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SUMMARY

Presence of asbestos fibres in indoor and outdoor air in the city of Thetford Mines: Estimation of lung cancer and mesothelioma risks

Québec

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In the autumn of 2007, the *Association des victimes de l'amiante du Québec* (AVAQ – a Québec association for asbestos victims) and the *Ministère du Développement durable, de l'Environnement et des Parcs du Québec* (MDDEP – Québec ministry of sustainable development, the environment and parks) published studies on the asbestos concentrations measured in indoor and outdoor air in Thetford Mines. The findings motivated the public health authorities in Chaudière-Appalaches and Estrie to request the assistance of the *Institut national de santé publique du Québec* (INSPQ – Québec institute of public health) to conduct an assessment of the risk of lung cancer and mesothelioma of the pleura in this population. The goal of using a risk assessment methodology is to provide scientific information to public health authorities that they can refer to when communicating the risk to the population. The results of this procedure can also be used by other stakeholders and decision-makers to guide decisions regarding the management of the environmental risks associated with asbestos exposure in the mining towns of Québec.

Asbestos is divided into two families: amphiboles (crocidolite, amosite, tremolite, actinolite and anthophyllite) and serpentines (chrysotile). The three main diseases associated asbestos exposure are asbestosis, lung cancer and mesothelioma of the pleura and peritoneum. All types of asbestos have been associated with the three diseases. Asbestosis is unlikely to occur among individuals exposed non-occupationally to asbestos concentrations generally present in the environment. All types of asbestos fibres are classified in Group A (human carcinogen) by the U.S. Environmental Protection Agency (U.S. EPA, 1993) and in Group 1 (carcinogenic to humans) by the International Agency for Research on Cancer (IARC, 2008).

Lung cancer affects the epithelial cells, and its minimum latency period is 10 years with an average of approximately 20 years. The main risk factor for lung cancer is smoking, but cigarette smoke and asbestos interact in synergy in the development of lung cancer. The toxic potential of amphiboles is higher than that of chrysotile, although uncertainties persist concerning this issue.

Mesothelioma is associated with direct or indirect exposure to asbestos. The latency period of this cancer varies between 20 and 40 years on average. Several authors agree that the risk attributable to exposure to amphibole fibres is higher than the risk attributable to chrysotile fibres, but discrepancies exist regarding the extent of this difference. Mesothelioma could also be caused by low and sporadic exposures to asbestos.

In the context of environmental exposure, the effects retained for the risk assessment are lung cancer and mesothelioma, the two diseases most likely to develop in a population exposed to asbestos in its environment.

Risk assessment

Two approaches were used to conduct the cancer risk assessment, that proposed in the *Lignes directrices pour la réalisation des évaluations du risque toxicologique pour la santé humaine* (guidelines for conducting assessments of toxicological risk to human health) of the *Ministère de la Santé et des Services sociaux du Québec* (MSSS) and that of Berman and Crump.

According to the methodology proposed in the MSSS guidelines, the estimation of lifetime excess mortality from cancer is calculated by multiplying a lifetime average exposure dose by a series of lifetime unit risks. In the case of asbestos, the lifetime unit risk represents the lifetime mortality risk for lung cancer and for mesothelioma attributable to a continuous lifetime exposure to 1 asbestos fibre/ml ($(f/ml)^{-1}$). It is determined on the basis of dose-response relationship models (K_L and K_M), which are derived from epidemiological studies conducted among workers. The risks attributable to environmental exposures were extrapolated from these models. The unit risk for lung cancer is the result of the difference between the lifetime lung cancer mortality risk in the exposed population and the expected lifetime lung cancer mortality risk in the control population. The unit risk for mesothelioma is derived from an absolute risk model. It is not contingent on the incidence of mesothelioma in an unexposed population. However, the all-cause mortality rates of the control population are taken into account. A review of the literature led to the identification and selection of some lifetime unit risks. The study by Nicholson, published in 1986, appears to be the most well respected in the scientific community. It is referenced by the U.S. EPA in its population risk analysis contained in the database *Integrated Risk Information System* (IRIS), and by the Health Effects Institute-Asbestos Research (HEI-AR). The lifetime unit risks retained for the present study are those from Nicholson, IRIS and HEI-AR, and they are respectively 0.35, 0.23 and 0.40 $(f/ml)^{-1}$.

