonary diseases committees, 38 were from the primary sector (mines), 19 from the secondary sector (processing), and 78 from the tertiary sector (construction). Compensation claims from this last sector came from younger individuals, that is, 39 (50%) from persons under 60 years of age working in several different building and construction trades (plumbers, insulators, mechanics, etc.)[2]. These data were of special concern because in previous years, there had been no systematic surveillance program of the respiratory health of workers in the construction industry as there had been in the primary sector.

A screening program was set up in 1995 by the community clinic *CLSC des Faubourgs à Montréal*. In spring 1997, 20 workers out of 972 (2.1%) were identified as having radiologic abnormalities compatible with a diagnosis of asbestosis. The cases occurred among plumbers, tinsmiths, mechanics, and insulators (42)[3]. Although this screening was carried out among volunteers, and therefore may be tainted by a selection bias, it suggests again that asbestosis can occur among construction workers. Considering that the development of this form of fibrosis requires a substantial exposure, on the order of 25 f/ml-year according to some authors (1), we see that building workers may have been highly exposed to asbestos in the past.

The authors of a CSST brief recently acknowledged this finding. In their opinion, the workers most exposed to dangerous concentrations of asbestos fibres are those from the demolition and renovation industries and those involved with the maintenance of asbestos-insulated buildings or installations; they recommend that a draft regulation be prepared, in conjunction with the *Régie du bâtiment* (Quebec building board), with respect to the management and control of asbestos by building owners (2). In light of existing data, it seems clear that this finding is accurate and that the recommendation is of the highest priority.

Controlling exposure

Due to the highly technical nature of the subject under discussion, this section gives an overview, rather than a comprehensive examination, of various factors that are likely to limit human exposure to ACM in public buildings.

Inventory

Controlling asbestos exposure in public buildings requires the identification of ACM, first by examining plans and specifications, and then by sampling and analyzing suspect material in the laboratory (3,41). In Ontario, owners of public buildings are responsible for the identification of ACM in their buildings. The same is true in elementary and secondary schools in the United States (7) where regulation requires ACM operations and maintenance programs be set up; owners of other types of buildings are strongly encouraged to set up such programs (3,7). Since 1997, in France, owners have also been required to inventory sprayed asbestos and insulating materials on their premises (9).

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[2] Monique Rioux, CSST, personal communication [Translation], 1998

[3] Another study has recently been carried out in the Montréal area (49). A total of 83 maintenance workers potentially exposed to asbestos during their work were examined by pulmonary radiography. Several of these workers had also worked in construction. No case of radiographic abnormality compatible with asbestosis was detected among these workers. The authors concluded that exposure had probably not been long enough or high enough to result in detectable chronic lesions.

In Quebec, no such regulation exists, but a CSST committee has just recommended one which would require owners of public buildings to look for the presence of sprayed asbestos and insulation, to inventory and locate ACMs, to identify the types of asbestos on the basis of their location, to notify their own maintenance workers as well as outside firms before any work is carried out in proximity to or on the ACM, to verify the condition of the sprayed asbestos and/or insulating materials, to periodically evaluate the condition of the materials, and to take appropriate corrective action depending on their condition (2). Obviously, a regulation such as this, adequately enforced, would be an enormous step toward protecting the public in general, and (in conjunction with the provisions in sub-section 3.23 of the Safety Code for the Construction Industry) workers in particular, against asbestos-related diseases.

3.2. IMPLEMENTATION OF OPERATIONS AND MAINTENANCE PROGRAMS

According to EPA, the aim of setting up an operations and maintenance program is to clean up asbestos fibres that have already been released, minimize damage to or alteration of ACM, and monitor the condition of ACM (3). Briefly, the components of the program involve the education and training of employees with regard to the location of ACM, the use of individual protective equipment and appropriate techniques for working with and cleaning up ACM, surveillance during work involving ACM to ensure that prevention measures are implemented, and finally, periodic inspection of the condition of the ACM.

3.3. EVALUATION OF THE CONDITION OF ASBESTOS-CONTAINING MATERIALS

The condition of ACM is evaluated with a view to determining the potential for release of asbestos into the air. Obviously, the situation is more problematic when dealing with insulating materials, especially sprayed asbestos (3,9). An examination of the literature on the subject shows there are three approaches: the first is essentially qualitative, the second is quantitative, and the third is a combination of both.

The qualitative approach

The qualitative approach was designed mainly by EPA. It is based on evaluating the condition of ACM by means of an algorithm, a matrix, or a decision tree (4).

The first algorithm (developed by Dr. Benjamin Ferris) was used in a study conducted in 1,425 schools in Massachusetts. The Ferris Index was based on the score assigned by an observer to five variables: accessibility, condition of the material, friability, presence in ventilation ducts, and asbestos content (6). The assigned score determined the extent of the control measures (removal, encapsulation).

At the same time, EPA developed its own algorithm. This used the same variables as the Ferris Index, to which were added water damage, activity and movement of occupants, and exposed surface area. Subdivided into three categories, the score also served to choose appropriate control measures.

Findley et al. evaluated this tool. A sampling of 43 graduate students in administration and public health was randomly split into two groups of 23 and 20 persons. Members of the first group had to assess five sprayed asbestos sites one week after receiving written instructions, while those in the second group had to perform the same task after being given, in addition, two hours of training that included formal review of the algorithm with discussion and slide presentation. A third group, which determined the condition of the same asbestos-containing materials, was made up of five industrial hygienists who had pertinent experience in risk assessment and served as a control. According to the authors, the results were somewhat disappointing. They found no statistical difference between the results of the first two groups and scores were highly variable among all observers (43). Nevertheless, an examination of the data shows that for four of the sprayed asbestos sites, a high percentage of members of the first two groups (67%, 84%, 88%, 98%) distinguished severely deteriorated sprayed asbestos from that which was intact or moderately deteriorated. This was consistent with the experts' consensus. In the last of these cases, which hygienists placed at the upper limit of the moderately deteriorated category, 81% of the students ranked the sprayed asbestos as severely deteriorated. Consequently, the algorithm generally allowed observers with relatively little training to distinguish ACM in poor condition. Nevertheless, the inter-observer variability subsequently led EPA to recommend the use of a matrix (3) that is simpler but possibly less susceptible to subjectivity (4). This method is principally based on two variables, the potential for future disturbance (low, high), and the current condition of the material (good, minor damage, severe damage). The conjunction of these two parameters provides priorities for remediation activities (3).

EPA considers that while interesting, air sampling measures only those conditions that exist during sampling. Thus, it does not provide information on the potential for fibre release or on future fibre concentrations in ambient air (3). It is nevertheless recognized as having a certain utility as a complement to visual inspection (7). However, not everyone shares this opinion.

The quantitative approach

Crump refutes EPA arguments concerning the possible short-term increases in fibre quantity that might not be reflected by ambient air monitoring. He cites the concentrations measured in 1,185 samples collected in public buildings that were equivalent to a three-year continuous sampling (44). In addition, in a study conducted in twelve buildings with and without friable asbestos, Guillemin et al. assessed ACM using the Ferris and EPA algorithms, while at the same time measuring ambient air by TEM. They are of the opinion that the visual algorithms can never adequately assess exposure to asbestos fibres and that they are misused (11).

This opinion is partially shared by Wilson et al. After the panic that arose in 1993 among parents of children attending schools with ACM in New York City, and the reaction of authorities who responded by closing these schools, the authors expressed the belief that the hysteria had occurred because of EPA policy with respect to asbestos, a policy that has no solid scientific basis with respect to risk assessment, which should be based on monitoring concentrations in ambient air (45). In the light of the body of literature, it is clear that there is no panacea and that we have to be aware of current limitations of exposure assessment.

The qualitative and quantitative approach

As part of the new regulations in France, authorities have developed a qualitative decision tree that classifies sprayed asbestos into three categories: in good condition, partially damaged, and in poor condition. In the latter case, remediation work must be undertaken. When sprayed asbestos is ranked in the first category, ACM must be reevaluated in three years. However, for ACM in the second category, a quantitative element is added, a TEM measurement of airborne asbestos fibres. If the concentration measured is less than or equal to 0.005 f/ml, the sprayed asbestos must be reevaluated after three years. If it is between 0.005 and 0.025 f/ml, it must be reevaluated in two years, and if it is equal to or higher than 0.025 f/ml, corrective action must be taken (9). This approach introduces a more objective measure to assist in deciding the most controversial cases.

Reducing the release of asbestos fibres in the air

There are three types of measures to control the release of asbestos by ACM: removal, enclosure, and encapsulation (3). While health officials are responsible for determining if a situation may result in risks to occupants, it is not up to them to decide which of these measures should be used. Therefore, we will discuss the subject only briefly. However, certain facts related to the U.S. experience ought to be mentioned here.

In its “Purple Book” of 1985, EPA recommended removal as the best alternative for problems relating to ACM in public buildings (3). However, certain studies have clearly demonstrated that removing asbestos often generates greater risks for workers and even for occupants than leaving the material in place (30,45). Consequently, in 1990, in the latest guide produced on the subject and based on existing data, EPA concluded not only that there is a low risk to occupants’ health secondary to the presence of asbestos in public buildings but also that removal is often not the best alternative for reducing exposure, and that it is not required in cases of demolition or renovation activities (7).

3.4. STUDY IN QUEBEC SCHOOLS

As early as June 1997, the members of the subcommittee on exposure measurement_determined that there were limited data available on asbestos exposure in public buildings in Quebec, both with regard to occupants’ exposure and workers’ exposure (46). A CSST working group was already studying the issue with regard to workers. At the same time, possibly due to the debate on the international scene, there was evidence of public concern and media interest in asbestos exposure among occupants of public buildings. The only data available on this, the findings recorded by McGill University from 1990 to 1995, pointed to ambient air concentrations distinctly higher than those gathered from studies conducted in the 1970s and 1980s in Europe and North America, possibly due to the aging condition of ACM. In addition, just as with the data recorded by HEI-AR, levels seemed to be higher in schools than in other types of public buildings. Also, due to their young age and the long latency period before the appearance of pathologies related to asbestos exposure, children are generally considered to be a group more at risk; it is clear that the few recent cases in educational institutions were also likely to create unwarranted panic and a quite inappropriate risk management response, as in the U.S. (30,45).

In June 1997, it was therefore recommended that a study be conducted in a random sample of 200 schools in Quebec to check the extent of asbestos use in educational institutions and its impact on public health. At the same time, this offered an opportunity to test different instruments (qualitative assessment method, sampling of airborne asbestos, communication strategy, and so on). The *ministère de l’Éducation du Québec* (MEQ—Ministry of Education) preferred to have all elementary and secondary schools investigated. This was begun in April 1998, with the school boards responsible for identifying all the sprayed asbestos in the buildings under their jurisdiction. Following this, a technician or an industrial hygienist from the health network assessed the condition of the ACM recorded.

A working group was formed bringing together representatives from the MEQ, IRSST, McGill University, the CSST, and the health network. This group developed a strategy to assess the potential for release of asbestos fibres in ambient air and for the management of ACM (see Appendix 3). This strategy was based on a combined approach (qualitative and quantitative) that was inspired by the policy in France. A decision tree was constructed based on five factors: condition, accessibility, friability, dispersion factors, and type of asbestos. After applying an assessment grid, analysts characterize ACM in one of three rankings on the basis of their state of deterioration and the potential for fibre release in ambient air. For ACM ranked 3, appropriate remediation measures must be taken. ACM ranked 1 are assessed every three years, except for amphiboles, in which case asbestos fibres in air samples are measured by TEM. If levels are lower than 0.01 f/ml, the action criterion recently adopted by the MSSS (23), an assessment is done every two years. If levels are higher, work must be undertaken to remedy the situation. For all ACM ranked 2, measurement of airborne asbestos fibres is also prescribed as a support to the decision-making process, and concentrations higher than or equal to 0.01 f/ml require remediation. Below the action criterion, periodic assessment is required. If the measurement is less than 0.005 f/ml, assessment must be done every 3 years for chrysotile, and every 2 years for amphiboles. If it is between 0.005 and 0.01 f/ml, assessments are more frequent, every 2 years for chrysotile and yearly for amphiboles. Measuring asbestos concentrations in ambient air by TEM poses a major logistical problem.

First, it is a costly form of analysis. Moreover, Quebec does not have the required infrastructures. In fact, in 1998, the only laboratory in the province of Quebec capable of performing the analytical technique was that of McGill University, which, at the time of the study, did not have adequate human and material resources to meet demand. Consequently, samples had to be sent to Ontario or the United States.

There is a possible alternative that would reduce the costs of TEM analyses. In the state of Michigan, PCOM is used as a screening measure. If measurements are greater than 0.01 f/ml by PCOM, TEM is then used to verify that the fibres measured are really asbestos (45).

Unfortunately, there are conflicting data on the correlation between measurements made by PCOM and TEM and it is difficult to compare the different studies due to differences in the sampling and analysis techniques used. From eleven samples taken in a factory using chrysotile asbestos, Cherrie, Addison and Dodgson estimated a TEM/PCOM ratio of 4 while for four laboratory-prepared amosite samples, the same ratio was 1.7 (47). More recently, Verma and Clark used 65 samples collected in different enterprises where the presence of chrysotile was known (mines, mills, brake manufacturers, and so on) to show TEM/PCOM ratios varying from 1.4 to 3.2 (48).

Looking at different environments, Cherrie et al. used 44 samples collected outside an asbestos-producing plant, in public buildings with ACM, and in the ambient air of urban environments, to show there was little correlation between PCOM and TEM (47). Kinney et al. share this opinion. Following a study of 76 duplicate filters, one set measured by PCOM and the other by TEM, Kinney et al. found a low correlation between the two measurements. However, the methods were hardly comparable, since one measured fibres and the other, structures. Moreover, when Kinney et al. included in the calculation measurements below the detection limit, the correlation coefficient was 0.87 ($p > 0.0001$)

(36), thereby indicating that in a case of very low contamination the two methods were nevertheless correctly correlated.

Similarly, Burdett and Jaffrey examined 235 samples that were taken in public buildings and analyzed by both methods; they considered there was a good correlation between PCOM and TEM, and that PCOM was a useful method for screening buildings with possibly elevated levels. However, the volume of air samples analyzed, on the order of 500 litres (13), was ten times lower than the current standard. Finally, on twelve samples collected in twelve buildings, Guillemin et al. concluded that even though PCOM was not really appropriate in situations where there might be different types of fibres, it could be useful as a screening method (11).

