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Personal and Static Sample Measurements of Asbestos Fibres During Two Abatement Projects

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Abstract Exposure assessment was performed during the abatement of amosite containing material (ACM) and chrysotile containing material (CCM). Mean fibre concentrations (MFC) in breathing zone (BZ) were 20.6 ± 7.9 f/cc and 6.3 ± 2.2 f/cc during abatements of ACM and CCM, respectively. At the fixed station, MFC were 5.4 ± 3.5 f/cc for ACM and 2.9 f/cc ± 1.6 for CCM. For observer's BZ, MFC were 3.1 ± 1.3 f/cc (ACM) and 1.8 f/cc (CCM) during the abatement. Though elevated, area and observer-type samples clearly underestimate exposure. Exposure remained unacceptable in the worksite with the class of respiratory protection used.

Keywords Asbestos · Abatement · Exposure · Respiratory protection

In the Province of Québec, when abatement projects are in process, the Safety Code for the Construction Industry (Code 2003) and the Regulation Respecting Occupational Health and Safety (RROHS 2001) require that exposure measurements be collected at least one per shift in the respiratory zone of workers with a high risk of asbestos exposure. However, strict decontamination procedures imposed in harsh occupational environments often lead to the use of area samples as a substitute for breathing zone (BZ) measurements as these are generally easier and more economical to collect (Lange et al. 1996). While the validity of area samples as surrogates for personal exposure measures has been questioned in recent publications (Cherrie 2004; Lange 1999, 2003; Lange et al. 2000, 2005; Lange and Thomulka 2002), few research have focused on the difference between fixed-site and personal asbestos exposure measures collected at work sites with a high risk of asbestos exposure. To address this issue, the present study compares simultaneous asbestos exposure measures collected in the breathing zone of workers (WBZ) and observers (NWBZ) in the work area relative to stationary samples (SS).

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Materials and Methods

Two exposure assessments were performed during the abatement (Fig. 1) of amosite containing material (ACM) and chrysotile containing material (CCM). The ACM at hand was friable 75%–90% amosite and the CCM was 5%–10% chrysotile in a matrix of gypsum and mica used for fire-proofing and insulation at the ceiling level. Sampling procedures were carried out in accordance with the Institut de recherche Robert-Sauvé en santé et sécurité du travail (IRSST) Sampling Guide for Air Contaminants in the Workplace (IRSST 2000). Fibre counting was carried out according to a modified National Institute for Occupational Safety and Health (NIOSH) 7,400 method (IRSST method 243) (IRSST 1995). In summary, air samples were

Fig. 1 View of the abatement field of work

Fig. 2 Close view of the batches cassette sampling system

collected on 25-mm mixed cellulose esters filters with 0.8 μm pore size in three piece conductive cassettes. Personal samples were performed with Gilair™ Air Samplers, calibrated with a DryCal™ primary flow metre. Area samples used larger pumps and were calibrated with a basic rotameter. These were fixed stations on a tripod 1 m above the floor near the removal work.

Workers performed the following tasks: scraping of insulation material, cleaning surfaces with a small broom, moving scaffolds, moving bags and others. They wore a clean protective suit, such as a Tyvek® model, a motorized high efficiency respirator with high efficiency particulate air (HEPA) filter (NIOSH Assigned Protection Factor = 50), a work helmet, gloves, and safety boots. They sprayed water mist to reduce dust emission and fibre concentrations.

Since preliminary air tests previously performed and analyzed by a consultant, these worksites revealed elevated concentrations of asbestos within the enclosure, it was concluded that a short sampling period was appropriate in order to avoid overloading of the membrane filter. Samples were obtained for workers, and for an observer (non-worker) who was one of the authors. This translated to sampling durations of about 15–40 min for the workers and 40–60 min for the bystander, who was expected to encounter lower airborne fibre concentrations since he stayed away from the platform where the removal of asbestos was performed.