The average lifetime exposure dose reflects the average cumulative exposure to asbestos during a lifetime. The calculation of the average lifetime exposure dose considers only the inhalation exposure pathway. This dose is obtained by weighting the average exposure dose of each age group relative to its duration, as defined in the MSSS guidelines. The average dose for each age group is equal to the sum of the average exposure dose by inhalation of indoor air and the average exposure dose by inhalation of outdoor air. The average exposure doses by inhalation of indoor air and outdoor air are based on the asbestos concentration in indoor air and in outdoor air as well as the proportion of time spent indoors and outdoors in a day.

The average lifetime exposure dose is also employed in the model of Berman and Crump. According to this model, the risk associated with amphiboles differs from the risk associated with chrysotile. As well, these two authors defined potency factors K_L and K_M for "pure" chrysotile fibres. They integrated more recent epidemiological data, collected among different groups of workers, with the U.S. EPA dose-response relationships defined by Nicholson. With the Berman and Crump model, it is possible to use the mortality rates of a local control population in order to estimate the lifetime mortality cancer risk arising from exposure to chrysotile asbestos. For the present study, the average all-cause mortality rates and the average lung cancer mortality rates (between 2000 and 2003) among men and among women in the Chaudière-Appalaches health and social service were retained.

The asbestos concentrations measured in the indoor and outdoor air, which are utilized to calculate the average exposure doses, come from two sources. First, the asbestos concentrations in indoor air are taken from the AVAQ study. In 2003 and in 2004, the authors of the study measured the asbestos concentrations in the indoor air of 26 residences in the city of Thetford Mines. The samples were analyzed by transmission electron microscopy (TEM) according to the modified NIOSH 7402 protocol (fibres > 5 µm long (L), between 0.25 and 3 µm in diameter (D), and with a L/D ratio of > 3:1). However, the total air volume collected in each residence, which was 1,220 L, is below the minimum required by the protocol. Most of the asbestos fibres detected were chrysotile fibres, but one actinolite fibre was identified in two residences and one tremolite fibre was detected in three residences. The concentrations measured range from < 0.000553 to 0.010 PCMe fibre/ml (phase contrast microscopy equivalent) (n = 26). The arithmetic mean was calculated from the raw data of the study. This mean is 0.0020 fibre PCMe/ml, with an upper limit (UL) of the 95% CI of 0.0031. As prescribed by the MSSS, it is this value (0.0031 f/ml) that is utilized to estimate the average indoor exposure dose.

A phase contrast microscopy analysis (PCM), according to the protocol defined in the Asbestos Hazard Emergency Response Act (AHERA), was also performed. The concentrations measured with the AHERA protocol (n = 28) range from < 0.004 to 0.311 structure/ml (s/ml). These results are not considered in the risk assessment, but they are utilized in the comparative study of asbestos concentrations measured in Thetford Mines and in other settings.

The outdoor air asbestos concentrations used by the authors of this report are taken from the study conducted by the MDDEP in 2004 in the ambient air of the city of Thetford Mines. In that study, two samplers were placed on the roofs of public buildings. The sampling took place between January and August 2004. The samples obtained were analyzed by PCM (n = 125) using the IRSST-243-1 protocol, and the concentrations vary between < 0.0015 and 0.056 f/ml (fibres > 5 µm long, ≥ 0.25 µm and < 3 µm in diameter, and with a L/D ratio of > 3:1). Seven of these samples were also analyzed by TEM according to the modified NIOSH 7402 protocol (fibres > 5 µm long, < 3 µm in diameter, and with a L/D ratio of > 3:1). The TEM concentrations range from < 0.0006 to 0.0082 fibre/ml. Chrysotile fibres were detected in 2 samples, and 4 other samples contained between 4 and 14 amosite fibres.

Since the number of samples analyzed by TEM is insufficient (n = 7) and in order to obtain a more representative distribution of asbestos fibre concentrations in the outdoor air, it was decided to estimate the asbestos fibre concentrations using the results of samples analyzed by PCM. Scientifically recognized methods and guidelines were utilized to estimate asbestos fibre concentrations from the results of 125 samples obtained by PCM. To do this, a ratio between the asbestos fibre concentration determined by TEM and the total fibre concentration also determined by TEM was established. For the samples that were analyzed by TEM, the ratio between the total fibres measured and the asbestos fibres is 0.5. This ratio was applied to the 125 results in total fibres obtained by PCM. The asbestos fibre concentrations estimated in this way range from 0.00038 to 0.028 f/ml. The average is 0.0029 f/ml, with a UL of the 95% CI of 0.0035 f/ml. In accordance with the MSSS guidelines, this value is retained as the outdoor air concentration to determine the average lifetime exposure dose.