Given the resources available in Quebec at the time, this committee recommended a pilot study to check asbestos concentrations in public buildings with damaged ACM and to verify the validity of PCOM as a means of detecting concentrations of asbestos in these locations. This study was conducted in 17 school buildings and indicated that a simple qualitative assessment was preferable to quantitative measures, whether done by phase contrast optical microscopy (PCOM) or by electron microscopy. The first method is not specific to asbestos fibres while the second should not be used except in problematic cases. Overall, the study showed in 84% of the samples measured that electron microscopy results were below or equal to the detection limit of the method used. However, the arithmetic mean of the set of samples—0.0031 f/ml—also appeared to be higher than the values cited in the literature. Nevertheless, the authors considered that, except in the premises where activities facilitated contact with the materials, ambient air concentrations were very low (50).

CONCLUSION

On the basis of this examination of the literature, we find that the presence of ACM in public buildings results in few risks to occupants. However, substantial exposures may occur during work involving ACM when the necessary protective measures are not taken. In such cases, there may be considerable contamination of the environment and a notable risk mainly for workers, but also for occupants. Quebec data show there may be severely damaged ACM in public buildings. Perhaps due to the advanced age of the ACM, concentrations measured in ambient air of public buildings where problems had been observed seem higher than concentrations recorded in the literature. Despite this, the risk for occupants is probably minimal. This may not be true for certain workers who, by the very nature of their job, have to work unknowingly with damaged ACM and do so without the necessary safety measures. The current investigation by the MEQ in its institutions is a step in the right direction and may serve as a base for a specific policy with respect to asbestos exposure in public buildings.

The list of asbestos-related diseases among construction industry workers indicates an increasingly high number of asbestos-related diseases among these workers reflecting significant exposure in the past. This also argues for appropriate management of ACM in public buildings. The CSST, which has already expressed an opinion on the situation, made pertinent recommendations on this matter, which we hope will be followed up. Also, we believe that a study of the current exposure of this population should be considered.

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4. THE ASBESTOS PROCESSING INDUSTRY

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Given recent concerns about the banning of asbestos in some countries, including France, and the public health issues raised by exposure of the public to asbestos, the *Direction de santé publique de Montréal-Centre* (public health department) decided to undertake a descriptive study of this workplace contaminant for establishments targeted by the application of the Act Respecting Occupational Health and Safety. At the same time, given the concentration of processing industries in Montréal-Centre, Quebec's asbestos committee wanted to assess the situation and describe the extent of the problem of asbestos use in processing industries.

This document has the following aims:

- Describe, in priority groups, the number of establishments manufacturing goods in which asbestos is a raw material.
- Describe the major sectors in which asbestos exposure is identified.
- Describe the population exposed, in terms of processes where prescribed occupational standards are likely to be exceeded, and levels of exposure.
- Describe the situation with respect to preventive measures introduced in these establishments.
- Make pertinent recommendations for preventive action.

4.1. METHODOLOGY

This assessment is based on the following sources of data:

1) Identification of establishments from the *Surveillance médicoenvironnementale de la santé des travailleurs* data files (SMEST —medico-environmental surveillance of workers' health) and SIG (a management information system). The specific code for chrysotile asbestos (1305020) was used. Because of the dates these databanks were created, our identification of business establishments begins with the year 1994. Consequently, it is possible that some establishments were not enumerated, that is those covered by a *Programme de santé spécifique à l'établissement* (PSSE—a specific health program for an establishment), particularly when no update of the PSSE was planned after 1994.

2) A survey of physicians, in connection with the data pertaining to workers in situations where standards were being exceeded as well as the control measures implemented.

The survey was carried out among physicians in each business establishment, in February and March 1997. In June 1997, a follow-up was done to fill in the missing information. At all the establishments identified, physicians had to fill out a data compilation sheet to report the presence of workers whose measured or estimated exposure exceeded standards, at the time of the survey and over the five preceding years. A specific section addressed the corrective measures instituted, when workers' exposure exceeded standards, up to the time of the survey.

3) A consultation of environmental data available in the *PSSE* to identify operations presenting an exposure risk and the exposure levels.

In all establishments where workers' exposure was identified as exceeding standards, pertinent data in the *PSSE* were reviewed, including in particular the levels measured, the procedures or operations at risk, the recommendations for controlling exposure, and when available, the implementation of these measures within the establishment. These data were reviewed by a physician and when necessary by a hygienist.

4) Data validation

The summarized information and accompanying conclusions were presented to the physicians in charge to ensure that the situation was depicted correctly. This last step of the survey took place from September 1997 to December 1997. To complete the analysis in cases where the presented data required explanations, specific questions were addressed to some of the physicians, by telephone or during a meeting.

4.2. RESULTS

In all, 29 establishments were identified from the databanks cited (Table 1). Establishments in the building and public works sector were excluded, due to the particular situation of this category (no industrial process that involves asbestos fibres).

One establishment coded 4252 in the *Classification des activités économiques du Québec* (CAEQ—an industry classification system) was eliminated due to the nature of its activities, which could be considered comparable to the exposure found in the building and public works sectors. Data were incomplete for one other establishment. We note the relative importance of the Transportation Equipment Industry (notably the Motor Vehicle Wheel and Brake Industry (CAEQ 3255), since it involves 6 establishments, and the Fabricated Metal Products Industry (CAEQ 3011, 3059, 3081, 3099), which involves 5 establishments. These CAEQ codes represent close to 40% of the establishments identified.

As for other activity sectors, we find a wide range of industries in which asbestos use is possible. For example, the Railroad Rolling Stock Industry (CAEQ 3261 in which workers' exposure, until the beginning of the 1990s, was mainly a result of repair work on asbestos-insulated ducts present in railway cars. A similar situation applies to the Shipbuilding and Repair Industry (CAEQ 3271), due to the application of asbestos-based insulation in ships. Even though the number of workers is small, the Non-Metallic Mineral Products Industry (CAEQ 3592) should not be ignored due to its production of various asbestos-containing gaskets. The same is true for the Adhesives Industry (CAEQ 3792), where asbestos may enter into the composition of various adhesive tapes or sealants.

In the case of the Food Industry (CAEQ 1099), no direct use of asbestos is described in processing: exposure was linked to incidental work on piping. The same situation prevails in the case of the Primary Metal Industry (CAEQ 2971) for pipe fitters. After validation, it was discovered that code 4591 represented mistaken identification of the contaminant. For codes 3241 and 6355, asbestos exposure is linked to accidental exposures during mechanical work and is not linked to processing as such.

Processes in which there is exposure risk

The compiled data from the survey indicate that potentially problematic situations, with respect to standards being exceeded, were confirmed in 7 establishments, which represents a considerable proportion (23%). Specifications for these establishments are summarized in Appendix 4. We should point out that the Brake Pads Industry (CAEQ 3255) seems to be a problematic sector, representing 3 of the 7 establishments identified. In addition, the size of the population potentially exposed is relatively large, about 400 to 500 workers.

Also, according to the details of the processes summarized in Appendix 4 and the environmental data gathered, several steps in the manufacturing process appear to be potential sources of exposure, which complicates the introduction of control measures. In addition, there is evidence of a widespread contamination of these plants due to the dissemination of asbestos, even in areas far from asbestos processing.

Table 1 Distribution of establishments by economic sector and total number of workers

Large classification group	CAEQ[1]	Number of establishments	Total number of workers
Food Industry	1099	1	45
Rubber Products Industry	1599	1	8
Primary Metal Industry	2971	1	383
Fabricated Metal Products Industry	3011 3059 3081 3099	1 1 2 1	67 55 53 50
Transportation Equipment Industry (Wheels and Brakes)	3255	6	803
Truck and Bus Body and Trailer Industry	3241	1	20
Railroad Rolling Stock Industry	3261	2	1728
Shipbuilding and Repair Industry	3271	3	91
Non-Metallic Mineral Products Industry	3592	2	21
Chemical and Chemical Products Industry	3712	1	10
Other Storage and Warehousing Industries	4799	1	50
Retail (Motor Vehicle Transmission Repair)	6355	1	15
Adhesives Industry	3792	1	70
Corrugated Box Industry	2732	1	238
Highway, Street and Bridge Maintenance Industry	4591	1	450
Total		**28**	**4157**

[1] Classification des activités économiques du Québec

The other establishments are distributed as follows:

- manufacture of asphalt products and roofing materials;
- fabrication of gasket linings;
- manufacture of asbestos products;
- manufacture of adhesives and caulking.

We observe that workers' exposure in these latter establishments, unlike the situation in brake manufacturing, is more limited at the processing level, and occurs mainly during manual debagging of asbestos, during mixing with other products, or during shaping (cutting, drilling).

Exposure levels

Given the exposure data obtained at different periods (from the end of the 1980s to the end of the 1990s), the limited sampling periods, and the missing data for some occupations, caution should be exercised in interpreting the exposure levels taken from environmental reports. For all these reasons, the estimation of the number of workers in situations where standards are exceeded is only approximative.

The same limitations apply to the conclusions presented regarding compliance with standards (short term exposure value (STEV) and time-weighted average exposure value (TWAEV) based on the professional judgment of a physician or a hygienist. Despite these limitations, to judge by the levels measured at several stages of the friction material manufacturing process, there is a strong possibility that the TWAEV is being exceeded in several of the work stations evaluated, despite improvements made to point source ventilation.

For the other establishments in which levels were documented, it appears that over-exposures are more sporadic and limited particularly to previously described operations of manual debagging, mixing, and shaping (cutting, drilling) of asbestos.

Prevention measures introduced

Medical surveillance

All workers potentially exposed to asbestos undergo periodic medical surveillance that basically complies with regional guidelines (1). It is interesting to note that according to the collective assessments made, no worker was identified as presenting radiological abnormalities compatible with asbestosis. This situation is explained in part by the long latency period of the disease and the high rate of labour force turnover typical of certain establishments.

At the same time, it is reassuring to observe the efforts expended by the occupational health services network to contact all exposed workers, including workers exposed in the past, who have expressed concerns. We also observe that doctors tend to include workers in surveillance programs if there is any doubt about exposure levels. This remark applies in particular to establishments in which exposure is difficult to quantify (ship repair, pipe fitting).

Environmental surveillance

The vast majority of identified establishments are covered by an environmental surveillance program, run by occupational health teams. In three cases, the program is run by an external organization.

Unlike the situation with medical surveillance, we observe variability in the assessment methodology followed, particularly with regard to the choice of occupations targeted for evaluation and the duration of sampling. Because of these factors, conclusions regarding compliance with standards and the number of workers exposed are limited.

Respiratory protection

According to survey responses and analysis of health programs for the establishments, the vast majority of establishments provide at-risk workers with respiratory protection equipment. However, little data is available on the conformity, use, or maintenance of this equipment. Moreover, according to anecdotal reports based on direct observation of workers, workers do not make optimal use of the equipment while carrying out at-risk tasks. Several establishments have also offered information and training sessions on respiratory protection, but this activity is not uniformly implemented.

Information on the risks to health

Training and information activities for workers have been conducted in all establishments where standards were exceeded, as well as in the vast majority of establishments where asbestos has been identified. For some establishments with large staff turnover, keeping up-to-date lists of adequately trained and informed workers is obviously more difficult to achieve.

Intervention of the CSST inspection service

Three of the seven establishments in which workers were exposed to levels that exceeded the standards were referred to the CSST inspection service.

Work methods / general maintenance of premises

Occupational health teams made several recommendations, particularly for establishments where workers were exposed to levels that exceeded the standards. Inappropriate work methods were identified (inappropriate use of asbestos to absorb spillage on the ground), as well as deficiencies in ventilation, personal protection (absence of protective outer clothing, absence of double change rooms, absence of respiratory protection), and maintenance of the premises (inappropriate cleaning and waste disposal methods). For some establishments, occupational health teams uncovered a problem of generalized contamination in several departments, even those far from production zones (airborne fibres). Specific recommendations were made for several workstations following the discovery of deficiencies in the ventilation system.

Point source ventilation

We noted that in establishments that possess this type of ventilation, efficiency of ventilation was variable and poorly documented. Some industries were in the planning stage to introduce modifications. Judging by the slow introduction of this measure over the last ten years, according to comparative data taken from environmental reports, we are led to conclude that plants have experienced technical difficulties in introducing this control measure. In addition, although it is present in many establishments, the assessment of its efficiency is still a matter of concern to occupational health teams.

Other establishments in which exposure is considered below standards

In 20 establishments, survey responses showed no workers currently in situations where standards are exceeded. After regrouping, these establishments can be classified as follows:

- ***Establishments that have abandoned the use of asbestos***

Two (2) establishments abandoned the use of asbestos, one involved in replacing railroad rolling stock brakes (discontinued use of asbestos-containing brakes) and the other involved in manufacturing electrodes.

- ***Establishments that have sub-contracted***

One (1) of these establishments dismantled brakes. The other sub-contracted the repair of asbestos-containing railway equipment to a specialized firm.

- ***Establishments that have controlled exposure by ventilation***

One (1) establishment, manufacturing friction material, incorporated an efficient ventilation system while renovating the plant.

- ***Establishments in which workers have intermittent accidental exposure***

In four (4) establishments, difficulties were encountered regarding the assessment of environmental exposure, according to comments by the occupational health teams. The situation in this category is similar to that in the building and public works sector. Two of these establishments repair ships. In the two others, exposure is similar to that of pipe fitters on construction sites.

- ***Asbestos exposure unrelated to industrial processes***

This category groups the establishments in which workers' exposure is caused not by the presence of asbestos in processing, but by its presence in the general environment (in walls, ceilings, or pipes). In general, this is accidental exposure linked to repairs to the building structure (1 establishment) or to unplanned work on asbestos-based products (1 establishment).

- ***Establishments that have had workers in situations where standards were exceeded over the past 5 years***

Here again, three (3) establishments producing friction material are found in this category. According to the comments of the physicians in charge, in most of these establishments, improvements to the ventilation of some workstations were under way. For one other establishment, the occupation identified as presenting exposure risk involved brake dismantling.

- ***Exposure judged to be well controlled***

In one (1) case, after environmental assessment, exposure seemed well controlled.

- ***Incomplete data***

For two (2) establishments, data were incomplete.

- ***Contaminant wrongly identified***

In two other cases, the physician decided that the contaminant was incorrectly identified.