Methodology for area samples was similar to that described for personal measures, but rather than having cassettes attached to workers, batches of 12 cassettes were connected to a pump 1 m from the ground on a tripod. This method was developed by the IRSST to collect large numbers of concurrent samples for air quality control purposes (Fig. 2). Three stations were set up and sampled simultaneously. Results presented in this paper reflect samples from pumps installed closest to work stations. The flow-rate was fixed at 2 L/min through the use of critical orifices.

Daily air tests were performed by a third party environmental consulting firm hired to take air samples to determine the work conditions in the enclosure during the ACM abatement project. The daily air tests are personal samples similar to the aforementioned personal observer samples, with the technician wearing a sampling pump and cassette and walking around the enclosure. These data are valuable for comparison to the area and other personal samples.

Results and Discussion

Results are presented separately for each sampling method from Tables 1, 2, 3 and 4 while Table 5 presents the ratios of worker's BZ sample to fixed station and ratio of worker's BZ to observer BZ.

Table 1 Workers' breathing zone samplings (WBZ)

Asbestos	Number of workers	n samples	Mean concentration (f/cc)	Standard deviation (f/cc)
Amosite	2	8	20.3	7.9
Chrysotile	3	18	6.3	2.2

Table 2 Observers' breathing zone samplings (NWBZ)

Asbestos	Number of observers	n samples	Mean concentration (f/cc)	Standard deviation (f/cc)
Amosite	1	2	3.1	1.3
Chrysotile	1	3	1.8	0.33

Table 3 Stationary samples (SS)

Asbestos	n samples	Mean concentration (f/cc)	Standard deviation (f/cc)
Amosite	5	5.4	3.5
Chrysotile	6	2.9	1.6

Table 4 Consultants' breathing zone samplings

Asbestos	n samples	Mean concentration (f/cc)	Standard deviation (f/cc)
Amosite	5	3.0	1.9

Table 5 Ratios

Asbestos	Ratio of worker's BZ to fixed station	Ratio of worker's BZ to observer BZ
Amosite	20.3/5.4 = 3.8	20.3/3.1 = 6.5
Chrysotile	6.3/2.9 = 2.2	6.3/1.8 = 3.5

Mean fibre concentration in worker's breathing zone (WBZ) was 20.3 f/cc (n = 8; SD = 7.9) during abatement of ACM while mean fibre concentration in WBZ was 6.3 f/cc (n = 18; SD = 2.2) during the abatement of CCM. At the fixed station, mean fibre concentration was 5.4 f/cc (n = 5; SD = 3.5) for ACM and 2.9 f/cc (n = 6; SD = 1.6) for CCM. For observer's BZ, mean fibre concentration was 3.1 f/cc (n = 2; SD = 1.3) during the abatement of ACM and 1.8 f/cc (n = 3; SD = 0.33) during the abatement of CCM.

The results for the consultant's sampling in Table 4 demonstrated a mean fibre concentration of 3.0 f/cc (n = 5; SD = 1.9). The ratios of worker's BZ to fixed station was 3.8 and 2.2 for amosite and chrysotile abatements projects, respectively. The ratios of workers's BZ to observer BZ were 6.5 and 3.5 for amosite and chrysotile abatement activities.

The personal sampling results revealed elevated asbestos concentrations in the workers' BZs in the enclosures especially when amosite was removed. This is consistent with the work published by Paik et al. (1983) during the removal of sprayed material or from structural surfaces by Sawyer et al. (1985).

Our findings suggest that assessing asbestos exposures by area samples alone is not adequate since the true fibre concentrations to which workers are subjected are not adequately reflected by these measures. When used as a surrogate for personal exposure measurements, the ambient and daily air tests almost exclusively suggest exposures within the acceptable range (with the full face powered air purifying respirator (PAPR)). However, personal samples reveal unacceptably asbestos concentrations during the ACM abatement project. The findings that area samples grossly under-estimate worker exposure are consistent with other such research (Lange et al. 1996; Lange 2003; Lange et al. 2000).