The estimated average lifetime exposure dose is 0.0031 f/ml. The lifetime mortality risk for lung cancer and for mesothelioma obtained by multiplying this average exposure dose with the three lifetime unit risks retained is respectively 72, 110 and 125 per 100,000 persons in Thetford Mines continuously exposed to asbestos during their lifetime.

The lifetime mortality risk for lung cancer and for mesothelioma estimated using the Berman and Crump model is 11.5 per 100,000 men and 4.88 per 100,000 women in the city of Thetford Mines, with a continuous lifetime exposure to chrysotile fibres. The risk for both sexes combined equals 8.2 per 100,000 persons exposed.

For comparative purposes, the risks associated with the background level, that is, the asbestos fibre concentrations generally found in the environment, are estimated. Data relating to background concentrations measured inside residences and outdoors are limited. In the United States, Lee and Van Orden determined an outdoor background concentration of 0.00002 PCMe fibre/ml, and the HEI-AR estimated an indoor background concentration of 0.00019 f/ml. When these values are used, the average lifetime exposure dose equals 0.00018 f/ml. The lifetime mortality risks arising from exposure to these background concentrations range from 0.46 to 7.1 per 100,000 persons depending on the approach utilized (Berman and Crump model or MSSS guidelines).

The results of the risk assessments must be interpreted with caution because some uncertainties exist. First, there are uncertainties regarding the determination of the lifetime unit risks. In this risk assessment, the unit risks are determined using dose-response relationship models derived from epidemiological studies conducted among workers. The methodological limitations linked to these studies, the variations in the fibre sampling methods and analysis methods, and the confounding factors are all elements that influence the K_L and K_M values. The statistical models, utilized for the extrapolation of the results obtained from cohorts of workers exposed to high doses of asbestos, may have overestimated the dose-response relationship. Low-dose exposure risks may be less than what is predicted by the linear model. A study by Camus et al. suggests that the lung cancer risks estimated from the K_L utilized by Nicholson, the U.S. EPA and the HEI-AR are 10 times higher than the risk established between 1970 and 1989 in a population of women in the regions of Thetford Mines and Asbestos, exposed to asbestos in their environment.

Second, there are also uncertainties regarding the concentrations utilized to determine the average lifetime exposure dose. This is because of limitations in the studies that measure exposure. To begin with, the results of the AVAQ study must be interpreted with caution because the sampling conditions were not all respected. As well, the residences in which a sample was taken were all located within 2 kilometres or less of mine tailing sites. Then, the MDDEP studies that measured outdoor air concentrations were not conducted to assess population risk and do not optimally reflect the real exposure of an individual, because the measurements taken for these studies were obtained on building roofs. In addition, the value retained as an exposure datum (UL of 95% CI) of the asbestos concentrations in outdoor air was calculated and not measured. Finally, almost all the samples of indoor air and outdoor air were taken under the prevailing winds.

Comparative analysis of asbestos concentrations measured in the city of Thetford Mines

The asbestos concentrations measured in the city of Thetford Mines are compared with those from studies conducted in other areas in Québec and the United States as well as with the air quality criteria established by various organizations. The studies surveyed for this comparison have very similar sampling and analysis protocols but also contain some dissimilarities.

The asbestos concentrations measured by the AVAQ in the indoor air of residences are compared to those of Dion et al. who sampled the indoor air of 17 Québec schools in which asbestos containing materials were found (ACM). In the United States, two sampling campaigns were conducted following the destruction of the World Trade Center (WTC) towers. Chatfield and Kominsky sampled the indoor air of two apartments (n = 6) located near the towers, and the U.S. EPA sampled asbestos in the air of 62 apartments and common rooms of residential buildings in Upper Manhattan, New York City (n = 14) in order to measure the urban background level of asbestos in Manhattan. Also, over a period of at least 20 years, Lee and Van Orden measured the asbestos present inside buildings that were the subject of litigation related to the removal of ACM.

The comparison of the AVAQ study results with the results presented in the studies mentioned above shows that the average concentration of asbestos fibres or structures measured in the air of residences in the city of Thetford Mines is:

- from 4 to 46 times higher than concentrations noted in U.S. schools, residences and public and commercial buildings containing ACM;
- 232 times higher than the background measured in Upper Manhattan apartments in New York City;
- 1.4 times lower than that measured in two residences affected by dust from the collapse of the WTC towers a few days after the events of September 11, 2001;
- 1.7 times lower than that found in Québec schools that presented a high level of degraded ACM.