4.3. DISCUSSION

Limitations of interpretation of results

Completeness of data

One of the main limitations of this descriptive study is that the search for target establishments was limited to economic activity sectors of priority groups I, II and III, covered by the application of the Act Respecting Occupational Health and Safety. This means that the establishments carrying out asbestos processing, as primary or secondary activity, and belonging to groups IV, V and VI could not be identified. Despite this limitation, it remains plausible that the major asbestos processing activities are found in the 15 activity sectors covered by priority groups I, II and III, if we refer to the processing activities described in the literature; textiles would be a notable exception (2). Consequently, this assessment may be considered relatively exhaustive with the exception of asbestos processing in textile products.

As mentioned above, the databank searches cover data compiled from 1994 on, relating to characterization visits to establishments and the development and updating of specific health programs. However, given that these establishments have been covered since the application of the Act Respecting Occupational Health and Safety, that is, for more than 10 years, and that updates are planned every three years approximately, it is unlikely that this factor could result in a sizeable exclusion of establishments. Nevertheless, some error in identifying establishments might persist if the contaminants were not identified or were incorrectly classified in the databanks. Without minimizing these sources of error, we should not consider them a serious problem due to efforts in recent years to validate and update the data in these banks.

Validity of environmental data

The present descriptive study is based on environmental data collected in connection with activities related to the initial development or the updating of specific health programs within the establishments, according to the mandate given by virtue of the Act Respecting Occupational Health and Safety. In this context, the goal of these activities is not to rule on compliance with standards, but rather to make a semi-quantitative assessment of exposure levels. It is therefore difficult to draw conclusions about the extent of compliance or non-compliance with standards (proportion of workers whose exposure exceeds standards, proportion of workstations or occupations in which standards are exceeded), both within each establishment and in the set of establishments targeted by the study. This would require an environmental strategy adapted to such objectives, notably sampling times covering a greater proportion of work shifts to take into account the daily variability of exposure and a more systematic selection of occupations to be evaluated. These limitations may create errors in classifying establishments in terms of time-weighted average exposure value (TWAEV), particularly in cases where values are close to the TWAEV.

Another difficulty arises from the fact that the data collection frequencies differ, making it difficult to establish an up-to-date profile. In general however, data from the last three years were available for each target establishment, due to the periodic updates of specific health programs.

Analytical methods complied with the sampling methods proposed by the *Institut de recherche en santé et en sécurité du travail Robert Sauvé* (IRSST) and fibre count was done by phase contrast optical microscopy (3).

Importance of processing industries

Notwithstanding the reservations expressed above, the present study sheds light on the importance of the use of chrysotile asbestos in the friction products industry in the Montréal-Centre area where 6 establishments carry out industrial activities related to this industry. These findings differ from those reported elsewhere in the world where asbestos is still used mainly in the asbestos-cement industry (84%) followed by the friction products industry (10%) (2).

In all, we estimate the workforce to be 800 workers.

Industrial processes presenting exposure risk and sources of exposure

Because of its physical properties, asbestos remains an important basic material in the manufacture of friction products, particularly brake pads. Data from the present study indicate that despite the introduction of substitutes, including fibreglass and certain metal-based resins, at least one third of production in Montréal friction material plants still uses asbestos, particularly chrysotile. The process for manufacturing brake pads dates to the turn of the century and involves several steps. There is a significant potential for release of asbestos fibres in initial handling and mixing operations, and particularly during finishing operations such as cutting, moulding and drilling (4). The environmental data presented in specific health programs, and the observations of occupational health workers tend to confirm these observations. In addition, the characteristics of the process to effectively control emission sources clearly impose technical challenges in terms of point source ventilation, which may in part explain the difficulties encountered in some plants.

The manufacture of asbestos-based adhesives, caulking, roofing, and gaskets also involve operations presenting exposure risk, which are described in the present report. Unlike the situation in the friction products industry, fibre emission is more limited to the initial operations of transferring and mixing raw materials, industrial processes that involve less shaping.

Significance of current exposure levels

Exposure levels linked to the operations described above were documented in a hygiene study with reliable methodology (5). For grinding and sanding finishing processes, the authors reported dust concentrations of the order of 20 to 50 f/cc, and for cutting, turning, reaming, and drilling, fibre concentrations of approximately 8 f/cc, when the operations are performed without point source ventilation. In this study, the authors also reported concentrations of approximately 20 f/cc during bag opening, fibre mixing, and cleaning up waste materials on the ground and work surfaces and 8 f/cc during parts inspection and labelling.

This study also documented the effectiveness of control measures introduced in the factory_over a period of 60 years. During the 1950s and 60s, local exhaust ventilation used for grinding and finishing processes, as well as the creation of separate departments, made it possible to reduce concentrations from 50 f/cc to approximately 10 f/cc. At the beginning of the 70s, additional measures related to dusting (vacuum cleaning prior to examination for quality control and labelling), isolation of fibre mixing and weighing in a ventilated enclosure, the increasingly widespread use and improvement of local exhaust ventilation (including for labelling, quality control, and all finishing machines) allowed the factory to meet the requirements of the time-weighted average exposure value (TWAEV) of this period in Great Britain, a maximum concentration of 2 f/cc, in close to 100% of the jobs documented during hygiene studies conducted periodically in this plant.

Bouige carried out an international investigation of the level of compliance by industry of the 1 f/cc exposure limit (6). He reported that for friction material manufacturers, 97% of his sample met this limit.

Bearing in mind the limitations mentioned above concerning the environmental samplings that were examined for the present assessment, exposure levels reported for this type of industrial establishment are comparable to those reported by Skidmore and Dufficy, that is, for the vast majority, below 2 f/cc. But unlike these authors, we note the persistence in certain establishments of sporadic problems of exposure control, particularly during certain finishing operations such as sanding, grinding, riveting, and drilling. However, substantial variations are observed in the levels reported between establishments, particularly those producing brake pads; one establishment with new installations meets legal requirements but at least 3 do not meet the TWAEV requirements of 1 f/cc for some jobs; in two other cases, control problems of control have been reported during the last 5 years. These variations require more exhaustive research so we may better understand the control difficulties reported.

With respect to the situation reported in the other asbestos processing industries, these being the manufacture of asbestos-based roofing materials, gasket linings, adhesives, and caulking, problems of over-exposure seem to be limited more to operations involving bag opening, pouring, and mixing.

Finally, we find that exposure levels are difficult to quantify in some cases, particularly for industrial activities linked to the repair and maintenance of ships and railroad rolling stock, maintenance of motor vehicle brakes, and work on asbestos-based construction material (particularly the cutting, fitting, maintenance, and installation of asbestos coverings on pipes). Although intermittent, significant accidental exposures may occur in these establishments and should be better documented.

Significance of health risks

The effects linked to exposure to asbestos fibres are well known and a causal relationship is generally accepted for asbestosis, pleural plaques, visceroparietal pleural reactions, pulmonary cancer, and mesothelioma (2). Due to the transversal nature of the data presented and the fact that several of these conditions are dependent upon the intensity and duration of exposure, or have a relatively long latency period, it is difficult to quantify the significance in terms of morbidity and mortality of exposures documented in the present study. The physicians in charge also emphasized these limitations as they collectively assessed the results of the screening. These gaps are filled in by data from cohort studies, particularly those of Berry, Newhouse and Sullivan (7,8). These authors analyzed the mortality over a period of 46 years of a cohort of 13,450 workers from the friction materials industry, which used chrysotile asbestos, except for two brief periods before 1944 when crocidolite was used. Exposure conditions in this industry were well documented and quantitative data were available (5). In their analyses, the authors took into account a latency period of at least 10 years after initial exposure. Three cases of death from asbestosis were reported in this cohort, among workers with a long history of career exposure; for deaths caused by cancers of the lung and the pleura, a SMR (Standardized Mortality Ratio) of 108 for men was reported, but did not reach the statistically significant threshold (SMR 108; 90% confidence interval from 97-120). When analyses take into account the hiring date, a cohort effect is evident and SMR for workers who started before 1940 reaches statistical significance (SMR 153, 90% confidence interval from 116 to 190 among men). Thirteen deaths are attributable to mesothelioma: 11 of these deaths occurred among workers who had worked during the periods when crocidolite was used. It is important to note that the cumulative exposure of this cohort is relatively low: one third of workers were employed in this industry for less than one year; also, the exposure control measures that began to be implemented in the 1950s generally reduced exposure to 0.1 to 1 f/cc, except in certain production zones (2-5 f/cc), right up to 1969.

In any case, these results support the effectiveness of reducing exposure levels to at least current standards, particularly for the prevention of asbestosis (9). Berry presents a review of other specific studies on friction materials; due to methodological limitations, it is more difficult to interpret the conclusions of these studies, but they do not show evidence of mortality attributable to occupational exposure (10).

For the pulmonary cancer risk, estimates from studies of the cohort of processing industry workers exposed to chrysotile asbestos predict that for a daily average occupational exposure of the order of 1 f/cc, with a career exposure of 20 years, the risk of developing a pulmonary cancer would be of the order of 2 to 34 per 1000 workers exposed, assuming a conservative linear model, with no threshold (11). The risk is considerably higher among smokers (2). For the mesothelioma risk, recent epidemiological data support a steep gradient for this type of fibre, the risk being considerably higher for amphiboles or mixes of amphiboles with chrysotile (12). Due to the absence of a clear relationship between exposure levels and occurrence of this type of cancer, it is difficult to estimate the long-term impact of current exposure levels (12).

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5. THE MINING INDUSTRY

(Alice Turcot and Luc Roberge)

Fibre concentrations in asbestos mines have decreased markedly since the 1980s, attesting to a cleanup of the work environment and a constant effort toward source reduction. As a result of union battles and the tightening of regulatory standards, workers' exposure to asbestos in mines has diminished greatly. Camus reported that between 1891 and 1980, asbestos fibre emissions and fallout were visible outside of mines (1).

According to management, the situation has progressively improved since 1974, when scientific studies were conducted by Dr. McDonald and Dr. Selikoff. And, as Dr. Monique Rioux of the *Direction des services médicaux de la CSST* states: *"During the years 1970-1975, the strikes that paralyzed production in the asbestos mining region fostered a greater abundance of information on the working conditions prevailing in the mines. Union demands concerning standards of hygiene, media interest, and political events, all created a climate conducive to awareness of the dangers inherent to exposure to asbestos fibres. This awareness was translated into action in June 1975 with the approval of the Act Respecting Indemnities for Victims of Asbestosis and Silicosis in Mines and Quarries (Act 52), with the setting up of the Comité d'étude sur la salubrité dans l'industrie de l'amiante (Beaudry Commission—commission of inquiry into health and safety conditions in the asbestos industry), and with an order-in-council that required, as of January 1, 1978, compliance with the standard of five fibres per cubic centimetre in an eight-hour average concentration"* [Translation] (2). Thus, collective efforts were undertaken in 1975 to clean up the work environment through a tripartite collaboration among union, management, and government representatives.

5.1. MINEROLOGY

Asbestos possesses unique physical and chemical properties such as fire resistance, low thermal and electrical conductivity, and resistance to micro-organisms. In addition, the tensile strength of chrysotile and crocidolite fibres is comparable to that of steel.

Asbestos is classified into two groups, serpentines and amphiboles. Chrysotile is the only fibrous variety of serpentine. However, there are several types of amphibole fibres such as crocidolite, amosite, anthophyllite, and the tremolite-actinote series. Worldwide, asbestos production is estimated to be 95% chrysotile fibres.

The chemical formula for chrysotile is $2Mg_3Si_2O_5(OH)_4$. It is composed of 38% to 42% silica (SiO_2), and 38% to 43% magnesium oxide (MgO) while amphiboles are chiefly composed of 50% to 60% silica (SIO_2), 2% to 40% FeO, and 1% to 18% Fe_2O_3. Magnesium oxide (MgO) content does not exceed 30%. Tremolite and anthophyllite contain the most magnesium.

In Quebec, chrysotile is found mainly in the area of the towns of Asbestos and Thetford Mines. The most common minerals associated with asbestos in these regions are carbonates (magnesite, dolomite, calcite, aragonite, brucite, picrolite, and magnetite) and phyllosilicates (talc, phlogopite, and antigorite). Occasionally, traces of actinolite, tremolite, and riebeckite are found.

Finally, tailings are composed of antigorite, chrysotile, magnetite, and iron oxide (3).

The procedure for sampling asbestos dusts is the same whether it involves chrysotile or amphibole fibres. However, as we will see, standards for permissible concentrations differ depending on fibre type, given the different health risks these fibres represent.

5.2. STANDARDS

Under the Regulation Respecting the Quality of the Work Environment (RQMT, S-2.1, r.19.01), the standards for permissible exposure values have been progressively tightened over the years. Thus, in the 1970s, the maximum allowable concentration (8-hour time-weighted average) was 5 f/cc by optical microscopy. It then dropped to 2 f/cc.

Since the 1990s, the average permissible concentration for chrysotile is 1 f/cc or the time-weighted average exposure value (TWAEV), and the 15 minute short term exposure level (STEL) is 5 f/cc.

The TWA and the STEL for crocidolite and amosite are respectively 0.2 f/cc and 1 f/cc. These concentrations are for asbestos fibres longer than 5 micrometres measured by phase contrast optical microscopy.

5.3. SAMPLING

Hygienists collect asbestos fibres in mines according to the sampling strategy accepted by the members of the health and safety committee. It is worthwhile to review the equipment used in the past and at present as well as the different elements of the sampling strategy.

Measurement equipment

Until the beginning of the 1970s, sampling was done with the midget impinger. This instrument was widely used to trap dusts. It was then replaced by membrane filters. With the midget impinger, dusts were drawn into an impinger containing water or alcohol and the particles were suspended in this liquid. Then, the liquid was placed on a slide and particles were counted through a microscope. This method was considered adequate at the time, but it was criticized by various scientists who believed that it gave imprecise results, that it was not an ideal method, and that it was inadequate for trapping dusts (3).

In 1972, mining companies began using the membrane filter assessment method. In 1988, the members of the IRSST program "*Hygiène et toxicologie*" (hygiene and toxicology) developed an analytical method, and since the early 1990s it has become the benchmark in Quebec. This method (243-1) is used by hygienists in the mining industry. They are responsible for sampling, analysis, and various related reports. The principle of this method is to draw a volume of air through a mixed cellulose ester filter to collect fibres in accordance with a standard method. The method includes a sampling guide and describes different aspects, such as the sensitivity of the method, possible interferences from any other airborne fibre, precision and exactitude of the method, analytical protocol, fibre counting, calibration of reading instruments, and the intralaboratory quality control program for fibre counters.