The daily air tests were performed by a technician who wore a pump and moved around the enclosure, in a similar fashion to the observer, but covering the entire enclosure. The justification for such a method is that should certain areas have higher concentrations, they will at least have some impact on the results, rather than potentially being overlooked by a static area sample. However, the results of the observer exposure samples taken during our visits prove that these values are far from representative of the concentrations to which the workers are subjected. The discrepancy is considerable, namely in comparison to the worker samples by a factor of approximately 2.2–6.5 times their concentration (Table 5).

While observer personal samples under-estimate worker exposure, ambient air samples do much the same. The average of the fixed ambient samples analyzed proved to be within acceptable concentration values, namely under 10 f/cc with the type of protection used (powered air-purifying respirator equipped with a full face and high-efficiency filters). This stands in stark contrast to the averages of the exposures the workers encountered, ACM and CCM exposure assessments falling significantly above this limit value. Thus, both common sampling approaches, fixed area and observer average exposure, do not reveal the extent of the workers' exposures. Fibre concentrations recorded from these tests indicate that the aforementioned ambient and observer samples greatly under-estimate worker exposure. Such results are concordant with previous research relating ambient and personal samples. The under-estimation could lead to inadvertently tolerating hazardous work conditions in such sites (Lange et al. 1996; Lange 2003; Cherrie 2004, 1999; Paustenbach et al. 2004).

Permissible exposure limits in the Province of Québec are 0.2 f/cc for amosite and 1 f/cc for chrysotile. On the other hand, the Occupational Safety and Health Administration Permissible Exposure Limit (OSHA PEL) is 0.1 f/cc for any type of fibre. According to the National Institute for Occupational Safety and Health (NIOSH) 2004 Respirator Selection Logic document (NIOSH 2004), a full-facepiece air-powered respirator for particulates offers a protection factor of 50, translating into an upper limit of 10 f/cc, for amosite, to meet the exposure limit in the Province of Québec. For the purpose of comparing, OSHA 29CFR1910. 1001 (Occupational Safety and Health Administration Code of Federal Regulations) requires respirators the following conditions of use: for less than or equal to 5 f/cc (fibres per cubic centimetre) (50 × OSHA PEL) a full-facepiece air-purifying respirator equipped with high efficiency filters; for less than or equal to 10 f/cc, (100 × OSHA PEL) any powered air-purifying respirator equipped with high-efficiency filters or any supplied-air respirator operated in continuous-flow mode; for less than or equal to 100 f/cc (1,000 × OSHA PEL) a full-facepiece supplied air respirator operated in pressure-demand mode. In the case at hand, a fifty times reduction in asbestos fibre concentrations would nonetheless remain appreciably above the 10 f/cc, meaning that if such work conditions were maintained, the workers' health could be compromised over time.

While airborne fibre concentrations were unusually elevated, certain measures were in place to diminish them. Wetting the asbestos and spraying water mist are common techniques to reduce fibre concentrations in the air by soaking the minerals, increasing their density and causing them to settle more rapidly. The downside to this method is its poor effectiveness with amosite. With amosite, the effectiveness of wetting can be augmented by the mere addition of soap to water, while using warm water may also increase the efficacy of the technique. While this should help in successfully abating airborne fibres, it may not on its own sufficiently decrease the highly elevated levels encountered in the enclosure (Lange et al. 2000; Sawyer et al. 1985; Brown 1990).

The personal sampling results revealed elevated asbestos concentrations in the workers' BZs in the enclosure. Since the protection factor accepted in this field was the 50× NIOSH value, the workers in an ACM abatement project can be considered at risk due to their unsafe exposure levels. In such work conditions, a respirator with a better protection factor should be worn as outlined in OSHA 29CFR1910.1001.

Though elevated, area and observer-type samples clearly underestimate exposure, and in a situation such as this, could allow for hazardous work conditions to be overlooked, creating a false sense of safety in a precarious milieu. Sampling is performed to measure the exposure of workers, and it seems that in this case, the most representative way to find this exposure is by monitoring the workers directly through personal breathing-zone samples.

Although it was attempted to abate airborne asbestos fibres in the enclosure, workers' exposure simply remained unacceptable in the ACM worksite with the class of respiratory protection used, as it was appreciably above the legal limits.

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