The asbestos fibre concentrations measured in 2004 by the MDDEP in the ambient air in Thetford Mines are compared with those obtained, in the same study, in the urban areas of Montréal and Québec City, and close to an inactive tailings site located at Tring-Jonction. A comparison is also made with the concentrations obtained by Lebel in the outdoor air of three Québec mining towns and with concentrations obtained by Lee and Van Orden, who sampled the outdoor air around buildings all across the United States.

These comparisons show that the average asbestos fibre concentration measured by the MDDEP in the outdoor air of Thetford Mines:

- has remained stable since 1997;
- is 215 times higher than that measured in samples taken across the United States;
- is, relative to urban areas in Québec and at Tring-Jonction where no asbestos fibre was detected, 7 times higher than the detection limit of 0.0006 f/ml.

The average total fibre concentration in the outdoor air in the city of Thetford Mines is statistically higher than that measured in urban areas in Québec and that obtained at Tring-Jonction.

Air quality criteria have been defined in Québec, in France and in the United States. Among the criteria surveyed, the Québec criterion (the one contained in the American AHERA act) and the French criterion were defined within the framework of managing asbestos containing materials in public buildings. Only the WTC criterion was determined using a lifetime unit risk. This benchmark was set at 0.0009 PCMe asbestos fibre/ml. This value represents the asbestos concentration to which a continuous exposure over 30 years would lead to not more than one excess cancer mortality per 10,000 persons. In the AVAQ study, the lower limit of the 95% CI of the concentration measured in 5 of 26 houses (19% of the samples) exceeds this reference value. According to Lorber et al., the simple comparison of concentrations measured with a benchmark based on health effects is a screening of potential health impacts. When more than 10% of samples exceed a benchmark, it is appropriate to consider that a health impact could have occurred or could occur.

Two outdoor air quality criteria were found: the criterion of the Ontario Ministry of the Environment and that of the City of Montréal. Since the Ontario criterion is based solely on the probability of onset of asbestosis, the outdoor air concentrations measured in Thetford Mines were not compared to that criterion in the present report, in which it is the carcinogenic risks that are being assessed. The results were also not compared with the Montréal criterion, since the basis of the standard is not available.

Conclusion

The lifetime mortality risk for lung cancer and for mesothelioma, which was estimated using the approach in the MSSS guidelines, is 72, 110 and 125 per 100,000 persons continuously exposed for 70 years, depending on the lifetime unit risk used. The lifetime mortality risk for these same cancers estimated by the Berman and Crump model is 8.2 per 100,000 persons. The risk is approximately 17 times higher than that estimated from background concentrations. The asbestos concentrations in indoor air and outdoor air are also higher than those found in other settings (for example, other residences, public buildings, urban area). As well, more than 10% of the airborne samples taken in houses exceed a criterion based on long-term health effects.

The conclusions of the cancer risk assessment must be interpreted with caution. As well, the risk levels estimated in this study cannot be extrapolated to the entire population of Thetford Mines except to the extent that the concentrations from these two data sources are representative of the concentrations to which the whole population of the city is exposed. It would be appropriate to test the risk estimated by the two approaches against recent epidemiological data on lung cancer and mesothelioma of the pleura in Thetford Mines to determine if there is an overestimation or underestimation of the risk, even though the epidemiological data available in the 2000s is derived from exposure that took place between the 1960s and the 1980s approximately. Notwithstanding the uncertainties and limitations mentioned above, the results of the risk assessment and of the comparative analysis of asbestos concentrations measured in the city of Thetford Mines suggest a health risk attributable to the presence of airborne asbestos in this region.

It is important to point out that, according to the WHO, there is no evidence of a safe threshold for the carcinogenic effects of asbestos, and an increased cancer risk has been observed in populations exposed to very low concentrations of asbestos. In light of this, it is desirable to reduce exposure as much as possible. Consequently, certain control measures must be considered such as prohibiting access to mine tailings sites, and halting the use of mine tailings for backfill and for abrasive or other purposes. In addition, it would be appropriate to take new measurements of airborne asbestos in Thetford Mines in order to monitor asbestos exposure over time, to ensure that is does not increase.

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