The industry also used another type of instrument, the RDM-101, to determine ambient air concentrations. This instrument gave results in mg/m^3 and was used to determine concentrations of respirable dusts by direct reading. It was mainly used to detect dust emissions in mill environments and also served as an indicator that better samples should be taken with membrane filters. It has not been used since 1990 because it did not meet the requirements of the Regulation Respecting the Quality of the Work Environment.

Another direct-reading instrument, the Anderson PM10, is used within a factory's air return filtration system. This non-portable instrument serves to evaluate respirable dust in the ambient environment and gives a reading in mg/m^3. It is permanently located within the filtration system. According to the Regulation Respecting the Quality of the Work Environment (RQMT, S-2.1, r.15, Schedule A, Part 11), the threshold value for dust concentration must be less than 0.1 mg/m^3.

Thus, companies have everything they need to be able to assess the work environment and carry out an adequate surveillance of workers' exposure to asbestos fibres.

Sampling strategy

Currently, mining companies use a sampling strategy accepted by the members of the health and safety committee. At LAB Chrysotile, the objective of this strategy, adopted in 1990, is to obtain a uniform sampling policy for all operations with the following basic goals:

1) Permit methodical assessment of exposure of workers exposed to asbestos dust.
2) Ensure the best air quality control methods are upheld in the operations.
3) For the longer term, permit uniformization of sampling methods in the asbestos industry.

LAB Chrysotile uses three types of sampling: personal, walk through survey, and fixed (stationary). A personal sample is taken in the breathing zone of a worker. Walk through surveys take place in the breathing zone of a company's industrial hygienist; these walk through surveys sample dust quantities present on an unchanging route the hygienist follows through the mill, year after year. This sampling is not part of the regulations and there is no standard for this type of sampling.

The duration of personal sampling is two hours for mainly sedentary workers and four hours for those who perform a variety of tasks, and includes breaktimes and mealtimes. To calculate exposure, the time-weighted average for an 8 hour period is distributed as follows: 6 1/2 hours at the concentration of the work environment and 1 1/2 hours of various ordinary activities at work calculated at the concentration of the lunch room. When the maximum allowable concentration is exceeded in sampling periods, the total time that standards were exceeded is calculated and this maximum value is recorded. Workers' exposure is assessed on the basis of affiliation with a job class. Two workers are sampled annually in a group of 25 workers or less (minimum of 1) and 10% are sampled in groups of over 25 workers.

The third type of sampling involves taking samples of dusts at representative locations within a single zone to learn the level of dust from a geographic standpoint. Since these measurements have been well documented statistically for many years, surveillance of the work environment is based more on personal sampling. However, fixed samples are taken sporadically to assist in determining the precise location of dust sources. Duration of these samplings is two hours, except in operation zones or underground development zones where work duration is less than 2 hours per half shift.

The aim of the sampling strategy is to measure the working conditions that are present on sampling days. It is not a question of looking for worst-case scenarios; nevertheless, if a measurement is above the permissible standard, notations are added to the analysis of results. All measurement results are compiled. When results are elevated, the company implements localized corrective or preventive measures if a leak, a break, or unsatisfactory working conditions are identified.

Results are compiled annually and allow the company to evaluate the progress made in the mine.

At JM Asbestos, the objectives of the sampling strategy are the following:

1. Formulate a strategy that will rationally assess workers’ exposure to asbestos dust in order to determine if standards are being met.
2. Set up a method for compiling and presenting annual results that will be easy to understand and will allow comparison to be made with the results of subsequent years.

The aim of the strategy is to react quickly to correct a situation at a personal or fixed workstation when standards are exceeded.

In general, the number of employees sampled in each job class varies according to the number of employees holding this classification in the department (or section) and according to the potential exposure of these employees. It is suggested that 20% of workers in a job class be sampled. This percentage may be adjusted when justified. For example, it may be increased if employees in this class are potentially exposed to high concentrations of asbestos fibres.

There are personal samplings that represent a normal workday in which sampling duration varies from two to four hours or from four to eight hours, depending on the stability of exposure and hygienists’ knowledge of the work environment. Samplings to assess maximum fibre concentration are taken if dust exposure is variable and the hygienist considers it pertinent to determine maximum concentration. In this strategy, samplings with a duration of two to four consecutive hours are not monitored continuously in the field because an employee’s exposure is constant. Occasionally, this type of sampling may be monitored in order to do a detailed check to see if the conditions, methods, and equipment have been modified. Samplings of four to eight consecutive hours are not systematically monitored if the hygienist believes that previous samples confirmed that the employee was not exposed to levels close to maximum concentration.

To calculate the average concentration over eight hours, if the sampling period faithfully represents a normal workday, we assume that exposure during the periods not sampled is equal to the time-weighted average concentration in relation to the period sampled. If the period does not faithfully represent a normal workday, the eight-hour time-weighted average will be equivalent to the value measured for the time sampled and to the value equivalent to mealtime or breaktime in the rooms provided for these purposes.

Short-duration samples are also taken if the concentration of asbestos dust where an employee works is variable. Hygienists determine the need for this test.

Finally, fixed samplings make it possible to check the level of dust in representative locations where a considerable number of person-hours are worked. All fixed sampling stations are sampled once a year. However, if the result for a year is less than one quarter the normal, this station may be sampled once every two years at minimum.

Fibre counting

Fibre counting is performed in mine laboratories by qualified personnel who have many cumulative years of experience. There are several counting rules that govern the reading and counting of fibres. They are described in IRSST Method 243-1. Counters must count only fibres with a diameter less than 3 μm and a length greater than 5 μm. They must also measure bent fibres taking into account their curvature to estimate total length. In addition, they must count only fibres with a length: diameter ratio greater than three (L:D > 3:1).

Counts higher than 1,300 fibres per mm^2 and counts of fibre samples in which more than 50% of the filter surface is covered with particles must be reported as “not countable” or “probably biased.” This method does not allow morphological differentiation of fibres. Even though experienced counters are able to selectively differentiate various types of fibres, there is currently no accepted method that ensures uniformity of interlaboratory evaluation. Therefore, all laboratories using this method are required to report the total number of fibres counted. If serious contamination by fibres other than asbestos occurs in the samples, other techniques such as transmission electron microscopy and polarized light microscopy must be used to identify the fraction of asbestos fibres present in the sample (4).

Quebec has a quality control program for the counting of airborne fibres. The IRSST undertook the implementation of this program. Two regulations, the Regulation Respecting the Quality of the Work Environment and the Safety Code for the Construction Industry, govern the standards to be complied with to ensure workers’ protection. These regulations require regular samplings to be taken, based on the IRRST sampling guide, as well as a counting method using optical microscope (243-1). Given the wide variation in results, it is important to ensure the quality of the fibre count.

Variations come from sampling (representativeness, condition of sample, value of sampling, distribution of fibres on membrane) and from the laboratory (handling, preparation of samples, counting). Due to statistical limitations, there can be a 30% variation in the coefficient of variation. This is the reason the program was introduced. All laboratories must take part in the quality control program.

In the mining industries, LAB Chrysotile (5) and JM Asbestos (6) take part in this program. All participating fibre counters are classified by comparing their results with the mean count. Counters are informed of their performances.

5.4. RESULTS

Exposure levels before 1975

It is difficult to determine the exact concentration of asbestos dusts to which workers have been exposed. According to the report of the *Comité d'étude sur la salubrité dans l'industrie de l'amiante (*a working committee on health in the asbestos industry): "*Until recently, measurements of dust levels in the asbestos industry were effected by counting dust particles in ambient air. The unreliability of this method for measuring dust is well established. Moreover, it is important to be aware that dust particle counts did not reflect the actual quantity of asbestos contained in the dusts. This means that, for a single count of 2,000,000 dust particles per cubic foot of air, one individual could have been exposed to a very small quantity of asbestos dusts while another individual could have been exposed to a substantial quantity of asbestos dusts.*" [Translation] (3).

According to Liddell et al. (7), beginning in 1974, net improvements were observed throughout the asbestos industry with respect to the concentrations of asbestos dust recorded, only 4% of men working in concentrations greater than 5 mppcf (million particulates per cubic feet). A few years later, low concentrations were reported in almost the entire mining industry. However, we must take into account that the average worker started in 1929 at very high average dust levels that, in 1953, were still around 50 mppcf (8), which is equivalent to 175 f/ml[4].

Gibbs and Lachance described the situation in chrysotile mines for the years 1950 to 1975 (8). The *Comité sur la salubrité dans l'industrie de l'amiante* commented: "*If we look at the curve of average dust levels during the last twenty years, we observe that dust level has not substantially diminished since 1965 and this date coincides with the enactment of the first standards*" [Translation] (3).

Exposure levels in the years 1975-1977

As part of operation "Blitz d'amiante" [asbestos blitz] in 1975-1977, led by King, Beaver, and Bell Asbestos Ltd mines, the situation with respect to working conditions was evaluated following an interministerial committee request. Data obtained at different workstations showed that exposure levels at the time were higher than the current standard at the time and that some tasks generated more dusts to which workers were exposed.

Sampling levels in the years 1978-1997

From 1978 to 1989, sampling procedure (Method 47-1) conformed to procedures established by OSHA. Since 1990, asbestos fibres counts are carried out according to analytical method 243-1. The standard is now 1 f/cm^3 for chrysotile.

Committee members were able to obtain the annual results of personal samplings taken during the years 1969 to 1997 for JM Asbestos, 1980 to 1997 for the operations at the Black Lake mine, and 1985 to 1997 for the Bell mine. Results from the years 1988, 1990, and 1997 were extracted for analysis.

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[4] Liddell et al. estimated a factor of 3.5 fibres/ml for each mppcf (7).

Bell Mine Operation

Bell mine was closed in 1988 following internal restructuration of LAB Chrysotile operations.

In 1990, asbestos concentrations measured for the various job classes were below the standard of 1 f/cc. Certain tasks exposed workers to greater dust concentrations, according to remarks written in the annual reports. For example, we find the following remark for the occupation *floorman*: dust produced while changing screens (3.51 f/cc) or again for *bagger* (1.69 f/cc): dust during bagging; for *ore dryer operator* (2.14 f/cc): adjusts supply trucks and unblocks pipe in the dust control system of the rock supply.

In underground operations, *mining-machine operators* were below standards, three mounted percussion drill operators were below standards while 2 miners who used a jackleg drill at level 1450-07 exceeded standards and were between 5.36 f/cc and 5.20 f/cc. Other drillers who used a jackleg showed values of 0.73 f/cc and 0.63 f/cc.

The work procedures of these miners involved flushing drill holes with water, with or without wetting surfaces beforehand, both for elevated and low values. “Ventilation nil” is noted for the value 5.20 f/cc and “ventilation nil or negligible,” for a value 1.11 f/cc. Consequently, it is difficult to postulate on the factors influencing the exceeding of standards. In all, during the year 1990, of a total of 44 personal samples, 15 positions in which standards were exceeded were noted with the relevant remarks.

In 1997, the annual report showed that the set of job classes (n=44) sampled was below the standard of 1 f/cc. Nine samples relating to six job classes were above the standard. For example, the jackleg driller working on a very poorly ventilated workface was at 1.27 f/cc. The vacuum operator (good housekeeping) who vacuum cleans various equipment, seals leaks with mastic, empties hoppers and transports this waste to the wheel barrow skip, and vacuum cleans traps located under conveyors showed values of 1.49 f/cc and 2.02 f/cc. *Truck drivers* who transport hopper waste to the dump showed values of 2.01 f/cc, 2.60 f/cc, and 1.14 f/cc.

Black Lake mine operation

In 1988, 40 personal samples were taken. Almost all the results were below the standard of 2 f/cc. Only one sample for a *blaster* was at a value of 2.17 f/cc.

In 1990, 69 samples were analyzed using analytical method 243-1. Fourteen results were above the standard of 1 f/cc. These were *floormen (*n=6), *industrial hygienist* (n=1), *mill operator* (n=1), *tester* (n=1), *mill labourers* (n=4), and *maintenance mechanic* (n=1). Notations in the report do not permit us to identify the causes for the exceeded standards. It was observed that employees generally used the respiratory protection means at their disposal.

In 1997, 142 personal samples were taken throughout the year. They were usually taken halfway through a workshift. Of this number, four samples were above the standard of 1 f/cc for the following occupations: *floorman* responsible for cleaning in conveyors galleries, *millwright* who performs maintenance work inside dust collectors, and *senior mill operator* who works to unclog various parts in the fiberizing equipment.

JM Asbestos

For the year 1988, 189 personal samples were taken as well as 66 fixed samples. Only seven samples exceeded the standard of 2 f/cc. This was in a normal work operation. The occupations or job titles were as follows: *good housekeeping at tailing sections, rotary drill operator, secondary drilling machine operator, main laboratory tester, labourers at mill No. 6, electrician in the mechanical shop*.

In 1990, 188 personal samples were taken and of this number 12 samples were above the standard of 1 f/cc. The following occupations were above this standard: *good housekeeping at tailing sections, locomotive operator (n=2), cabin brakeman (n=2), blaster assistant, industrial mechanic for mill No. 5 (n=2), carpenter for mill No. 5, sweeper for tower No. 5, conveyor labourer, mill labourer*. Eighteen personal samples assessing the maximum concentration were below the standard of 5 f/cc for duration of 15 consecutive minutes.

In 1997, 115 personal samples were taken and 8 samples were above the standard of 1 f/cc. Explanations referred to tasks such as repairing a conveyor belt, unclogging fibre lines, replacing hammers and wear plates in fiberizers, and repairing screen pans. The annual report also noted that the workers concerned would receive the training needed to understand the procedure involving the wearing of respiratory protection.

5.5. DISCUSSION

Preliminary analysis of exposure data (1988, 1990 and 1997) collected from the two mining companies shows that on the whole, the standard was respected for the different occupations sampled over the last 20 years. For the most part, personal samples from the various job classes remain below standards.

Analysis allows us to indicate the number of occupations in which standards were exceeded. Results that exceed standards are often related to certain precise tasks such as repairing screens, unclogging conveyors, or drilling underground. According to information provided by these companies, corrective measures were implemented to remedy unsatisfactory situations. In addition, respiratory protective equipment was provided to workers to ensure their protection.

From the numerous results in the annual reports, a wide variation in workers’ exposure can be observed for a single job position over different years. Consequently, it would be advisable to do a more in-depth analysis of the data already collected to obtain a profile of exposure by job class. Taking into account exposure variability and the statistical power required, this analysis would more precisely estimate real exposure and thus determine exposure risk by job class. From results in the annual assessments and over and above the analysis already provided (arithmetic mean), the analysis could also reveal data on general descriptive measurements such as measurements of dispersion (range, variance, standard deviation). This analysis might also permit us to determine the factors that make workers’ exposure vary and to readjust sampling strategy as needed. Current sampling strategy contributes very useful information to describe workers’ exposure. The number of workers sampled annually does not meet the guideline statistically determined as necessary for identifying conditions representative of workers’ exposure to a given contaminant, as defined in the IRSST sampling guide for air contaminants in the work environment.

Furthermore, it seems, upon checking with the industrial hygiene departments of Quebec companies, that they find it impossible to fully comply with the number of samples required by regulations or by specific programs involving certain contaminants such as noise, heat and so on. This is due to the lack of personnel in industrial hygiene and to the amount of work required to assess workers' exposure to certain contaminants. Current and previous analyses of many samples over the last few years suggest that the sampling done covered all working conditions encountered. Interpreting the data, with the help of statisticians and industry representatives, could make it possible to organize existing raw data into a set of measurements to describe exposure.

CONCLUSION

Workers' exposure is determined according to a sampling strategy approved by the members of the health and safety committee. Personal and fixed samples are taken annually under this strategy. Results indicate that on the whole, the standard is respected. However, we do not know if sampling volume meets application guidelines that are between 100 and 1300 f/mm^2 in analytical method 243-1. In densities below 100 f/mm^2, concentration is often overestimated in results while in densities above 1300 f/mm^2, fibre content tends to be underestimated.

In addition, we would have to verify whether these sampling volume parameters were respected for the results obtained, especially when this volume is very low. We would also have to verify whether a quality assurance manual and a written record of supporting evidence exist. This would allow us to ensure that the information and data pertinent to this quality control were collected. To obtain a more detailed profile of exposure by job class, more elaborate studies using existing raw data are indicated.

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6. THE OUTDOOR ENVIRONMENT

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This chapter discusses measurement of exposure of the general population to asbestos fibres in outdoor air. Since the subcommittee’s mandate was principally directed at exposure of the population in public buildings, our main focus was on airborne fibres. First, we summarize the scientific information available on fibre concentrations measured by currently accepted hygiene techniques in certain specific environments: background concentrations without occupational exposure, environments affected by point sources, mining towns, areas in the vicinity of asbestos waste, and asbestos-asphalt pavement sites. Second, we summarize the knowledge on the measurement of certain exposure biomarkers reflecting the presence of asbestos fibres in pulmonary tissue: asbestos bodies and fibre concentrations in tissues. Then, we assess the situation in Quebec and draw certain conclusions about pertinent follow-up actions.

6.1. BACKGROUND CONCENTRATIONS

Asbestos fibres are found not only in the workplace and public buildings but also in the general environment, either in the ground, water or air. However, outdoor concentrations are generally much lower than indoor concentrations. Sampling strategy must therefore meet certain specific requirements. Sampling must be done in sites representative of the population’s exposure. In addition, due to the low concentrations, sampling must be done over a relatively long period of time, from several hours to several weeks. Air sampling instruments are often placed at existing stations in areas that are fairly inaccessible to the public, such as building roofs or schools. Given the very low fibre concentration in the media sampled, we use transmission electron microscopy (TEM). Standardized laboratory methods are used, such as NIOSH Method 7042.

Chrysotile asbestos fibre is ubiquitous in the environment and levels have been almost constant for the last ten thousand years (1). Significant concentrations of chrysotile asbestos fibres have been measured in the Antarctic and in Greenland. Unless particular sources exist, airborne levels are generally higher in urban environments than in rural environments. In rural environments, in the absence of point sources, fibre concentrations in the air do not usually exceed 1 ng/m^3 or 0.00001 f/ml (2). Also, in rural environments few fibres are longer than 5 micrometers.

Higher concentrations have been measured in urban environments where the main sources are vehicle brakes, demolition work, and industries. Before 1980, spray-applied asbestos insulation for buildings was a significant source. Other sources are asbestos ore itself and open-air disposal sites.

Concentrations are higher when there are local emission sources. A review of 20 published studies was carried out for the United States Congress and re-examined by the Health Effects Institute (3). The great majority of concentrations measured in urban environments were lower than 10 ng/m^3 or 0.0001 f/ml. For example, Sébastien et al. showed that 99% of concentrations measured in Paris were lower than 7 ng/m^3 (4). Concentrations measured in Paris by the *Laboratoire d'étude des particules inhalées* (Laboratory for the study of inhaled particles) showed an average concentration for the years 1993-94 of 0.00013 f/ml, which represents a substantial decrease since 1974 (5) Results of various studies are reported in Table 2 (6). Concentrations up to 8,200 ng/m^3 have been measured by TEM in the vicinity of asbestos mines in large cities in the United States. In Great Britain, concentrations varying from 35 to 1,300 ng/m^3 were measured near asbestos mines and concentrations of 200 ng/m^3 were measured near waste dumps.

Table 2 Studies on asbestos fibre concentrations in outdoor air

STUDY SETTING	METHOD	RESULTS
Large cities in the United States	TEM	1 ng/m^3 - 10 ng/m^3 New York +++ (brakes) ↑ 8200 ng/m^3 vicinities of asbestos plants
Ontario: 5 localities, Metro Toronto, certain buildings	TEM	No "abnormal" situation
Green Bay, Newfoundland	TEM	24 f/l (avg.) (0.024 f/ml)
Netherlands	TEM	4 f/l (vicinity of an asbestos-cement factory) (0.004 f/ml) 3.6 f/l (in a highway tunnel) (0.0036 f/ml) 0.7 f/l (Amsterdam and Rotterdam) (0.0007 f/ml)
Germany	Scanning electron microscopy (SEM)	0.1 – 18 f/l (vicinities of asbestos-cement and friction materials factories) (0.001 – 0.018 f/ml)
Great Britain	TEM	< 4 ng/m^3 (avg. background concentration in urban environments) 35 – 1300 ng/m^3 (vicinities of asbestos plants) 200 ng/m^3 (vicinities of waste dumps)

Source: Sébastien et al, 1986

6.2. MINING TOWNS

Studies by the *Association des mines d’amiante du Québec* (Quebec asbestos mines association)

Since 1973, the *Association des mines d’amiante du Québec* (AMAQ), and the organizations that preceded it, have measured asbestos fibre concentrations in the ambient air of mining towns (7). Between 1973 and 1981 inclusively, sampling was generally carried out during the summer over a period of 6 hours at 2 litres per minute. Thirty-two sampling stations were used in five mining towns. Between 1982 and 1996, sampling flow rate varied from 390 to 1,050 litres/cm^2, depending on the year. Laboratory analyses were performed by phase contrast optical microscopy. Since 1982, transmission electron microscopy has been used. Mean concentrations in mining towns have decreased substantially, dropping from 0.076 f/ml in 1973 to 0.003 f/ml in 1996 (Figures 1, 2). In 1996, the mean concentration in mining towns measured by electron microscopy was 0.002 f/ml.

In 1997, as part of a sampling program, AMAQ carried out a study in three mining towns (7). Seven sampling stations were used in the towns of Asbestos, Thetford Mines and Black Lake. Sampling took place from June 2 to 12, 1997. The sampling period was 13.2 hours, from/between 8:40 a.m. to 4:45 p.m. at each station. A 25 mm Millipore filter was used, with a 0.8 micrometer diameter; flow rate was 5 litres per minute. Phase contrast optical microscopy was used in accordance with IRSST Method 243-1 and transmission electron microscopy in accordance with NIOSH Method 7402. Concentrations by electron microscopy were 0.004 f/ml in Asbestos, 0.004 f/ml in Thetford Mines, and 0.007 f/ml in Black Lake. The average for the three towns was 0.005 f/ml.

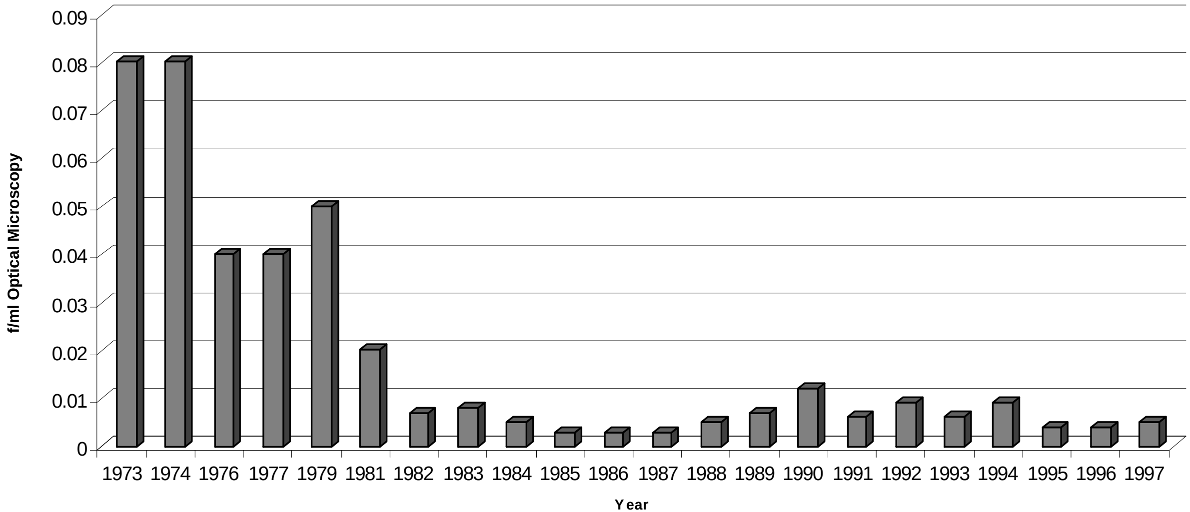
Survey by Environment Canada and the *ministère de l’Environnement du Québec*

A very detailed survey of ambient air asbestos in Quebec mining towns was conducted from 1983 to 1986 by Environment Canada in collaboration with the *ministère de l’Environnement du Québec* (5) This was a remarkably complete and thorough survey. New air sampling and analytical techniques such as transmission electron microscopy were used. It was the first survey of this scale in the field of atmospheric pollution related to asbestos.

The survey was conducted in three mining towns, Asbestos, Thetford Mines and Black Lake, as well as in two control areas, Montréal and Saint-Étienne. All of the sampling stations were installed at the centres of the mining towns and most often on the roofs of schools or other public buildings. In all, nine sampling stations were placed between 0.35 and 6.25 km from industrial sources of asbestos. During the survey, the *ministère de l’Environnement du Québec* continued to sample airborne particles in the area of these stations.

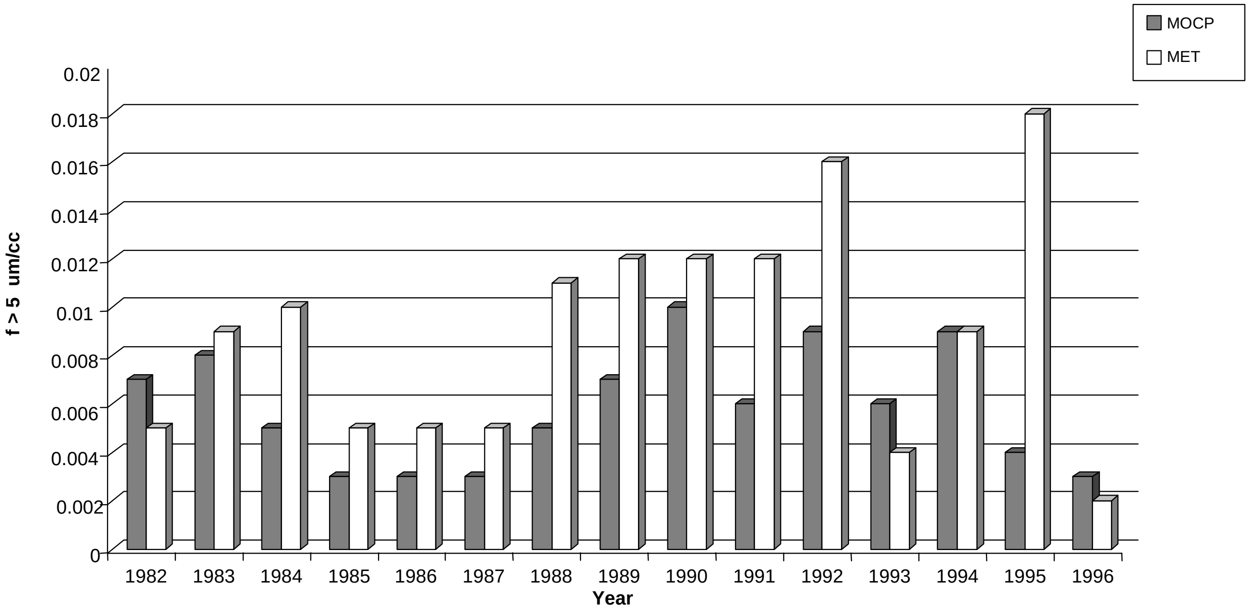
Sampling took place from January 17 to December 19, 1984, and was carried out over 12 continuous 4-week periods. The sampling instruments were the “Connecticut Lo-Vol” using a 400 cm^2 Millipore filter with a porosity of 0.45 µm. Every four weeks, after a sampling of approximately 5,000 m^3 of air, the filter was removed for analysis.

Figure 1 Asbestos fibre concentrations in ambient air of Quebec mining towns



Source : Lebel, 1997

Figure 2 Asbestos fibre concentrations in ambient air of Quebec mining towns



MOCP: PCOM Phase Contrast Optical Microscopy
MET: TEM Transmission Electron Microscopy

Source : Lebel, 1997

Direct TEM was used for laboratory analyses. First, a comparative analysis of the direct and indirect methods was carried out. A selective count was done of particles longer than 5 μm with a length: diameter ratio greater than 3.

Two types of asbestos were identified, chrysotile (99% and higher) and tremolite (between 0.5 and 1%). The chrysotile fibres measured from 5 to 20 μm; the tremolite fibres had an average diameter of 0.53 μm and an average length of 9.2 μm.

Mean annual levels of fibres in the air were 0.9 fibre per litre in Montréal and Saint-Étienne, 52.5 fibres per litre in Asbestos, 73.7 fibres per litre in Thetford Mines, and 188.7 fibres per litre in Black Lake (Table 3). Mean levels were approximately three times higher in Black Lake compared with Thetford Mines and Asbestos. It should be noted that results varied greatly at different stations within the same town. There was also considerable seasonal variation with a maximum in April and in October (Figure 3). It should also be emphasized that a little over 14% of the fibres detected were longer than 5 μm and had a length: diameter ratio greater than 3. They were therefore visible by PCOM. Mean concentrations visible by PCOM were therefore estimated at 0.026 fibres per cm^3 in Black Lake, 0.010 fibres per cm^3 in Thetford Mines, and 0.007 fibres per cm^3 in Asbestos. Concentrations measured in Thetford Mines and Asbestos were on average 70 times higher than those in Montréal and Saint-Étienne. Annual concentrations measured in Black Lake were approximately 200 times higher than in Montréal and 1,000 times higher during seasonal peaks. It should be pointed out that mean concentrations of tremolite in the air were 1.5 fibres per litre in Thetford Mines, 0.9 fibres in Black Lake, and 0.2 fibres per litre in Asbestos.

Table 3 Concentrations of chrysotile particles[1]: Annual means by station and by region

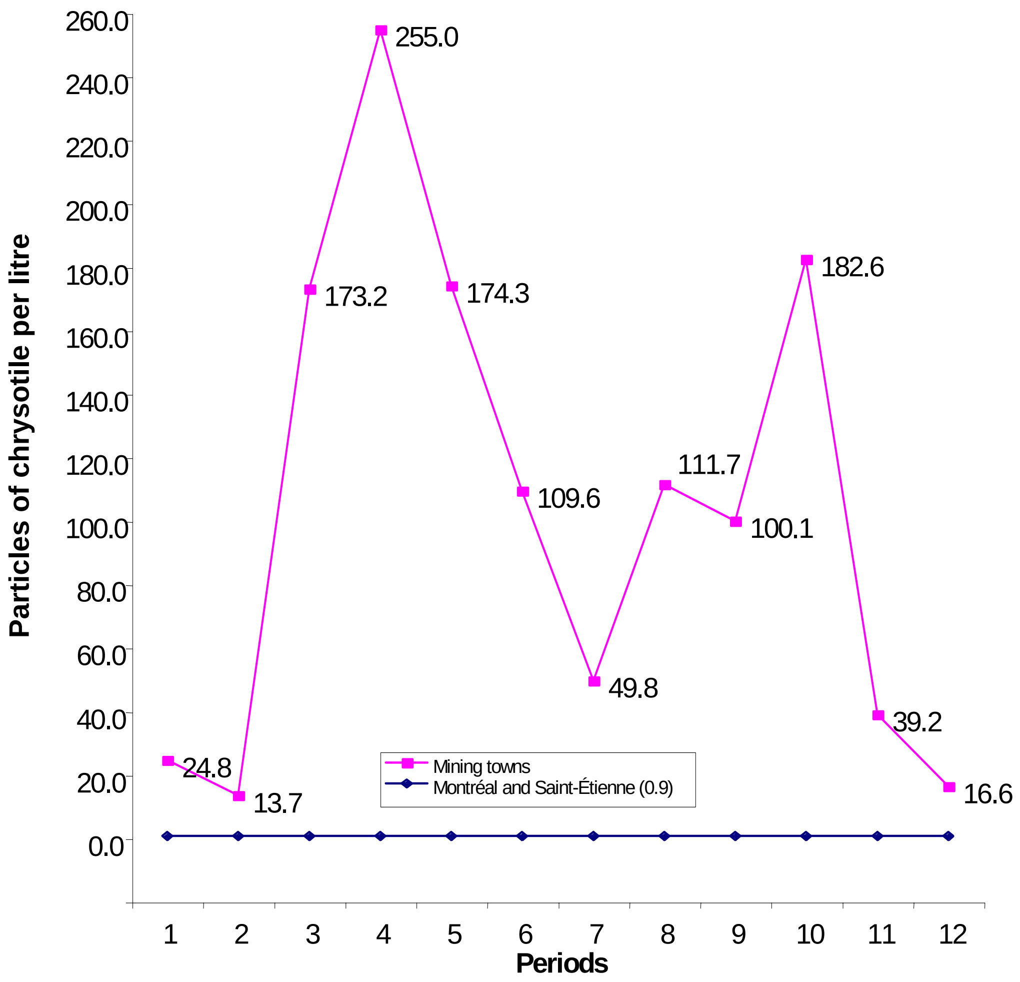
Station No.	Number of samplings	Geometric mean	Geometric standard deviation	Arithmetic mean estimated*
Saint-Étienne 000	9	0.6	1.3	0.6
Montréal 012	10	0.9	2.2	1.2
Asbestos 706	11	29.8	3.1	47.6
Asbestos 709	11	37.2	3.3	57.5
Thetford Mines 722	12	64.2	3.4	107.9
Thetford Mines 723	12	16.7	3.1	26.8
Thetford Mines 725	11	61.5	3.3	102.3
Black-Lake 732	12	86.2	3.7	153.2
Black-Lake 736	12	141.4	3.1	223.4
Saint-Étienne and Montréal 000 and 012	19	0.7	1.9	0.9
Asbestos 706 and 709	22	33.3	2.9	52.5
Thetford Mines 722, 723 and 725	35	39.9	5.7	73.7
Black-Lake 732 and 736	24	110.4	3.4	188.7

Source: Sébastien et al., 1986

[1] Number of chrysotile fibres per litre, longer than 5 micrometers.

* Using Oldham's technique, *Biometrics*, 1965, No. 213, pp. 235-239.

Figure 3 Seasonal variation of atmospheric pollution by asbestos



Source: Sébastien et al., 1986

6.3. ASBESTOS WASTE

Sources

Some waste may contain significant quantities of asbestos and in certain cases represent sources of fibre release in the environment, particularly with friable materials. This waste comes mainly from mining and processing industries and from construction. Extraction plants and mine operating sites produce considerable quantities of asbestos-containing waste. This waste ore is stored in dumps, which may cover a sizeable area. The use of waste ore as landfill is another potential source of fibres in outdoor air. The current situation is presently being assessed by a working group set up by the *ministère de l'Environnement du Québec*. Other sources of waste include air pollution control equipment, bags that contained asbestos, and some materials containing asbestos dusts. Asbestos-containing materials from demolition, such as insulation, asbestos cement, and sprayed asbestos are other sources of waste.

When waste is stored or disposed of, it may contaminate air and water. The principal contamination problems occur with open-air disposal sites that are poorly protected from the elements. Studies were conducted in the vicinity of an open dump site containing asbestos materials (8,1). Airborne concentrations of asbestos fibres in ambient air around these dump sites can be much higher than background concentration; in some cases they are 10 to 10,000 times greater, approaching concentrations found in the work environment. In addition, water may be seriously contaminated as a result of poorly protected dumps.

Occupational health and safety

Under the Safety Code for the Construction Industry, friable materials that contain asbestos and that are likely to spread shall be kept thoroughly wetted for the duration of the work (R.6 s. 3.23.9), and during work, debris of materials containing asbestos shall be placed in airtight containers appropriate to the type of debris (R.6 s. 3.23.10). Asbestos is a hazardous material identified on a material safety data sheet in the Workplace Hazardous Materials Information System (WHMIS). Transportation of asbestos is subject to federal regulation on the transportation of hazardous material.

In the case of work authorized and carried out in accordance with the Safety Code for the Construction Industry, asbestos arrives at waste burial sites inside airtight containers, usually polypropylene bags. At waste burial sites, potential problems are related to the rupture of airtight containers when bags are compacted by heavy machinery before being covered. This is when asbestos fibres may be released into the environment. In the case of unauthorized asbestos removal, workers and managers at waste burial sites are not informed of the presence of asbestos in the waste. Sometimes CSST inspectors are informed of non-compliance with regulations.

Disposal of waste

In the United States, the Clean Air Act of 1970, amended in 1990, covers the management of asbestos wastes. Asbestos is identified as hazardous waste by the Environmental Protection Agency (EPA). The section "National Emission Standards for Hazardous Air Pollutants" (NESHAP) regulates work practices during the renovation and demolition of structures containing asbestos. Owners and operators must inform local authorities before commencing demolition or renovation work. The regulation also decrees standards relating to the handling and disposal of asbestos. The buildings concerned must be registered. During transportation and disposal of asbestos waste, vehicles must be identified as well as the disposal location. EPA must approve new disposal sites.

In Quebec, there are no specific management criteria for asbestos waste under the existing regulation[5]. Nevertheless, several documents have been published by the *ministère de l'Environnement* on this subject in recent years, notably the September 1992 "*Document de préconsultation sur la refonte du règlement sur les déchets solides*" (preconsultation document on revision of the Regulation Respecting Solid Waste). The *Comité de santé environnementale du Québec* (CSE—environmental health committee) formulated recommendations based on this document to remove asbestos from the category of dry materials and construction and demolition debris (9). The CSE also recommended that wastes be covered as soon as they arrive at disposal sites for coverings and waste materials. It further recommended that asbestos-containing wastes and friable materials be placed in airtight containers and labelled in accordance with existing regulations. In 1994, a technical version of the *projet de règlement sur les déchets solides* (draft regulation respecting solid waste) was produced by the *MEF* (Quebec's ministry of the environment). In this regulation, asbestos was still a solid waste but was no longer considered construction and demolition debris. Therefore, burial in dry materials disposal sites was prohibited.

Since 1996, the technical version of this regulation requires asbestos to be buried in sanitary waste disposal sites that can collect and treat leachate. It is recommended, though not required, that material be handled in airtight containers and covered immediately.

Currently, asbestos is a solid waste under the definition of the Regulation Respecting Solid Waste in effect since 1982[6]. The current regulation has no specific provision concerning asbestos. The Regulation Respecting Hazardous Materials, in effect since December 1, 1999, that replaces the Regulation Respecting Hazardous Waste, specifically excludes asbestos from the list of hazardous materials (s. 2 (14)). During the 1996 environmental public hearing consultations on waste management by Quebec's *Bureau d'audience publique de l'environnement*, Quebec's *ministère de l'Environnement* published a draft regulation respecting the disposal on land and incineration of waste *(projet de règlement concernant la mise en décharge et l'incinération des déchets)*. This draft regulation would require operators of sanitary disposal sites to cover friable wastes in compliance with certain safety practices. The proposed regulation does not prescribe a specific practice for burying asbestos. However, it generally prescribes that wastes be covered daily in sanitary landfills. There is no such requirement for dry materials disposal sites. In in-trench disposal sites, wastes may be burned and they are covered every month.

At this time, we do not know the volumes of asbestos waste taken to sanitary disposal sites. However, during large-scale removal such as in highrise office buildings, the volume of waste may be considerable. Section 57(1) of the Regulation Respecting Solid Waste requires the operator of a sanitary disposal site to keep a register that identifies the nature and the origin of the waste of each truck that comes to the sanitary landfill site. Section 31 of the *projet de règlement sur l'élimination des matières résiduelles* (L.R.Q., C.Q.-2 draft regulation respecting the elimination of residual materials), published for comment in Autumn 2000, stipulates: "Residual materials that contain asbestos in a

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[5] Marcel Bélanger, DSP de Lanaudière, personal communication, 1998

[6] René Binette, MEF, personal communication, 1998

concentration equal to or greater than 1% by weight and that are likely to be released into the air shall, immediately on admission to the site and before being compacted, be completely covered with materials that meet the criteria of section 33, or with other residual materials” [Translation].

Asbestos-asphalt

Asbestos-asphalt may be a source of asbestos fibres in outdoor air. In 1996, the *Direction de santé publique de Montréal-Centre* assessed the use of asbestos-asphalt in a pilot project carried out in Quebec by the *ministère des Transports* (10). The technique of using asbestos in surfacing materials has existed for about ten years. Asbestos is used as a binder in the mix, which substantially increases durability and rutting resistance, according to the *ministère des Transports*. Environmental studies were conducted during pilot projects in Villeroy and St-Apollinaire to measure fibre concentrations at asphalt plants, and among operators and block pavers, both upwind and downwind from the resurfacing site. The results of these studies show that permissible workplace concentrations would not be exceeded and ambient air levels upwind and downwind of the resurfacing site would not change.

The *Direction de santé publique de Montréal-Centre* assessed environmental reports and consulted the *Institut de recherche en santé et en sécurité du travail* (IRSST). Several methodological weaknesses were pointed out by the IRSST, in particular regarding the representativeness of the measurements taken among workers and in the vicinity of resurfacing sites. Due to the incomplete data, it is impossible to express a definitive opinion on the safety of using asbestos for road resurfacing. Elements that require further study are wear and tear of roads and use in densely populated areas. The *ministère de l'Environnement* recommended studies be continued to measure the impact of asbestos-asphalt use on air quality, utilizing more adequate ambient air sampling and measuring the impact of wear and tear and road traffic on outdoor air concentrations.

Biomarkers of exposure

Pleural plaques

Pleural plaques are fibrous lesions that appear in the parietal pleura. These benign pleural lesions are manifestations of asbestos exposure (2). Pleural plaques can be found in populations of mine workers, in the asbestos industry, in sectors with sporadic and accidental contact with asbestos, and in the general population. The prevalence of pleural plaques in these different populations varies greatly (2). According to different studies, it varies from 1.5 to 12.9% among miners, 4.6 to 14.6% in the manufacturing industry, and 4.4 to 58.2% among workers who use or remove asbestos-containing products. Prevalence was 5.7% among maintenance and custodial workers in public or commercial buildings who had no prior exposure to asbestos and who had worked 10 years or more in a public building (11). Prevalence was 7.2% among workers in New York City schools and 26% among Boston school district janitors with more than 15 years seniority (12).

In Quebec, a screening for pleural plaques was carried out among 1,205 building and public works sector workers: insulators, plumber-pipe fitters, tinsmiths, elevator mechanics, fire protection mechanics, air conditioning repairmen, boilermakers, and bricklayers (13). Among these groups, 262 workers (22.7%) had pleural abnormalities. Among these workers, 25 suspected cases of asbestosis were identified; 12 of these cases were in plumbers-pipe fitters.

For exposure unrelated to work, a prevalence of 20% was detected among close family members of asbestos workers (14). In the general population the prevalence of pleural plaques varies from 0.5 to 6.8% (15). Prevalence is approximately 2 times higher in the rural environment population than in the urban environment population. The highest prevalence was reported among men in Finland. In most studies, prior exposure to asbestos is reported among persons who have pleural plaques (2). Clinically, the presence of pleural plaques is not highly significant, except for a slight reduction in pulmonary function (2). Some studies have shown a possible increased risk of cancer of the lung and the larynx and of mesothelioma associated with the presence of pleural plaques.

Asbestos fibres in pulmonary tissues

Asbestos bodies and fibres retained in pulmonary tissue are also biomarkers of exposure to asbestos fibres (2,16). Asbestos bodies are iron-protein-coated asbestos fibres. They are found with great frequency in the lungs of asbestos-exposed workers. Asbestos bodies can be studied directly in tissue or in specimens obtained by bronchial washings. At first, asbestos bodies were studied mainly by optical microscopy. With the arrival of electron microscopy, new techniques permitted the identification and quantification of asbestos fibres present in pulmonary tissue (2).

Despite some methodological difficulties related to laboratory analyses of fibres in tissues, a gradient in fibre concentrations has been demonstrated in the lungs of different populations exposed to asbestos (11). Highest concentrations were found among asbestos workers, intermediate concentrations among persons residing in miners' homes, and lowest concentrations among persons exposed in the general environment (2).

Using optical microscopy, Case and Sébastien showed a higher concentration of asbestos bodies in the pulmonary tissue of persons living in a mining town than in a control population (16). In a study conducted between 1979 and 1983 of 1,300 autopsy cases at the *Centre hospitalier universitaire de Sherbrooke*, the same researchers used transmission electron microscopy to show a significantly higher concentration of chrysotile fibres longer than 5 micrometers in the population of mining towns than in a control population (17). Fibre concentrations in the pulmonary tissue of the population studied were 50% lower than that of miners. It should be noted that the concentration of tremolite was much higher among workers and slightly higher in the population studied than among the controls. In a study of seven cases of Thetford Mines residents who had never worked in the mines or the asbestos industry, fibre concentrations in pulmonary tissue were compared to the concentrations found in 20 miners and 20 persons from Vancouver (18). The concentration of chrysotile and tremolite fibres among the Thetford Mines residents was approximately 20% of the concentration found among the miners; it was 10 times higher than the concentration found in the Vancouver residents. Moreover, the asbestos fibres found in the Thetford Mines residents were longer.

Results of some studies on biomarkers support the hypothesis of an elevated risk of mesothelioma associated with exposure to amphibole fibres. Two case-control studies of mesothelioma cases showed an association between a higher concentration of amphibole fibres and mesothelioma (16). According to the first study, the presence of long amphibole fibres in pulmonary tissue was responsible for 65 to 70% of mesothelioma cases. A study of nine cases from Quebec showed the same trend associated with the presence of tremolite fibres (16).

It is difficult to evaluate the association of certain health problems such as mesothelioma with asbestos exposure from the environment. Due to methodological difficulties, the identification of asbestos bodies has not enabled researchers to demonstrate a valid link between the two (2). The more recent use of electron microscopy to study fibres in the pulmonary tissues of suspected cases in the general population seems to be a promising avenue of research (15,12).

6.4. ASSESSMENT OF THE SITUATION IN QUEBEC

Concentrations in outdoor air

Background concentration

In general, in Quebec, concentrations measured in outdoor air in the absence of point sources are very low. Background concentration in rural areas is lower than in urban areas. As reported by the Health Effects Institute, concentrations measured by Sébastien et al. in Montréal and in Saint-Étienne were nevertheless higher than concentrations measured in other studies (2). In 1984, the mean value of samples was 0.0012 f/ml in Montréal and 0.0006 in Saint-Étienne. According to HEI, these higher concentrations may be due to the greater analytical sensitivity of the method used or to the relatively long sampling time (4 weeks). This sampling time could permit the recording of peak events that would go unnoticed in much shorter periods. Also, the indirect analytical method using transmission electron microscopy tends to give higher results than the direct method. However, at present, there are no recent results from which to assess background concentration in Quebec, and assessing these trends continues to be difficult.

Mining towns

For mining towns, measurements of ambient air by the Asbestos Institute starting in 1973 and using optical microscopy show concentrations much higher than background concentration. There was a substantial decrease of outdoor air concentrations, notably from 1973 to 1982. Concentrations measured from 1982 onward remain much lower. Results of analyses carried out from 1983 to 1997 by the Asbestos Institute using transmission electron microscopy also showed a very substantial decrease in outdoor air concentrations (6). However, it should be pointed out that the results still show notable fluctuations of mean concentrations in mining towns from the end of the 1980s to 1995 inclusively. Mean concentrations during these years frequently exceeded 0.01 f/cc. In 1996 and 1997, mean concentrations were much lower, varying from 0.003 to 0.005 f/cc. It is important to remember that the results of the Asbestos Institute studies are averages for mining towns. In 1997, results of the averages for each of the towns showed that concentrations were higher in Black Lake than in Asbestos and Thetford Mines. These results confirm results measured by Environment Canada and Quebec's *ministère de l'Environnement*, between 1983 and 1986.

Permissible concentrations

In Quebec, there is currently no regulatory standard with respect to the permissible concentration of asbestos fibres in outdoor air. In 1998, the MSSS *Comité aviseur sur l'amiante* (asbestos advisory committee) recommended 0.01 f/cc as the new action criterion in schools with sprayed asbestos. In France, the action criterion was set at 0.025 f/cc. The Health Effects Institute did not assess the concentration(s) deemed acceptable in indoor air. Sébastien et al. indexed recommendations on air quality standards for asbestos in certain countries (Appendix 5). These recommendations were taken from the report of a symposium held in Sweden in 1983. We note in particular that the recommendations were 0.04 f/cc in Ontario and British Columbia and 0.05 f/cc in Montréal. Since 1981, mean values in mining towns have been consistently lower than 0.04 f/cc. However, from 1973 to 1980, mean values measured by optical microscopy were equal to or higher than 0.01 f/cc. In 1984, the average annual levels measured by Sébastien et al. in the three mining towns were all higher than the criterion of 0.04 f/cc. In 1997, the criterion of 0.04 f/cc was complied with in the three mining towns.

CONCLUSION

In the outdoor environment in Quebec, concentrations measured in outdoor air in the absence of point source emission are very low. Background concentration in rural environments is lower than in urban environments. However, in Quebec, we do not have recent results to assess background concentration and we do not know if concentrations have decreased or increased, especially in very urbanized areas.

For mining towns, data are available from 1973. Concentrations, measured by optical microscopy, were much higher than background concentration. However, we observe a considerable decrease from 1973 to 1982. Electron microscopy analyses began in 1983, under the auspices of the Asbestos Institute. Since 1982, concentrations have been very low. Nevertheless, substantial fluctuations in mean concentrations in mining towns were observed until 1995. Mean concentrations during these years frequently exceeded 0.01 f/cc. In 1996 and 1997, mean concentrations of mining towns were much lower, varying from 0.003 to 0.005 f/cc. Results of measurements taken in Black Lake are systematically higher than in Asbestos and Thetford Mines.

The only recent data available on ambient air surveillance in mining towns comes from the Asbestos Institute in Quebec. These results are drawn from sampling campaigns carried out in June of each year, generally over a six-hour period at two litres per minute. In 1984, an elaborate survey was conducted by Sébastien et al. for Environment Canada in collaboration with *Environnement Québec*.

We do not know the volume of asbestos waste, one of the potential sources of asbestos fibres in outdoor air, taken to sanitary disposal sites. Asbestos is a solid waste according to the definition of the Regulation Respecting Solid Waste in effect since 1982. This regulation has no specific provision regarding asbestos. A draft regulation on the disposal on land and the incineration of waste (published for comment) included the requirement that operators of sanitary disposal sites cover friable wastes such as asbestos following a specific safe practice. It should also be noted that section 57(1) of the current regulation on solid waste requires operators of sanitary landfills to keep a register that identifies the nature and origin of the waste of every truck that comes to the sanitary landfill site.

With respect to asbestos-asphalt, a possible source of asbestos fibre in outdoor air, studies on the impact on air quality of asbestos use in asphalt surfacing materials give inconclusive results. The IRSST pointed out the methodological shortcomings of these studies in relation to the representativeness of the measurements taken among workers and in the vicinity of resurfacing sites. Data are still incomplete. According to researchers with the IRSST and the *Direction de santé publique de Montréal-Centre*, a duly executed impact assessment is needed, especially in areas with higher exposure risk such as tunnels and enclosed highways in urban environments. An impact assessment should be done for all new large-scale uses of asbestos.

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GENERAL CONCLUSION

The information available on asbestos exposure in public buildings, other than schools, is incomplete. Some particular situations have been assessed, often in emergency situations, for example in one university, certain municipal recreation centres, certain hospitals, as well as in Montréal’s Olympic Stadium. The common denominator in these situations was the accidental discovery of the presence of sprayed asbestos, and it was mainly workers who were exposed during work. In some cases, students or the public could have been exposed. As the committee observed in its preliminary work and consultation, other categories of public buildings should also be systematically assessed. However, this assessment could be much more general and require fewer resources than in elementary and secondary schools. The other public buildings referred to are CEGEPs, universities and municipal buildings (especially those intended for community and health institution use). For these buildings, the prioritization criteria should be the type of population affected and the duration of exposure. In public buildings, it is generally workers who risk being exposed to significant concentrations of asbestos fibres when work is poorly planned and poorly managed. Therefore, in public buildings, interventions among employers and workers are of crucial importance.

In the workplace, for asbestos exposure among workers in the mining sector, existing standards have generally been complied with at the different work areas sampled during the last twenty years. A study was conducted by the *Direction de santé publique de la région Chaudière-Appalaches* using the 1988, 1990 and 1997 environmental surveillance data from two mining companies. Results showed that where standards were exceeded, it was often in relation to the specific tasks of certain workers, for example repairing screens, unclogging conveyor belts, or underground drilling. The report by the Chaudière-Appalaches public health department documented important variations in workers’ exposure in the same work area during the different years of the study. More in-depth analyses might help identify the factors that lead to such varying levels of workers’ exposure. At present, the number of workers sampled does not meet the guideline provided for this purpose by the IRSST. The feasibility of applying current sampling guidelines seems to be a serious problem for the industries concerned. The standard (8-hour time-weighted average concentration) currently in force in Quebec in all work environments is 1 f/cc for chrysotile. Use of amosite and crocidolite is prohibited and the standard for existing materials containing amosite and crocidolite is 0.2 f/cc. In the United States, the standard enacted for mines by the Mine Safety and Health Administration (MSHA) in 1978 was 2 f/cc using the membrane filter, phase contrast microscopy method. However, a recent report from the U.S. Office of the Inspector General recommended lowering the standard to 0.1 f/cc, concentration measured by phase contrast microscopy, as in other workplaces.

With respect to the asbestos processing industry, a study was conducted in Montréal by the *Direction de santé publique (DSP) de Montréal-Centre* and overseen by Dr. Robert Simard. In keeping with the activities of the provincial asbestos committee, the aim of this study was to describe asbestos exposure in the processing industry. Methodology involved using SMEST and SIG data sources from 1994 onwards. This investigation was carried out among occupational health physicians in February and March 1997. The goal of the investigation was to identify the presence of workers in situations where standards were exceeded at the time of the survey and over the five preceding years. Occupational health and safety programs were consulted to identify the operations with high exposure risk and the documented exposure levels. Physicians validated the findings between September and December 1997.

The results identified 29 establishments as being at risk of over exposure. The building and public works sector was subsequently eliminated due to its distinctive situation. Manufacturers of transportation equipment and metal products represented 40% of the establishments. Some other industries were also identified as being likely to cause significant asbestos exposure, namely industries that produce insulation, gaskets, and other asbestos-based products. Seven of the 28 establishments (23%), were identified as not complying with the standard. Three of these establishments manufactured brake pads. Several stages in the manufacturing process were above the standard. Exposure in the other establishments was more limited. The authors detailed the limitations inherent in this type of study with regard to measuring exposure levels and compliance with standards. Nevertheless, they point out, we ought to be concerned by the strong possibilities that standards are being exceeded in the processing industry. We should emphasize that no worker presenting radiological abnormalities was identified in this milieu.

In the building and public works sector (BTP), certain data from a study on the prevalence of pleural plaques and signs of asbestosis among more than 1,200 workers (insulators, pipe fitters, plumbers, tinsmiths, elevator mechanics, fire protection mechanics, air conditioning repairmen, boilermakers, bricklayers) showed a prevalence of pleural plaques greater than 22%. Prevalence in the general population is on the order of 0.5 to 6.8% (15). It might reach 20% among close family members of asbestos workers. In the same study, 25 cases of suspected asbestosis were also identified, 12 of which were among plumbers-pipe fitters. These results indicate that for several years these workers have experienced significant exposure to high concentrations of asbestos fibres in ambient air. Intervention programs are essential in these activity sectors. An asbestos intervention program for BTP workers was implemented by the CSST.

With respect to outdoor air, the concentrations measured in recent years in mining towns are generally very low. The background concentration measured in 1984 in rural areas was far lower than in urban areas. However, there are no recent measurements of background concentration. An ambient air surveillance program overseen by the Asbestos Institute provides data from mining towns as far back as 1973. Originally measured by light microscopy, concentrations have been measured by electron microscopy since 1983. Concentrations have decreased substantially. Since 1981, mean concentrations in mining towns have always been less than 0.04 f/ml. In 1996 and 1997, mean concentrations in mining towns varied between 0.003 and 0.005 f/cc.

Asbestos waste taken to waste disposal or landfill sites may represent another significant source of exposure. Currently in Quebec, asbestos is a sold waste according to the definition in the Regulation Respecting Solid Waste. While there is no specific provision concerning asbestos, operators of sanitary disposal sites are required to keep records identifying the nature and the origin of the waste. A draft regulation on the disposal on land and incineration of waste, published in 2000, includes the requirement that operators of sanitary disposal sites cover friable waste such as asbestos. Another potential exposure source is asbestos-asphalt. So far, however, asbestos-asphalt use is rare. Some studies have been conducted to measure its impact on ambient air. A more precise analysis of airborne concentrations is required to conclusively judge the real impact of this new use. This analysis should be done for any new large-scale use of asbestos.

APPENDIX 1

FIBRE COUNTING

FIBRE COUNTING

ANALYTICAL METHOD 243-1

Institut de recherche Robert Sauvé en santé et en sécurité du travail (IRSST)

Date of issue: 88-12-15

Permissible exposure value (PEV): 0.2 fibres/cm^3 crocidolite and amosite; 1 fibre/cm^3 chrysotile or other types of asbestos.

Maximum allowable concentration (MAC): 1 fibre/cm^3 crocidolite and amosite; 5 fibres/cm^3 chrysotile and other types of asbestos.

Sampling: MCE Filter
Diameter of filter: 25 mm
Diameter of pores: 0.8 to 1.2 µm
Cassette: conducting extension cowl
Flow rate: 0.5 to16 L/min (0.5 to 2.5 L/min preferred for PEV in industrial settings)
Volume: minimum 400 L to 0.1 fibres/cm^3

Analytical method: Fibre counting by phase-contrast optical microscopy

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Source : *Insitut Robert Sauvé en santé et en sécurité du travail* (IRSST). Direction des opérations. Notes et rapports scientifiques et techniques. Méthode 243-1. Numération des fibres. 1990, 24 p

APPENDIX 2

EVOLUTION OF STANDARDS IN THE WORKPLACE

EVOLUTION OF STANDARDS IN THE WORKPLACE

QUEBEC REGULATIONS

- **REGULATION RESPECTING THE QUALITY OF THE WORK ENVIRONMENT (RQMT):**

  1975(?) – 1990: 5 f/cc (respirable fibres per cubic centimetre of air) not to be exceeded

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- **REGULATION RESPECTING THE SALUBRITY AND SAFETY OF WORKMEN IN MINES AND QUARRIES:**

  1975 – 1978: mines: 5 f/cc TWA (8-hour time-weighted concentration)
  1978 – 1990: mines: 2 f/cc TWA (8-hour time-weighted concentration)

- **ALL REGULATIONS:** FROM 1990 TO THE PRESENT

Permissible asbestos concentrations in numbers of respirable fibres/cm^3

Type of asbestos	Average permissible concentration	Maximum permissible concentration
Chrysotile	1	5
Crocidolite[1]	0.2	1
Amosite[1]	0.2	1
Tremolite	1	5
Anthophylite	1	5
Actinolite	1	5

Permissible concentration of recirculation of respirable dusts: 0.1 mg/m^3

[1] The use of these products is prohibited. The standard applies to notwithstanding cases and to the management of existing asbestos.

Note: Since 1994, all forms of asbestos are included in the list of substances for which workers' exposure must be reduced to a minimum.

AMERICAN CONFERENCE FOR GOVERNMENTAL HYGIENISTS (ACGIH)

Period	Types of standards	Values	Comments
1946 – 1947	MAC	5 mppcf	
1947 – 1973	TWA	5 mppcf	
1968 – 1969	TWA	12 f/ml or 2 mppcf	proposed
1970 – 1972	TWA	5 f/ml	proposed
1974 – 1979	TWA	5 f/ml	
1978	TWA	0.5 for amosite and tremolite 0.2 f/ml for crocidolite 2 f/ml for chrysotile and other forms	proposed
1980 – 1991	TWA	0.5 f/ml for amosite 0.2 f/ml for crocidolite 2 f/ml for chrysotile and other forms	
1992 – 1997	TWA	0.2 f/ml for all forms	proposed
1998 to the present	TWA	0.1 f/ml for all forms	

MAC: maximum allowable concentration
TWA: time-weighted average (8 hrs)
mppcf: million particulates per cubic feet
f: fibre > 5µm

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) (from 1989)

Year	Types of standards	Values	Comments
1989	TWA	0.2 f/ml	All forms
	STEL (30 min.)	1 f/ml	All forms
1994	TWA	0.1 f/ml	All forms
	STEL (30 min.)	1 f/ml	All forms

TWA: time-weighted average (8 hrs)
STEL: short-term exposure limit
f: fibre > 5µm

HEALTH AND SAFETY COMMISSION (HSC), London

Period	Types of standards	Values	Comments
In force in 1998	Average over 4 hours	0.5 f/ml	Chrysotile
	Average over 10 minutes	1.5 f/ml	Chrysotile
	Action level over a continuous 12-week period	96 f-hr/cc	Chrysotile
	Average over 4 hours	0.2 f/cc	Other forms and mixes
	Average over 10 minutes	0.6 f/cc	Other forms and mixes
	Action level over a continuous 12-week period	48 f-hr/cc	Other forms and mixes
1998 Proposal	Average over 4 hours	0.3 f/cc	Chrysotile
	Average over 10 minutes	0.9 f/cc	Chrysotile
	Action level over a continuous 12-week period	72 f-hr/cc	Chrysotile
	Average over 4 hours	0.2 f/cc	Other forms and mixes
	Average over 10 minutes	0.6 f/cc	Other forms and mixes
	Action level over a continuous 12-week period	48 f-hr/cc	Other forms and mixes

f: fibre > 5µm

APPENDIX 3

PROTOCOL FOR ASSESSING THE POTENTIAL FOR RELEASE OF ASBESTOS FIBRES IN AMBIENT AIR

PROTOCOL FOR ASSESSING THE POTENTIAL FOR RELEASE OF ASBESTOS FIBRES IN AMBIENT AIR

1) CONTRIBUTING FACTORS TO CONSIDER

CONDITION OF THE SPRAYED MATERIAL

- Current condition of the material assessed by simple visual inspection

No sign of deterioration: good condition

- Overall appearance good and uniform.

Slight damage

- Material on the whole well bonded to its substrate with only a few small bare patches caused by minor localized disturbance (accidents).

Moderate damage

- Material swollen or no longer tightly bonded over a small area, the rest well bonded and in good condition.
- Localized discolouration of the material following limited water damage, the rest in good condition.

Severe damage

- Extensive dislodging or swelling, material poorly bonded to its substrate.
- Discolouration of the material in several areas or widespread, secondary to water infiltration, condensation or excessive humidity (e.g.: leaking roof, indoor pool)
- Much scraping, indentation or cracking from direct contact or frequent accidents.
- Material in suspension or sections missing.

ACCESSIBILITY OF SPRAYED MATERIAL

- Ease with which the fibres may be found in ambient air on the basis of their location and the activities of occupants.

Non-friable or low friability

- Non-friable to pressure or very tightly bonded to its support.
- Not easily damaged by hand pressure or slight crumbling in patches removed from support (good fibre cohesion).

Moderate friability

- Dislodges, breaks or crumbles quite easily by hand pressure (e.g.: granular finish with binder in poor condition).

High friability

- Breaks and crumbles with simple hand contact or with little pressure or simply on exposure to vibrations
- and to impacts in the surroundings (e.g.: flaked finish, spongy finish, pieces hanging loose).

ACCESSIBILITY OF SPRAYED MATERIAL

Factors that may contribute to the dispersion in ambient air of fibres in suspension or deposited on surfaces.

(A) Clientele frequenting the room

(0) Adults
(1) Children
(2) Adolescents

(B) Level of circulation or activities in the room

(0) None or few activities (library, study area, most classrooms).
(1) Moderate circulation or activities (e.g.: kindergarten classrooms, specialized classrooms, etc. and corridors leading to these rooms).
(2) High circulation or activities (e.g.: gymnasium, pool, specialized workshops, cafeteria, cloakrooms, stairwells, etc. and corridors leading to these rooms).

(C) Air movement in the room

(0) Natural ventilation e (e.g.: windows).
(1) Mechanical ventilation (air conditioning system, forced-air heating—ventilation).
(2) Ceiling ventilators, ventilator-cooler equipment, use of portable vacuums, regular opening of large garage doors, etc.

Classification: total of points from A+B+C

0 to 1: Potential of dispersion low

2 to 3: Potential of dispersion moderate

4 to 6: Potential of dispersion high

ACCESSIBILITY OF SPRAYED MATERIAL

Following the diagnostic findings reflected by the ranks 1, 2, and 3 during qualitative assessment, the type of asbestos found in the materials will determine the frequency of controls of the condition of these materials and the level of dust, as well as the speed with which necessary corrective measures are undertaken.

- Presence of the “amphibole” type of asbestos in the material, particularly amosite, leads to the need for more rapid implementation of corrective action and more frequent control of the condition of the materials and the level of dust in the rooms.
- Amosite is recognized by most experts as being more harmful to health, given its physico-chemical characteristics and particular fibrous texture. Its fibres are shorter, bond less easily and are released more easily.
- In this case, the diagnostic rank will be revised upward by a + symbol indicating a higher intervention priority.

2) RESULTS OF THE QUALITATIVE ASSESSMENT

Current condition of the materials and potential for future damage (friability and accessibility) mainly determine the level of intervention.

RANK 3

- Materials severely damaged.
- Materials moderately damaged with a high to very high potential for future deterioration.
- Materials slightly damaged with a very high potential for future deterioration.

Requires appropriate corrective action as soon as possible, in compliance with procedures prescribed by the CSST and taking into consideration the school calendar. Corrective measures should be determined on the basis of the nature and characteristics of the materials as well as the extent of their current deterioration and expected future damage. A program to control the condition of the materials and a program of periodic preventive maintenance should be put in place, if the materials are not removed (enclosure, encapsulation, localized or temporary correction before permanent correction).

Following corrective activities, dust level in the rooms should be below 0.01 f/cc before restitution of the premises. Condition of the materials should be visually reassessed with the assessment grid when the material is left in place, in order to determine the nature and frequency of control measures required after remediation work.

RANK 2

Materials in good condition with a very high potential for future damage.

- Materials slightly damaged with a moderate to high potential for future damage.
- Materials moderately damaged with a low to moderate potential for future damage.

Requires measurements of dust levels in air, during a time period representative of normal school activities (in the cold season when doors are closed).

- When dust levels in ambient air reach 0.01 f/cc and higher, appropriate corrective action must be taken within a reasonable amount of time in compliance with procedures prescribed by the CSST. If the materials contain amphiboles, corrective measures must be taken as soon as possible, taking into account the school calendar.
- When dust levels are below 0.01 f/cc, the condition of the materials must be assessed: every three years, when the level is below 0.005 f/cc and, every two years, if amphiboles, particularly amosite, are present in the materials. When the level is between 0.005 f/cc and 0.01 f/cc, the condition must be assessed every two years and if amphiboles are present in the materials, every year.

In addition, rank 2 requires implementation of a program of periodic preventive maintenance of the materials.

RANK 1

- Material in good condition with a moderate to nil potential for future damage.
- Materials slightly to moderately damaged with a low to nil potential for future damage.

Requires assessment of the condition of the materials every three years and implementation of a program of periodic preventive maintenance of the materials.

If amphiboles are present, dust levels in ambient air must be determined during the period most representative of the normal activities of occupants:

- Dust levels are below 0.01 f/cc, condition of the materials must be assessed every two years.

APPENDIX 4

CHARACTERISTICS OF ESTABLISHMENTS IN WHICH EXPOSURES EXCEEDING STANDARDS WERE IDENTIFIED

CHARACTERISTICS OF ESTABLISHMENTS IN WHICH EXPOSURES EXCEEDING STANDARDS WERE IDENTIFIED

CAEQ	General characteristics	*PSSE* interventions	Processes at risk	Type of asbestos
3712	**Manufacture of asphalt products and roofing materials** Five asbestos-containing products: - Fibrated asphalt cement for NIS roofing. Roof coating for cementing shingles - Black caulking - Plastic cement - Plastic cement for drains. 4 production workers affected.	First plan elaborated in January 1985, subsequent update in May 1987 and June 1995.	Manual debagging of asbestos into a shredder. Incorporation of bulk asbestos into an asphalt tank (sporadic production).	Chrysotile
3255	**Motor vehicle brake pad manufacture**. 40 production workers affected.	First *PSSE* plan elaborated in May 1987; update in November 1996.	Production of two types of brake pads: 1) organic, using asbestos as friction material 2) metallic Exposure documented during most industrial process operations: mixing, hot pressing, polishing, drilling, packaging and shipping, due to general contamination of the work place.	Chrysotile
3099	**Fabrication of gasket linings**. 32 production workers.	First plan elaborated in August 1989, update in 1991 and December1994.	Use of asbestos at mixing station for extrusion and braiding. Parts manufacturing.	Chrysotile

CHARACTERISTICS OF ESTABLISHMENTS IN WHICH EXPOSURES EXCEEDING STANDARDS WERE IDENTIFIED (CONTINUED)

CAEQ	General characteristics	*PSSE* Interventions	Processes at risk	Type of asbestos
3592	**Manufacture of asbestos products, silica, refractory ceramic and fibreglass**. 16 production workers affected.	First *PSSE* plan elaborated in September 1995.	Exposure linked to cutting of materials, some asbestos-based.	Not documented
3792	**Manufacture of adhesives and caulking from solvents and solid components, including asbestos**. 40 production workers affected.	First *PSSE* plan elaborated in 1985. Updates in 1992 and 1996.	Exposure linked to operations involving adding asbestos to mixes for production of tar caulking.	Chrysotile
3255	**Manufacture of disc brake pads for motor vehicles**. The organic type represents 80% of production. 68 production workers	First *PSSE* plan elaborated in 1993, update in 1995.	Exposure linked particularly to the operation of hot presses and to finishing (sanding). Most production steps (mixing, preforming, curing, sanding, drilling, painting, labelling, packaging) involve documented exposure (0.5 f/cc).	Chrysotile
3255	**Manufacture of disc brake pads for motor vehicles**. 376 production workers.	First plan elaborated in 1988; first update in March 1993.	Three types of brake pads are produced: 1) metallic brake linings (50%) 2) organic brake linings (40%) 3) fibreglass brake linings (10%). Exposure documented (0.3 f/cc) during most industrial processing operations: mixing, preforming, moulding and curing, finishing (sanding and shaping, drilling, and painting), packaging and shipping.	Chrysotile

APPENDIX 5

RECOMMENDATIONS ON AIR QUALITY STANDARDS FOR ASBESTOS

RECOMMENDATIONS ON AIR QUALITY STANDARDS FOR ASBESTOS

CANADA	
Ontario	40 f/l (> 5 µm), 24 hr. average Electron microscopy
British Columbia	0.04 f/cm^3 Optical microscopy
City of Montréal	0.05 f/cm^3 (24 hr. average) Optical microscopy
UNITED STATES	
Connecticut	30 ng/m^3 or 30 f/l (30 day average) Electron microscopy
New York City	100 ng/m^3 Electron microscopy
FRANCE	
Conseil supérieur d'hygiène publique de France (inside buildings)	50 ng/m^3 (5 day average) Electron microscopy
FEDERAL REPUBLIC OF GERMANY	1 f/l Electron microscopy

Note: f/l here represents fibres per litre.
Source: Sébastien et al., 1986